Unemployment Insurance in Macroeconomic Stabilization

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Abstract

I study unemployment insurance (UI) in general equilibrium with incomplete markets, search frictions, and nominal rigidities. An increase in generosity raises the aggregate demand for consumption if the unemployed have a higher marginal propensity to consume (MPC) than the employed or if agents precautionary save in light of future income risk. This raises output and employment unless monetary policy raises the nominal interest rate. In a quantitative analysis of the U.S. economy over 2008-2014, UI benefit extensions had a contemporaneous output multiplier around 1 or higher. At its peak, the unemployment rate would have been 0.5pp higher absent these extensions.

**JEL codes:** D52, E21, E62, J64, J65

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Introduction

Economists have long viewed unemployment insurance (UI) as an important automatic stabilizer — but should it also serve as a discretionary tool in the stabilization of short-run fluctuations? Since the 1950s, policymakers in the United States have treated UI generosity as precisely such an instrument, extending benefits in recessions. This practice was expanded in unprecedented and controversial fashion during the Great Recession, when benefit durations were raised almost four-fold at the depth of the downturn. While critics emphasized the costly supply-side effects of more generous UI, supporters pointed to potential stimulus benefits of transfers to the unemployed. At the time of writing, a similar debate is ongoing with respect to UI benefit increases during the Covid-19 pandemic.

The existing analysis of UI in the literature cannot speak fully to these debates because it has largely ignored these potential interactions between UI and aggregate demand. Most prior work has studied UI in partial equilibrium, while analyses in general equilibrium have focused on environments in steady-state or in the real business cycle tradition. This paper studies the output and employment effects of UI in a general equilibrium framework with macroeconomic shocks and nominal rigidities.

I demonstrate that the effect of UI on aggregate demand makes it expansionary when monetary policy is constrained. An increase in UI generosity raises aggregate demand if the unemployed have a higher marginal propensity to consume (MPC) than the employed or if agents precautionary save in light of future income risk. If monetary policy does not respond to the demand stimulus by raising the nominal interest rate, this raises equilibrium output and employment. Calibrating the model to the U.S. economy during the Great Recession implies an important stabilization role of UI through these channels. With monetary policy and unemployment matching the data over 2008-2014, the observed extensions in UI duration had a contemporaneous output multiplier around or above 1. At its peak, the unemployment rate would have been 0.5pp higher absent these extensions.

Several real and nominal frictions interact to set the stage for the paper’s results. First, search and matching frictions in the tradition of Diamond [1981], Mortensen [1982], and Pissarides [1984] give rise to unemployment and disincetive effects of UI. Second, market incompleteness with respect to unemployment risk, building on Bewley [1983], Huggett [1993], and Aiyagari [1994], generates a consumption insurance role for publicly provided UI. Third, nominal rigidities render the level of production partially demand-determined.

In such an environment, I first analytically demonstrate how nominal rigidities and ac-
commodative monetary policy reverse the conventional effects of UI on macroeconomic aggregates. A budget-balanced increase in UI raises the aggregate demand for consumption in the same period if the unemployed have a higher MPC than the employed. Expectations of more generous future UI raise aggregate demand by reducing agents’ incentive to precautionary save. Absent nominal rigidity, these impulses are undone by a rise in the equilibrium real interest rate, and the effects of UI on wages and search intensity drive a reduction in equilibrium output and employment. The same results obtain with nominal rigidity but monetary policy which replicates the aforementioned path of real interest rates. In contrast, with nominal rigidity but monetary policy which maintains a constant real interest rate, the stimulus to aggregate demand drives an increase in equilibrium output and employment. These results are only amplified when monetary policy implements a constant nominal rather than real interest rate — as at the zero lower bound — in which case the supply-side effects of UI raise inflation expectations, lower real interest rates, and thus further stimulate demand.

I then study these mechanisms in a richer model calibrated to the U.S. economy. Because the model is consistent with evidence on consumption sensitivities to income by employment status, the cross-sectional incidence of unemployment, and declines in wealth and consumption during unemployment, we can have confidence in its predictions regarding MPC heterogeneity and precautionary saving. Because it is consistent with evidence on the disincentive effects of UI and degree of price rigidity, and because it can flexibly accommodate real wage rigidity as in much of the literature, we can have confidence in its supply-side predictions.

I first quantitatively characterize the roles of nominal rigidity and accommodative monetary policy in rendering UI extensions expansionary around the model’s steady-state. Absent nominal rigidity, extending UI benefit duration by three months for one year has a contemporaneous output multiplier of -0.6: while the increase in generosity would raise short-run consumption in partial equilibrium, the real interest rate rises so that output falls in general equilibrium. With nominal rigidity but assuming that monetary policy follows a conventional Taylor rule, the output multiplier is close to zero as the nominal and thus real rate rises in response (though not in the exact same way as under flexible prices). However, if monetary policy maintains a fixed nominal interest rate during the period of benefit extensions and follows a Taylor rule thereafter, the output multiplier becomes positive at 1.1. Quantitatively, MPC heterogeneity and diminished precautionary saving drive the equilibrium stimulus in this last case. Absent cross-sectional heterogeneity in the incidence of unemployment which contributes to MPC heterogeneity, the output multiplier is substantially diminished. Conversely, if agents have a higher degree of prudence and thus respond more to changes in income risk, the multiplier rises. Finally, if UI is expected to be extended over a greater horizon, the multiplier substantially rises due to the feedback loop between
lower precautionary saving and higher job-finding rates. While a greater search or wage response to UI only amplifies the stimulus at a constant nominal interest rate, the direct effects of UI on aggregate demand via heterogeneity in MPCs and diminished precautionary saving account for a majority of the baseline equilibrium effects.

I then study the role of UI benefit extensions during the Great Recession. I first isolate 13 distinct shocks to UI policy during this period. Twelve of these correspond to distinct pieces of legislation introducing or reauthorizing benefits under the Emergency Unemployment Compensation Act of 2008 (EUC08). One of these corresponds to the initiation of benefits under the Extended Benefits (EB) program for the median U.S. state. Given these shocks to UI policy, I then calibrate a sequence of discount factor shocks to match the dynamics of U.S. unemployment from May 2008 through December 2014, and I calibrate the degree of real wage rigidity to match the dynamics in the U.S. CPI over this period. Untargeted macroeconomic time series validate the fit of the model despite the parsimony of focusing on a single driving force. In the simulation, as (almost completely) in the data, the nominal interest rate is at a binding zero lower bound during the period when UI benefits are extended.

Comparing the model to a counterfactual economy without these UI extensions, I conclude that at its peak the unemployment rate would have been 0.5pp higher absent the extensions. Moreover, at no point is the unemployment rate ever lower in the counterfactual economy than in the baseline. I explore the mechanisms underlying these results in three ways, all of which are consistent with the steady-state impulse responses described above. First, in an analysis of each of the 13 shocks to UI policy in isolation, I find output multipliers ranging between 0.8-2.6, with the variation across these explained by agents’ endogenously evolving expectations regarding the horizon over which the zero lower bound will bind and variation in the horizon of each UI shock. Second, the accommodative response of monetary policy is indeed crucial: in a counterfactual in which there is no zero lower bound (so nominal interest rates can be negative), UI extensions have essentially no effect on the unemployment rate as they are endogenously undone by a monetary policy tightening. Third, the stimulus from UI is primarily driven by heterogeneity in MPCs and diminished precautionary saving at my estimated degree of real wage rigidity. That being said, more flexible wages would only amplify the model-implied stimulus from UI at the zero lower bound.

**Related literature** The results of this paper are distinct from previous models of UI because I accommodate and focus on the combination of incomplete markets, nominal rigidities, and constraints on monetary policy. In environments without nominal rigidity, Krusell et al. [2010], Nakajima [2012a], and Mitman and Rabinovich [2015, 2020] find that increases in UI are contractionary. I demonstrate that these results are reversed with nominal rigidity
and constraints on monetary policy. In New Keynesian models with a zero lower bound but with complete asset markets, Albertini and Poirier [2015] and Christiano et al. [2016] find that increases in UI can be expansionary because the induced rise in inflation expectations lowers the real interest rate. I demonstrate that this channel is complemented by the direct stimulus to aggregate demand through heterogeneity in MPCs and diminished precautionary saving when markets are incomplete. Quantitatively, the latter channels are more important than that through inflation expectations in my simulation of the Great Recession. While MPC heterogeneity and precautionary saving have featured prominently in the policy debate regarding UI extensions, to my knowledge this is the first paper to quantify their role in a dynamic stochastic general equilibrium model.

In doing so, my paper contributes to the rapidly growing literature on heterogeneous agent New Keynesian (HANK) models.² The most closely related strand of this literature also accounts for endogenous unemployment, including Challe et al. [2017], den Haan et al. [2018], Gornemann et al. [2016], Heathcote and Perri [2018], McKay and Reis [2020], and Ravn and Sterk [2017, 2020]. Relative to all of these, my focus is on discretionary changes in UI rather than its time-invariant level. For this reason, my analysis emphasizes heterogeneity in MPCs alongside the effects of UI on precautionary savings, whereas the above papers have largely emphasized the latter alone. Furthermore, constraints on monetary policy play a crucial role in my analysis. Indeed, to my knowledge, my quantitative analysis of a HANK model subject to a sequence of shocks gradually pushing it “far” from steady-state with an endogenous and time-varying duration at the zero lower bound is novel to this literature.

By focusing on benefit extensions in a model calibrated to the Great Recession, my results also provide a structural interpretation of empirical analyses of the UI extensions in the U.S during this period. This includes the work of Boone et al. [2019], Chodorow-Reich et al. [2019], Dieterle et al. [2020], Hagedorn et al. [2016a], and Hagedorn et al. [2016b]. Researchers in this literature have obtained conflicting results. My findings are consistent with the upper end of stimulus estimated in this literature; the stimulus remains modest in terms of employment because, despite a sizeable output multiplier, transfers to the long-term unemployed are small versus output. The model can further explain differences in the precise estimates of researchers as arising from differences in the horizon of UI shocks studied, since these imply differential stimulus through precautionary saving.

Outline The rest of the paper is structured as follows. In section 2 I analytically characterize the effects of marginal increases in UI generosity in a very simple environment. In

²In addition to the papers focused on unemployment risk which I discuss here, this literature has included analyses of government spending (as in Auclert et al. [2018] and Hagedorn et al. [2019], among others) and monetary policy (as in Auclert [2019], Kaplan et al. [2018], and Werning [2015], among others).
section 3 I introduce the full model and in section 4 I parameterize it to the U.S. economy. In section 5 I study impulse responses to UI policy, and in section 6 I evaluate the effects of benefit extensions during the Great Recession. Finally, in section 7 I conclude.

2 UI, nominal rigidity, and monetary policy

I first characterize the marginal effects of UI in a simple setting to frame the quantitative results which follow. An increase in UI raises aggregate demand if the unemployed have a higher MPC than the employed or if agents have a precautionary saving motive given future income risk. With nominal rigidity and monetary policy which does not respond by raising the nominal interest rate, this raises equilibrium output and employment.

2.1 A simple two-period environment

Consider the following environment with incomplete markets, search frictions, and nominal rigidity which captures the essence of the full model studied in the rest of the paper.

There are two periods, 0 and 1. In period 0 (the “short run”), firms producing an intermediate good post vacancies, a measure one of potential workers search, matches occur randomly, and then production takes place. Monopolistically competitive retailers purchase intermediate goods and sell them as differentiated final goods subject to adjustment costs in price-setting. For simplicity, all firm profits are paid to employed agents. Period 1 (the “long run”) is an endowment economy in which agents receive an identical endowment. Agents trade a real bond between periods 0 and 1, and have standard concave, separable preferences over consumption and a convex, separable disutility from searching in period 0.

We can summarize agents’ micro-level optimization as follows. The representative agent’s optimal search effort at the start of period 0 is $s_0(\theta_0, y_0^e, b_0, r_0)$, which is a function of labor market tightness $\theta_0$, income when employed $y_0^e$, income when unemployed $b_0$ (UI), and the real interest rate $r_0$. An employed agent’s value function and optimal consumption in period 0 are $v_0^e(y_0^e, r_0)$ and $c_0^e(y_0^e, r_0)$. For an unemployed agent these are $v_0^u(b_0, r_0)$ and $c_0^u(b_0, r_0)$, respectively. We suppress the dependence of these policies on exogenous period 1 income.

A small set of conditions fully characterize the equilibrium. Goods market clearing in period 0 requires

$$p(\theta_0)s_0(\cdot)c_0^e(\cdot) + (1 - p(\theta_0)s_0(\cdot))c_0^u(\cdot) = p(\theta_0)s_0(\cdot) - k\theta_0s_0(\cdot),$$

where the left-hand side is aggregate consumption and the right-hand side is aggregate

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production, and I have suppressed the arguments of $s_0$, $c_0^e$, and $c_0^u$ for brevity.\footnote{This condition also uses that the consumption and production of each individual retailer variety is the same, an implication of the symmetry across retailers which we assume.} Aggregate consumption depends on the consumption levels of employed and unemployed workers as well as the employment rate $p(\theta_0)s_0$, where $p(\theta_0)$ is the job-finding probability per unit search. Aggregate production depends on the employment rate less the measure of labor used in recruiting rather than production, $k\theta_0 s_0$.\footnote{Since tightness $\theta_0$ is given by the ratio of vacancies to search, $k\theta_0 s_0$ equals $k$ times the measure of vacancies, so that $k$ corresponds to the measure of recruiters per vacancy as in Shimer [2010]. This interpretation of course makes more sense with incumbent workers in period 0.} We normalize productivity to one.

Government budget balance implies that

$$p(\theta_0)s_0(\cdot)y_e^0 + (1 - p(\theta_0)s_0(\cdot))b_0 = p(\theta_0)s_0(\cdot) - k\theta_0 s_0(\cdot),$$

(2)

where the left-hand side is aggregate income and the right-hand side is aggregate production.

Optimal vacancy posting by intermediate good firms requires

$$\mu_0^{-1} \left( 1 - \frac{k}{q(\theta_0)} \right) = w_0,$$

(3)

where $\mu_0$ denotes the price of final goods relative to intermediate goods, $q(\theta_0)$ is the vacancy-filling probability,\footnote{As is standard, this is related to the job-finding probability and tightness according to $q(\theta_0) = \frac{p(\theta_0)}{\mu_0}$.} and $w_0$ is the real wage. The left-hand side is the marginal benefit of hiring a worker, rising in the relative price of intermediate goods $\mu_0^{-1}$ and falling in the hiring costs per worker $k/q(\theta_0)$. The right-hand side is the marginal cost of employing a worker, simply the real wage.

Finally, Nash bargaining implies

$$\frac{1}{u'(c_0^e(\cdot))} (v_e^0(\cdot) - v_u^0(\cdot)) = \frac{\phi}{1 - \phi} \left( \mu_0^{-1} - w_0 \right),$$

(4)

a standard surplus-sharing condition in which $\phi$ denotes the bargaining power of workers.

Conditional on $b_0$ and $r_0$, these constitute 4 equations in 4 unknowns $\{y_e^0, \theta_0, \mu_0, w_0\}$.\footnote{By Walras’ Law, these conditions imply that the bond market also clears.} The real interest rate $r_0$ is in turn determined by the Fisher equation

$$1 + r_0 = (1 + i_0) \frac{P_0}{P_1},$$

which in turn depends on monetary policy $\{i_0, P_1\}$ as well as the short-run price level $P_0$, which reflects the optimizing behavior of retailers subject to adjustment costs in price-setting.
2.2 Effects of a change in UI

I now characterize how a change in UI \( b_0 \) affects equilibrium output \( y_0 \equiv p(\theta_0)s_0 - k\theta_0s_0 \).

Regardless of the price-setting and monetary policy regime, (1) and (2) together imply the following result.

**Lemma 1.** As \( k \to 0 \),

\[
\frac{dy_0}{db_0} \to (1 - p(\theta_0)s_0) \left( \frac{\partial^2 c_e}{\partial y_0^2} - \frac{\partial^2 c_u}{\partial y_0^2} \right) + \left( p(\theta_0)s_0 \frac{\partial c_e}{\partial r_0} + (1 - p(\theta_0)s_0) \frac{\partial c_u}{\partial r_0} \right) \frac{dr_0}{db_0},
\]

where all partial derivatives refer to the micro-level policy functions defined in the main text.

The first term in the numerator summarizes the direct, contemporaneous effect of UI on aggregate demand. It says that an increase in UI will raise aggregate demand if the unemployed have a higher MPC than the employed. This is scaled by the economy’s unemployment rate, which determines the volume of transfers.

The second term in the numerator summarizes the indirect effect of UI on aggregate demand through the induced change in the real interest rate.

The denominator reflects amplification through the Keynesian cross. The more that employed agents consume versus unemployed agents, the larger will be the feedback to aggregate demand when employment rises. The higher is the MPC of employed agents, the larger will be the feedback to aggregate demand when employment rises and thus employed agents’ tax burden to finance UI falls.

The assumption that the hiring cost \( k \) is sufficiently small ensures that the direct resource cost associated with changes in vacancy posting vanishes from Lemma 1.

Armed with Lemma 1, we can interpret the main result of this section:

**Proposition 1.** Suppose \( k \) is small and agents face a sufficiently tight borrowing constraint in period 0. Then:

- If prices are fully flexible (and UI \( b_0 \) is close to optimal), \( \frac{dy_0}{db_0} < 0 \) and \( \frac{dr_0}{db_0} > 0 \).
- If prices are sticky but monetary policy replicates the real interest rate \( r_0 \) absent nominal rigidity, \( \frac{dy_0}{db_0} < 0 \) is identical to that under flexible prices.
- If prices are sticky and monetary policy maintains a constant \( r_0 \), then \( \frac{dy_0}{db_0} > 0 \).

This proposition makes two empirically plausible assumptions. A small \( k \) again ensures the output effects of UI are not driven by the direct resource costs of recruiting. A sufficiently
tight borrowing constraint implies that the unemployed will be constrained whereas the employed will not, and thus the unemployed have a higher MPC than the employed. By Lemma 1 the increase in UI will thus generate an initial stimulus to aggregate demand.

With fully flexible prices, equilibrium output nonetheless falls with more generous UI because it raises equilibrium wages, depressing vacancy creation, and further reduces workers’ incentive to search.\(^7\) Lemma 1 thus makes clear that the initial stimulus to aggregate demand must be met by an increase in the real interest rate which is sufficiently strong that it lowers aggregate consumption (since \(\frac{\partial c}{\partial r} \) is necessarily negative when the magnitude of borrowing/lending is small and thus substitution effects dominate income effects). With sticky prices but monetary policy replicating this real interest rate, the equilibrium effects of UI are identical to the flexible price case.

Conversely, with nominal rigidity and monetary policy maintaining a constant real interest rate, there is no crowd out of the stimulus to aggregate demand characterized in Lemma 1. As is standard in New Keynesian models, endogenous mark-ups are crucial to this mechanism. Indeed, in firms’ optimal vacancy-posting condition (3), a lower gross mark-up earned by retailers \(\mu_0\) is consistent with firms’ increase in real marginal cost.

### 2.3 Additional insights

The key takeaway from the prior subsection is that if a marginal increase in UI stimulates aggregate demand, it will raise output given nominal rigidity and a constant real interest rate. This contrasts starkly with the equity-efficiency trade-off emphasized in partial equilibrium analyses in public finance and general equilibrium analyses ignoring nominal rigidity.

Several extensions presented in appendix A provide additional insights on this result which help to frame the quantitative analysis in the remainder of the paper.

**Precautionary saving and dynamic amplification** The above results demonstrate that aggregate demand rises with UI in the same period if the unemployed have a higher MPC than the employed. Extending the model to an infinite horizon with unemployment risk in future periods, an expected future increase in UI in any period \(t \geq 1\) also stimulates aggregate demand in prior periods by reducing agents’ incentive to precautionary save. This again raises output given nominal rigidity and a constant real interest rate.

We can also ask how the magnitude of stimulus in period 0 varies with the period \(t\) in which UI is raised. As \(t\) rises, there are two offsetting forces. On the one hand, the stimulus in period 0 is dampened because binding borrowing constraints limit the fraction of agents

\(^7\)The assumption that the initial level of UI is close to optimal is sufficient to sharply sign these general equilibrium responses of wages and search.
which respond to changes in future income. This is consistent with the dampening effects of forward guidance in models with incomplete markets, as in McKay et al. [2016]. On the other hand, the stimulus in period 0 is amplified because of the dynamic interplay between lower income risk, higher aggregate demand, and thus a higher job-finding rate. This mechanism has been emphasized by Acharya and Dogra [2020], Challe et al. [2017], McKay and Reis [2016, 2020], and Ravn and Sterk [2017, 2020]. We can prove that this latter effect will dominate the former effect if the initial generosity of UI is sufficiently low.

**Trade in equities and investment** These insights are robust to allowing for trade in equities and a separation rate less than one (as in the quantitative analysis of the rest of the paper). In previous work, Challe et al. [2017], den Haan et al. [2018], and Krueger et al. [2016a,b] have emphasized that a decline in savings would reduce the demand for firm equity and investment, counteracting the stimulus to output. The endogenous rise in the real interest rate is the key mechanism by which investment — which encompasses hiring in a frictional labor market — is crowded out. Conditional on the path of real interest rates, an increase in UI stimulates output. In particular, the decline in desired savings must be met by an increase in income rather than decline in investment to clear the asset market.

**Constant i versus r** The above results assume that the monetary authority maintains a constant real interest rate. In practice, monetary policy more naturally features a constant nominal interest rate — as when the nominal interest rate is at the zero lower bound. In such a context, the rise in firms’ marginal cost due to an increase in UI will further amplify its stimulus, as it raises expected inflation, lowers the ex-ante real interest rate, and thus stimulates output. This mechanism exists in representative agent economies, having been studied in a standard New Keynesian model by Eggertsson [2010] and Werning [2012] and in the context of UI in particular by Albertini and Poirier [2015] and Christiano et al. [2016]. The above analysis complements this work by demonstrating that with incomplete markets, UI is stimulative even absent this inflation expectations channel.

### 2.4 Summing up

Taken together, the effects of a marginal increase in UI depend crucially on the degree of nominal rigidity and response of monetary policy. Absent nominal rigidity, an increase in UI is contractionary. This remains with nominal rigidity but monetary policy which replicates the real interest rate under flexible prices. With nominal rigidity and a constant real interest rate, a marginal increase in UI is instead expansionary if the unemployed have a higher MPC than the employed or if agents have a precautionary saving motive. With a constant
nominal interest rate, a marginal increase in UI is further expansionary by raising inflation expectations. In such an environment, the question is thus not whether, but by how much and through what channels, changes in UI raise output. The rest of the paper seeks to answer this question in a quantitative model of the U.S. economy during the Great Recession.

3 Model

The framework integrates workhorse quantitative models of incomplete markets, search and matching, and nominal rigidities in a unified framework.

3.1 Environment and equilibrium

Timing Each period, firms post vacancies, workers search, and matches occur randomly; production takes place and agents face a standard consumption-savings problem; and then a fraction of employed workers exogenously separate.

Workers Each period workers differ in their employment status \(i \in \{e, u\}\), wealth in bonds \(z^b_t\) and shares in firm equity \(z^f_t\), and a vector of other idiosyncratic states \(\zeta_t\) which evolve exogenously conditional on \(\{e, u\}\) transitions. These latter states will capture dimensions of heterogeneity such as labor productivity when employed and the duration of unemployment when unemployed. Conditional on an unemployed worker becoming employed in period \(t\), they transition according to \(\Gamma_t(\zeta_e|\zeta_u^u)\). Conditional on an employed worker remaining employed or separating between \(t\) and \(t+1\), they transition according to \(\Gamma_t(\zeta_{e,t+1}^e|\zeta_t^e)\) and \(\Gamma_t(\zeta_{u,t+1}^u|\zeta_t^e)\), respectively. Finally, among unemployed workers between \(t\) and \(t+1\) they transition according to \(\Gamma_t(\zeta_{u,t+1}^u|\zeta_t^u)\).

We study an environment without aggregate risk (in the transitional dynamics, aggregate shocks are unanticipated). Hence, except for the initial period when any shock is realized, in equilibrium we can collapse the state variables \((z^b_t, z^f_t)\) into a measure of real wealth

\[
z_t \equiv z^b_t + \frac{\Pi_t + Q_t}{P_t}z^f_t
\]

where \(\Pi_t\) is the dividend paid on firm equity, \(Q_t\) is its price, and \(P_t\) is the price level. To simplify notation, we thus exposit the model in terms of aggregate wealth \(z_t\) alone.

At the beginning of period \(t\), incumbent workers’ value functions are

\[
\tilde{v}^e_t(z_t; \zeta_t^e) = v^e_t(z_t; \zeta_t^e),
\]

where
and initially unemployed workers’ value functions are

\[
\bar{v}_t^u(z_t; \zeta_t^u) = \max_{s_t} (p_t(\theta_t; \zeta_t^u) s_t) \int_{\zeta_t^u} v_t^e(z_t; \zeta_t^e) \Gamma_t(\zeta_t^u|\zeta_t^e) d\zeta_t^e + (1 - p_t(\theta_t; \zeta_t^u) s_t) v_t^u(z_t; \zeta_t^u) - \psi(s_t).
\]

In the latter, unemployed agents’ disutility of search effort is given by \(\psi(s_t)\) and their job-finding probability per unit search is

\[
p_t(\theta_t; \zeta_t^u) = \tilde{m}_t^{-1} \eta m_t(\zeta_t^u) \theta_t^q.
\]

where \(\tilde{m}_t\) controls overall match efficiency, \(m_t(\zeta_t^u)\) controls relative match efficiency, and \(\theta_t\) is labor market tightness characterized further below.

In the middle of period \(t\), the employed face

\[
v_t^e(z_t; \zeta_t^e) = \max_{c_t^e \geq z_t^{e+1}} u(c_t^e)
\]

\[
+ \beta_t(\zeta_t^e) \left[ (1 - \delta_t(\zeta_t^e)) \int_{\zeta_t^{e+1}} \bar{v}_{t+1}^e(z_{t+1}^e; \zeta_{t+1}^e) \Gamma_t(\zeta_{t+1}^u|\zeta_t^e) d\zeta_{t+1}^e + \delta_t(\zeta_t^e) \int_{\zeta_t^{e+1}} \bar{v}_{t+1}^u(z_{t+1}^u; \zeta_{t+1}^u) \Gamma_t(\zeta_{t+1}^u|\zeta_t^e) d\zeta_{t+1}^u \right]
\]

s.t.

\[
P_t c_t^e + (1 + i_t)^{-1} P_{t+1} z_{t+1}^e \leq Y_t^e(\zeta_t^e) + P_t z_t,
\]

\[
z_t^{e+1} \geq \bar{z}_t,
\]

and the unemployed face

\[
v_t^u(z_t; \zeta_t^u) = \max_{c_t^u \geq z_t^{u+1}} u(c_t^u) + \beta_t(\zeta_t^u) \int_{\zeta_t^{u+1}} \bar{v}_{t+1}^u(z_{t+1}^u; \zeta_{t+1}^u) \Gamma_t(\zeta_{t+1}^u|\zeta_t^u) d\zeta_{t+1}^u
\]

s.t.

\[
P_t c_t^u + (1 + i_t)^{-1} P_{t+1} z_{t+1}^u \leq Y_t^u(\zeta_t^u) + P_t z_t,
\]

\[
z_{t+1}^u \geq \bar{z}_t,
\]

where each agent’s discount factor is \(\beta_t(\zeta_t^e)\), income inclusive of government taxes and transfers is \(Y_t^i(\zeta_t^i)\), and when employed, separation rate at the end of the period is \(\delta_t(\zeta_t^e)\). In asset markets, agents face the nominal interest rate \(i_t\) and borrowing constraint \(\bar{z}_t\).\(^8\)

**Producers** A representative producer hires workers to produce a homogenous intermediate good sold at price \(P_t^l\). In period \(t\), the producer starts with a stock \(\tilde{p}_t^e\) of incumbent workers\(^8\)
and can hire more workers by posting $\nu_t$ vacancies which are filled with probability $q_t(\theta_t)$. Managing a vacancy requires $k$ incumbent workers with the average level of productivity, $\bar{a}_t$. The distribution of vacancies which are filled with probability $\bar{s}_t \equiv \int_{\zeta_t^u} \int_{z_t} m_t(\zeta_t^u) s_t(z_t; \zeta_t^u) \bar{\varphi}_t^u(z_t; \zeta_t^u) dz_t d\zeta_t^u$. 

Hence, the representative producer faces

$$J^I_t(\bar{p}_t^e, \bar{\varphi}_t^e) = \max_{\Pi_t, \nu_t, \bar{p}_{t+1}, \bar{\varphi}_{t+1}} \Pi_t^I + (1 + i_t)^{-1} J^I_{t+1}(\bar{p}_{t+1}^e, \bar{\varphi}_{t+1})$$

subject to its flow of funds

$$\Pi_t^I = \int_{\zeta_t^e} \int_{z_t} (P_t^I a_t(\zeta_t^e) - W_t(\zeta_t^e)) \times \left[ \bar{p}_t^e \bar{\varphi}_t^e(z_t; \zeta_t^e) + q_t(\theta_t) \nu_t \int_{\zeta_t^u} \Gamma_t(\zeta_t^e|\zeta_t^u) \frac{m_t(\zeta_t^u) s_t(z_t; \zeta_t^u)}{\bar{s}_t} \bar{\varphi}_t^u(z_t; \zeta_t^u) d\zeta_t^u \right] dz_t d\zeta_t^e - P_t^I \bar{a}_t k \nu_t,$$

the evolution of its stock of incumbents

$$\bar{p}_{t+1}^e = \int_{\zeta_t^e} \int_{z_t} (1 - \delta_t(\zeta_t^e)) \left[ \bar{p}_t^e \bar{\varphi}_t^e(z_t; \zeta_t^e) + q_t(\theta_t) \nu_t \int_{\zeta_t^u} \Gamma_t(\zeta_t^e|\zeta_t^u) \frac{m_t(\zeta_t^u) s_t(z_t; \zeta_t^u)}{\bar{s}_t} \bar{\varphi}_t^u(z_t; \zeta_t^u) d\zeta_t^u \right] dz_t d\zeta_t^e$$

and the evolution of $\bar{\varphi}_t^e$ consistent with Bayes’ Rule. Nominal wages $W_t(\zeta_t^e)$ depends on each worker’s type and are described further below. Since there is no aggregate risk, the producer discounts future profits at the nominal interest rate $i_t$.

**Retailers** Retailers purchase the intermediate good and sell a differentiated variety to consumers. When choosing its price $P_{ij}$, retailer $j$ faces Rotemberg [1982] adjustment costs

$$AC_{tj} = \frac{\psi}{2} \left( \frac{P_{tj}}{P_{t-1j}} - 1 \right)^2 \left( \int_0^1 P_{tky_{tk}} dk \right)$$
given its prior period price $P_{t-1j}$ and aggregate nominal output $\int_0^1 P_{tk} y_{tk} dk$. Hence, retailer $j$ faces

$$J^R_{tj}(P_{t-1j}) = \max_{\Pi^R_{tj}, P_{tj}, y_{tj}, x_{tj}} \Pi^R_{tj} + (1 + i_t)^{-1} J^R_{t+1j}(P_{tj}) \text{ s.t.}$$

$$\Pi^R_{tj} = P_{tj} y_{tj} - (1 + \tau^R) P^I_t x_{tj} - \frac{\psi}{2} \left( \frac{P_{tj}}{P_{t-1j}} - 1 \right)^2 \left( \int_0^1 P_{tk} y_{tk} dk \right) - T^R_t,$$

$$y_{tj} = x_{tj},$$

$$y_{tj} = \left( \frac{P_{tj}}{P_t} \right)^{-\varepsilon} c_t,$$

where $y_{tj}$ is its production using $x_{tj}$ units of the intermediate good and a linear technology; $c_t$ is the sum of $c^i_t(z_t; \zeta^i_t)$ across the idiosyncratic state space; and $\tau^R$ is an ad-valorem tax on inputs, rebated back to retailers via the lump-sum instrument $T^R_t$. I focus on the case with symmetric initial prices and thus identical production and consumption of varieties in equilibrium, so I drop the index $j$ going forward.

**Policy** The government specifies a Taylor rule for $i_t$, its bond position $z^g_t$, and its schedule of real UI benefits $b_t(\zeta^u_t)$. It balances its budget using a tax on the employed $T_t$.

**Wages and income** Finally, a union represents workers of each type $\zeta^e_t$ and Nash bargains the wage $W_{t}^{nb}(\zeta^e_t)$ with producers given a bargaining share $\phi$ and a utilitarian welfare function over workers of that type having different levels of wealth. In the model’s steady-state, the real wage is given by the Nash bargained wage: $w(\zeta^e_t) = W_{t}^{nb}(\zeta^e_t)$. Following Hall [2005] and Blanchard and Gali [2010], in response to aggregate shocks we then allow the equilibrium real wage to be a weighted average of the re-bargained wage and the steady-state real wage

$$\frac{W_t(\zeta^e_t)}{P_t} = \iota w(\zeta^e_t) + (1 - \iota) \frac{W_{t}^{nb}(\zeta^e_t)}{P_t},$$

allowing us to accommodate real wage rigidity within the bilaterally efficient bargaining set.

By assuming wages are (at least partially) Nash bargained, but are bargained at the level of worker types rather than individual workers, we retain the desirable axiomatic properties of Nash bargaining while avoiding the substantial computational difficulties of solving for the transitional dynamics of a wage schedule over the entire wealth distribution over time. I further assume that the price adjustment costs are paid to the government and rebated back via $T^R_t$, so that the only effect of these costs is on retailers’ price-setting decisions, not on resources used.

Following Woodford [2003], I model the “cashless limit” where money serves only as the unit of account.

We assume the union represents newly matched workers and incumbents then receive the same wage.

A similar approach has been used by Costain and Reiter [2005] and Nakajima [2007]. Using a Krusell–Skiba-type technology, we can...
I verify that equilibrium wages remain bilaterally efficient for all individual workers in all calibrations and all transitional dynamics studied in the paper.

Given these wages and the above policy instruments, agents’ incomes are

\[
Y^e_t(\zeta^e_t) = W_t(\zeta^e_t) - T_t, \quad (15)
\]

\[
Y^u_t(\zeta^u_t) = P_t b_t(\zeta^u_t). \quad (16)
\]

**Market clearing**  As already defined, at the beginning of period \( t \) the employment rate is \( \bar{p}^e_t \) and the distributions of incumbent and unemployed workers are \( \bar{v}^e_t(z_t; \zeta^e_t) \) and \( \bar{v}^u_t(z_t; \zeta^u_t) \), respectively. Let \( p^e_t, \varphi^e_t(z_t; \zeta^e_t) \), and \( \varphi^u_t(z_t; \zeta^u_t) \) denote the analogs in the middle of period \( t \).

Then asset market clearing (the sum of bond and equity market clearing) is

\[
p^e_t \int_{\zeta^e_t} z^e_{t+1}(z_t; \zeta^e_t) \varphi^e_t(z_t; \zeta^e_t) dz_t d\zeta^e_t
\]

\[
+ (1 - p^e_t) \int_{\zeta^e_t} z^u_{t+1}(z_t; \zeta^u_t) \varphi^u_t(z_t; \zeta^u_t) dz_t d\zeta^u_t + z^g_{t+1} = \frac{\Pi_{t+1} + Q_{t+1}}{P_{t+1}}, \quad (17)
\]

where aggregate dividends and the price of equity satisfy

\[
\Pi_t = \Pi'_t + \int_0^1 \Pi_{tj}^R dj, \quad (18)
\]

\[
Q_t = (1 + i_t)^{-1} (\Pi_{t+1} + Q_{t+1}). \quad (19)
\]

In the labor market, labor market tightness

\[
\theta_t = \frac{\nu_t}{(1 - \bar{p}^e_t)\bar{s}_t} \quad (20)
\]

determines the vacancy-filling probability and job-finding probability per unit search. Hence, the aggregate number of matches corresponding to the job-finding probabilities in (8) is

\[
\bar{m}_t^{1-\eta}((1 - \bar{p}^e_t)\bar{s}_t)^{1-\eta} \nu_t^{\eta},
\]

and the vacancy-filling probability referenced in the producer problem (12) is given by

\[
q_t(\theta_t) \equiv \bar{m}_t^{1-\eta}((1 - \bar{p}^e_t)\bar{s}_t)^{1-\eta} \nu_t^{\eta} = \bar{m}_t^{1-\eta} \theta_t^{\eta-1}.
\]

and Smith [1998] solution approach, Krusell et al. [2010] and Nakajima [2012b] solve for wages as a function of individual worker wealth. Using my sequence space solution approach — which affords other advantages, such as the ability to study a wide variety of aggregate shocks to UI policy and fundamentals — this is extremely computationally demanding. I leave it to future work to make progress on this important task.
Absent heterogeneity in match efficiency \( m_t(\zeta_t^u) = 1 \) for all \( \zeta_t^u \), this specification of the labor market collapses to the Cobb-Douglas case of that in Pissarides [2000].\(^{13}\)

Goods market clearing is

\[
p_t^e \int_{\zeta_t^e} \int_{z_t} c_t^e(z_t; \zeta_t^e) \phi_t^e(z_t; \zeta_t^c) dz_t d\zeta_t^e + (1 - p_t^e) \int_{\zeta_t^u} \int_{z_t} c_t^u(z_t; \zeta_t^u) \phi_t^u(z_t; \zeta_t^c) dz_t d\zeta_t^u = \int_{\zeta_t^e} \int_{z_t} a_t(\zeta_t^e) \left[ \bar{p}_t \phi_t^e(z_t; \zeta_t^e) + \right] q_t(\theta_t) \nu_t \int_{\zeta_t^u} \Gamma_t(\zeta_t^e | \zeta_t^u) \frac{m_t(\zeta_t^u) s_t(z_t; \zeta_t^u)}{\bar{s}_t} \phi_t^u(z_t; \zeta_t^c) dz_t d\zeta_t^u - \bar{a}_t k \nu_t. \tag{21}
\]

Finally, budget balance for the government is characterized by

\[
p_t^e T_t + P_t \bar{z}_t^g = P_t (1 - p_t^e) \int_{\zeta_t^e} \int_{z_t} b_t(\zeta_t^u) \phi_t^u(z_t; \zeta_t^c) dz_t d\zeta_t^u + (1 + i_t)^{-1} P_{t+1} \bar{z}_{t+1}^g. \tag{22}
\]

**Equilibrium** Conditional on policy \( \{b_t(\zeta_t^u), \bar{z}_{t+1}^g, T_t\} \) and the monetary policy rule, as well as exogenous aggregates \( \{a_t(\zeta_t^e), \delta_t(\zeta_t^e), m_t(\zeta_t^u), \beta_t(\zeta_t^i), \bar{a}_t, \bar{m}_t, \bar{z}_t\} \) and initial prices \( \{P_{-1}\} \), the definition of equilibrium is standard. I characterize the equilibrium in appendix B.

### 3.2 Functional forms

I now specify the functional forms assumed when parameterizing and quantifying the model.

#### 3.2.1 Heterogeneity beyond employment status and wealth

Beyond employment status and wealth, I assume that agents differ in

\[
\zeta_t^e \equiv (a_t^P, a_t^T, \nu^\beta),
\]

\[
\zeta_t^u \equiv (a_t^P, a_t^T, \nu^\beta, d_t, 1_{UI}),
\]

where \( \{a_t^P, a_t^T\} \) are components of productivity, \( \nu^\beta \) indexes discount factor heterogeneity, \( d_t \) is the duration of unemployment, and \( 1_{UI} \) is an indicator for UI eligibility and take-up. The

\(^{13}\)Shimer [2004] challenges an equilibrium implication of this matching function that search effort rises in tightness. Mukoyama et al. [2018] propose a generalized job-finding function where search effort can fall in tightness, consistent with evidence from the Great Recession. I conjecture that the results in this paper would be little changed under such a job-finding function, since I find that the aggregate consumption responses dominate search responses in determining the macroeconomic effects of UI in the presence of nominal rigidity and accommodative monetary policy. I maintain the Pissarides [2000] approach because it can easily accommodate an aggregate matching function with heterogeneous match efficiencies, which I need to quantitatively match negative duration dependence in observed job-finding rates later in this paper.
transition probabilities $\Gamma_t(\zeta^e_t|\zeta^u_t)$, $\Gamma_t(\zeta^e_{t+1}|\zeta^e_t)$, $\Gamma_t(\zeta^u_{t+1}|\zeta^u_t)$, and $\Gamma_t(\zeta^u_{t+1}|\zeta^u_t)$ are induced by the transitions for each state variable described below.

**Shocks to labor productivity** To capture income volatility conditional on employment, I adopt a standard persistent-transitory process for labor productivity $a_t$ such that

$$a_t(\zeta^e_t) \equiv a^P_t a^T_t.$$  \hfill (23)

When a worker is employed in period $t$, these components evolve as

$$\log a^P_t = \log \bar{a}_t + \eta^P_t,$$

$$\eta^P_t = \rho^P \eta^P_{t-1} + \epsilon^P_t, \epsilon^P_t \sim N(0, (\sigma^P)^2),$$

$$\log a^T_t \sim N\left(-\frac{1}{2}(\sigma^T)^2, (\sigma^T)^2\right),$$  \hfill (24)

where $\bar{a}_t$ controls the economy-wide average productivity and follows an exogenous process. When a worker is unemployed in period $t$, the transitory component $a^T_t$ continues to evolve as above, and the persistent component $\eta^P_t$ remains fixed.

**Heterogeneous discount factors** As argued by Carroll et al. [2015] and Krueger et al. [2016a], discount factor heterogeneity can further help in matching the empirical distribution of wealth. I assume that $\nu^\beta$ indexes this heterogeneity, with a fraction one-third of worker-consumers having $\nu^\beta = -\Delta^\beta$, one-third having $\nu^\beta = 0$, and one-third having $\nu^\beta = \Delta^\beta$ for some positive dispersion parameter $\Delta^\beta$. An agent’s period $t$ discount factor is then

$$\beta_t(\zeta^e_t) = \bar{\beta}_t + \nu^\beta$$  \hfill (25)

where $\bar{\beta}_t$ is the economy-wide average discount factor and follows an exogenous process.

**Heterogeneous separation rates** Separation rate heterogeneity allows the model to accommodate the uneven risk of unemployment across the population, with its attendant consequences for the wealth distribution. In particular, an agent’s separation rate when employed $\delta_t$ may vary with her productivity and discount factor according to

$$\delta_t(\zeta^e_t) = \bar{\delta}_t + \epsilon^\delta_a (\log a^P_t - \log \bar{a}_t) + \epsilon^\delta_\beta (\log \beta_t(\zeta^e_t) - \log \bar{\beta}_t),$$  \hfill (26)

where $\bar{\delta}_t$ controls the economy-wide average separation rate and follows an exogenous process.
Incomplete eligibility and take-up In practice, not all newly unemployed workers are eligible for benefits, and many who are still do not take it up (Blank and Card [1991]). To capture this pattern in the data, I assume that only with probability $\zeta$ does a newly unemployed worker begin receiving benefits, a state denoted with indicator $1_{UI}$.$^{14}$

Structural duration dependence Finally, structural duration dependence allows the model to better reflect empirical hazard rates out of unemployment, consistent with the evidence of Ghayad [2013], Kroft et al. [2013], Eriksson and Rooth [2014] and others. I assume that the relative match efficiency of an unemployed agent with duration $d_t$ relevant for her job-finding probability per unit effort (8) is

$$m_t(\zeta_u) = \begin{cases} 
1 - \lambda_0 + \lambda_0 \exp(d_t \lambda_1) & \text{for } d_t < 8, \\
1 - \lambda_0 + \lambda_0 \exp(7 \lambda_1) & \text{for } d_t \geq 8.
\end{cases} \tag{27}$$

Here, $\{\lambda_0, \lambda_1\}$ control the relative efficiencies by duration. I assume furthermore that match efficiencies are flat after an unemployed agent has been unemployed for 8 months or more.$^{15,16}$

3.2.2 Functional forms for primitives and policy

I specify the structure of UI and monetary policy to be consistent with U.S. practice, and choose standard preferences over consumption and search.

Household income during unemployment UI benefits in the U.S. have finite duration and scale with earnings over a base period prior to job loss. Moments from the Survey of Income and Program Participation (SIPP) in appendix C reveal the importance of non-UI income through unemployment. I thus assume transfers to an unemployed agent with productivity $\{a_t^P, a_t^T\}$, duration $d_t$, and UI eligibility/take-up indicator $1_{UI}$

$$b_t(\zeta_u) = \begin{cases} 
rr_t (1 - \omega_0) w_t(a_t^P, 1) + \omega_1 w_t(a_t^P, a_t^T) & \text{if } 1_{UI} = 1, d_t < \bar{d}_t, \\
\omega_2 w_t(a_t^P, a_t^T) & \text{if } 1_{UI} = 0 \text{ or } d_t \geq \bar{d}_t,
\end{cases} \tag{28}$$

$^{14}$Using the 2001 and 2008 SIPP panels studied in appendix C, I find that household income prior to unemployment has an association with an indicator for UI receipt which is statistically indistinguishable from zero once we exclude the bottom 25% of income observations. Hence, for parsimony, I assume that all workers have an identical probability of receiving UI conditional on job loss.

$^{15}$This is computationally convenient because it limits the state space. But it is also consistent with the flatter empirical hazards out of unemployment after 8 months reported in Figure 7(A) of Kroft et al. [2016].

$^{16}$An alternative literature has argued that dynamic selection among heterogeneous job-seekers better explains observed duration dependence in job-finding rates (Ahn and Hamilton [2015], Alvarez et al. [2015]). I refer the reader to the previous drafts of this paper on my website in which I demonstrate that the macroeconomic effects of changes in UI are robust to this alternative environment.
where UI policy parameters in period $t$ are replacement rate $rr_t$ and duration $\bar{d}_t$, the job loser is assumed to have earned a fraction $1 - \omega_0$ of household income prior to job loss, and $\{\omega_1, \omega_2\}$ control the level of non-UI income through the spell.\footnote{As documented in appendix C, non-UI income is mostly the earnings of other household members. Modeling this as a transfer is a parsimonious way of accounting for it without extending the framework to model dual-income households. The results are robust to modeling this income as an endowment instead.} Higher $\omega_1$ than $\omega_0$ parsimoniously captures the household income implications of an “added worker effect” after job loss (e.g., Lundberg [1985], Stephens [2002]). Higher $\omega_2$ than $\omega_1$ captures the crowd-out of non-UI income during UI receipt, another form of moral hazard associated with UI.

**Taylor rule**  Monetary policy specifies the nominal interest rate according to a standard Taylor rule with a zero lower bound

$$i_t = \max \left\{ r + \phi^\Pi_t^P + \phi^y (\log y_t - \log y), 0 \right\}, \tag{29}$$

where $r$ denotes the steady-state real interest rate, $\Pi_t^P \equiv \frac{P_t}{P_{t-1}} - 1$ denotes aggregate inflation, $y_t$ denotes aggregate output, and $y$ denotes its value in steady-state.

**Preferences**  Finally, among workers, I assume CRRA flow utility from consumption

$$u(c) = \frac{c^{1-\sigma} - 1}{1 - \sigma}$$

as well as isoelastic disutility of searching when unemployed

$$\psi(s) = s^{\xi + 1}.$$

4 Stationary recursive competitive equilibrium

In this section I calibrate the model to match patterns in wealth, income, and employment in U.S. data. The consistency of the stationary recursive competitive equilibrium (RCE)
with available evidence on consumption sensitivities to income by employment status, the incidence and effects of unemployment, and disincentive effects of UI can give us confidence in its demand- and supply-side predictions in response to redistribution.

4.1 Calibrating the stationary RCE

I first set a subset of parameters to be consistent with common benchmarks and the broader literature. Relative risk aversion is $\sigma = 1$, allowing us to normalize $\bar{a} = 1$ since the environment is consistent with balanced growth. The elasticity of job-finding with respect to tightness is $\eta = 0.7$ consistent with Petrongolo and Pissarides [2001], and the average separation rate is $\bar{\delta} = 0.034$ as calculated by Shimer [2010] at a monthly frequency. The persistent-transitory process for worker productivity is $\rho^P = 0.997$, $\sigma^P = 0.057$, and $\sigma^T = 0.228$, based on Krueger et al. [2016a]’s estimates using post-tax, per-capita household earnings data conditional on an employed household head, adjusted to a monthly frequency. The fraction of household income earned by the head prior to job loss is $1 - \omega_0 = 0.67$, consistent with evidence from the SIPP in appendix C. UI features a replacement rate of $rr = 50\%$ for the first $\bar{d} = 6$ months of unemployment, consistent with regular benefits in the U.S. Finally, I assume $\tau^R = -\frac{1}{\epsilon}$ to undo the mark-up from monopolistic competition in steady-state.

I calibrate the remaining parameters to match salient patterns in wealth, income, and unemployment in U.S. data prior to the Great Recession. The targeted moments and simulated values are summarized in Table 1. The table indicates the value of the model parameter which is primarily varied in order to target the given moment.

The first set of parameters target key features of (liquid) wealth and income. Combining the data for employed and unemployed households from the 2004 Survey of Consumer Finances (SCF) summarized in appendix C, and defining wealth as transaction accounts plus directly held bonds less credit card balances, I find that mean wealth equaled 3.7 times average monthly household income, mean wealth of households with an unemployed head was 2.7 months of average household income below that of households with an employed head, and 26% of households had negative wealth. I use the average discount factor $\bar{\beta}$ to target mean wealth, the sensitivity of separation rates $\epsilon^\delta_\beta$ to target the mean difference in

19 Using annual data from the Panel Study of Income Dynamics, these authors estimate a persistent-transitory process of $\rho^P_a = 0.9695$, $(\sigma^P_a)^2 = 0.0384$, $(\sigma^T_a)^2 = 0.0522$. They then translate these estimates to a quarterly frequency; using their same approach, I adjust these to a monthly frequency using $\rho^P = (\rho^P_a)^{1/12}$, $(\sigma^P)^2 = (1 - (\rho^P)^2)(\sigma^P_a)^2$, $\sigma^T = \sigma^T_a$.

20 Over 1997-2007, the U.S. Department of Labor’s Employment and Training Administration reports an average pre-tax replacement rate of 47%. I set $rr = 50\%$ to reflect additional savings in taxes.

21 The computational algorithm used to solve the stationary RCE is discussed in appendix F.

22 In appendix D, I re-calibrate the model using total wealth rather than liquid wealth.
<table>
<thead>
<tr>
<th>Moment</th>
<th>Target</th>
<th>Achieved</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Real rate, wealth, and average MPC</strong></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Real interest rate (ann.)</td>
<td>2%</td>
<td>2.0%</td>
<td>$z^g/\bar{a}$</td>
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<td>Mean wealth / monthly HH income</td>
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<td>3.5</td>
<td>$\beta$</td>
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<tr>
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<td>-2.7</td>
<td>-2.5</td>
<td>$\epsilon^g_\delta$</td>
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<tr>
<td>Fraction HH with negative wealth</td>
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<td>0.30</td>
<td>$\tilde{z}/\bar{a}$</td>
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</tr>
<tr>
<td>Mean quarterly MPC to $500$ rebate</td>
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<td>0.22</td>
<td>$\Delta^\beta$</td>
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<td><strong>Income during unemployment</strong></td>
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<td>Share unemployed receiving UI</td>
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<td>0.41</td>
<td>$\zeta$</td>
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<tr>
<td>Mean HH income w. UI / pre job loss</td>
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<td>0.77</td>
<td>$\omega_1$</td>
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<tr>
<td>Mean HH income w.o UI / pre job loss</td>
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<td>0.56</td>
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<td><strong>Incidence of unemployment</strong></td>
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<td>Unemployment rate</td>
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<td>5.0%</td>
<td>$\phi$</td>
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<tr>
<td>Fraction w/ duration 4-6 mos</td>
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<td>Fraction w/ duration &gt; 6 mos</td>
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<td>0.20</td>
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<td>$\epsilon^g_a$</td>
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<td><strong>Search and the labor market</strong></td>
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<td>Duration elasticity to benefit duration</td>
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<td>$\xi$</td>
<td>16</td>
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<tr>
<td>Vacancies per unemployed worker</td>
<td>0.634</td>
<td>0.634</td>
<td>$\bar{m}$</td>
<td>0.19</td>
</tr>
<tr>
<td>Fraction of monthly wage to hire worker</td>
<td>0.108</td>
<td>0.108</td>
<td>$k/\bar{a}$</td>
<td>0.045</td>
</tr>
</tbody>
</table>

Table 1: targeted moments and calibration results

Note: sources for targets are provided in the main text. The table provides the main parameter used to target each moment. Figure 1 describes the identification of key parameters in particular.

wealth by employment status, and the borrowing constraint $\tilde{z}$ to target the fraction with negative wealth. To match a 21% mean quarterly MPC out of an unanticipated $500 rebate (the midpoint of the 12%-30% range reported by Parker et al. [2013]), I use the dispersion in discount factors $\Delta^\beta$. To clear the asset market at a targeted 2% annualized real interest rate, I use the government’s bond position $z^g_{gb}$. To match the 39% of unemployed receiving benefits computed by Chodorow-Reich and Karabarbounis [2016] over 1961Q1-2008Q2, I use the probability of UI receipt conditional on job loss $\zeta$. Finally, to match the dynamics of household income through unemployment using the SIPP in appendix C, I use $\omega_1$ to target 24% lower income after job loss and $\omega_2$ to target 45% lower income after UI exhaustion.

The second set of parameters target key features of unemployment and job search. Based on monthly data over 1995-2007 from the Bureau of Labor Statistics, I calculate a 5.0% average unemployment rate with 14% of the unemployed having duration between 15-26 weeks and 17% having duration greater than 26 weeks. I use the bargaining power of

---

23To compute these MPCs, I translate this rebate into model scale using average monthly household income from the 2004 SCF and then simulate agents over the three months including and after receipt. As in Kaplan and Violante [2014], I focus on a $500 rebate to be consistent with the evidence on tax rebates.
workers $\phi$ to target the overall unemployment rate and the duration dependence of match efficiency \{$\lambda_0, \lambda_1$\} to target fractions 0.14 and 0.17 of unemployed with duration between 4-6 months and greater than 6 months, respectively. Since much of my analysis will focus on policy affecting UI duration, I use the elasticity of workers’ disutility from search $\xi$ to target a micro-elasticity of unemployment duration to potential duration of benefits of 0.1, within the range surveyed by Schmieder and von Wachter [2016].\(^{24}\) I use the sensitivity of separation rates $\epsilon_\delta$ to match the negative relationship between EU probabilities and wages which I estimate using the Current Population Survey (CPS) over 2004-2007 in appendix C. Finally, I use the level of match efficiency $\bar{m}$ to target 0.634 vacancies per unemployed worker reported by Hagedorn and Manovskii [2008], and the cost $k$ to target the 10.8% of a recruiter’s monthly wage used in hiring one worker reported by Silva and Toledo [2009].

Figure 1 illustrates the identification of several parameters deserving further comment. First, the convexity of MPCs by cash on hand implies that the average MPC is rising in discount factor heterogeneity. Consistent with Carroll et al. [2015], such heterogeneity is needed to generate an average MPC high enough to match the data provided that the average level of wealth is also consistent with the data. Second, separation rates must fall with discount factors ($\epsilon_\delta < 0$) to match the mean difference in wealth between the unemployed and employed. Indeed, separation rates which fall only with productivity ($\epsilon_\delta < 0$) to match the observed relationship between EU probabilities and wages cannot rationalize this large difference in wealth by employment status.\(^{25}\) Notably, this is consistent with evidence from the SIPP in appendix C that EU probabilities are negatively related to wealth even conditional on income.\(^{26}\) Finally, match efficiencies must fall with duration ($\lambda_1 < 0$) to match the observed fraction of unemployed agents who are long-term unemployed. Absent this decline in efficiency, job-finding rates rise with duration as agents search harder through unemployment, rendering the fraction of long-term unemployed counterfactually low.

4.2 MPCs, wealth, and unemployment risk: data vs. model

The model’s consistency with additional moments on MPCs, wealth, and unemployment risk can give us further confidence in its predictions for the effects of redistribution. I assemble a broad set of related moments from a variety of data sources in Table 2. I provide more

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\(^{24}\)As in the data, this micro-elasticity in the model is computed using the change in expected duration for a single unemployed agent able to receive longer UI benefits in an unchanged macroeconomic environment.

\(^{25}\)While the sensitivity of separation rates to discount factors is needed to match these features of the wealth distribution, note that even without such sensitivity, Table 5 demonstrates that MPCs rise with unemployment duration.

\(^{26}\)I do not use the EU-wealth relationship from the SIPP to calibrate the model because it is imprecisely estimated. But I show in the next subsection that the model is consistent with this untargeted moment.
Figure 1: identification of selected parameters in stationary RCE

Note: each panel characterizes a given moment in the stationary RCE as I vary a single parameter, keeping all other parameters unchanged from their values in Table 1. The only exception to this is in the first panel where I vary $\Delta \beta$; in that case, I also vary $\tilde{\beta}$ such that $\tilde{\beta} + \Delta \beta = 0.99825$, ensuring a bounded wealth distribution. In each panel, the horizontal line denotes the targeted value of the moment, and the shaded marker denotes the calibrated value of the parameter and resulting moment in the stationary RCE.

detail on the estimates, including standard errors and sample descriptions, in appendix C.

The model is first consistent with estimates of consumption sensitivities to income by employment status. Using the 2010 Survey of Household Income and Wealth (SHIW), unique in providing household heads’ employment status alongside (self-reported) MPCs, I find that the annual MPC out of unexpected, transitory income shocks is 25% higher for unemployed versus employed households.27 The results of Ganong and Noel [2019] using data from

27While the horizon of spending was not explicitly asked, as Auclert [2019] notes, the consistency with the annual MPCs elicited in a later 2012 survey suggests that respondents had an annual horizon in mind.
JPMorgan Chase indicate that the consumption sensitivity to income is especially high among the long-term unemployed: at the month of UI exhaustion, spending falls by 20% of the reduction in household income. The calibrated model implies corresponding moments very close to the empirical counterparts.

The model is also consistent with additional moments relating wealth and unemployment from the SIPP, complementing the evidence from the SCF used in the calibration. First, constructing a measure of liquid wealth in the 2004 panel comparable to that used in Table 1 as well as a measure of unemployment duration among household heads (which is not possible in the SCF), I find that the mean wealth of households with a long-term unemployed head is 0.5 months of income less than that of households with a short-term unemployed head. Further exploiting the panel structure of the SIPP, I estimate that one additional month of income in liquid wealth is associated with a 0.09pp decrease in the probability that a household head becomes unemployed one year in the future. Qualitatively, the model matches each of these predictions. Quantitatively, it is especially close on the second.

Finally, the model is consistent with evidence on consumption after UI exhaustion, which together with its success in matching features of the incidence of unemployment can give us confidence in its precautionary saving responses. The decline in consumption through unemployment has been estimated by a literature beginning with Gruber [1997] using progressively richer data. Using the JPMorgan Chase panel, Ganong and Noel [2019] estimate that the spending of UI exhaustees falls by 9% during UI receipt and a further 11% after exhaustion. As in the partial equilibrium analysis of Ganong and Noel [2019], the model implies that agents should reduce consumption by substantially more in anticipation of exhaustion.

### Table 2: untargeted moments on MPCs, wealth, and unemployment risk

<table>
<thead>
<tr>
<th>Moment</th>
<th>Estimate</th>
<th>Source</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual MPC unemp. - emp.</td>
<td>0.25</td>
<td>2010 SHIW</td>
<td>0.28</td>
</tr>
<tr>
<td>Δ spend. / Δ inc. at UI exhaustion</td>
<td>0.20</td>
<td>Ganong and Noel [2019]</td>
<td>0.23</td>
</tr>
<tr>
<td>Mean wealth LT unemp. - ST unemp.</td>
<td>-0.5</td>
<td>2004 Panel SIPP</td>
<td>-0.8</td>
</tr>
<tr>
<td>EU probability on wealth</td>
<td>-0.0009</td>
<td>2004 Panel SIPP</td>
<td>-0.001</td>
</tr>
<tr>
<td>During UI receipt</td>
<td>0.91</td>
<td>Ganong and Noel [2019]</td>
<td>0.80</td>
</tr>
<tr>
<td>After UI exhaustion</td>
<td>0.80</td>
<td>Ganong and Noel [2019]</td>
<td>0.76</td>
</tr>
</tbody>
</table>

Note: further details on the estimates are provided in appendix C. The model moments are computed in the same way as the estimates except for the annual MPC, which is self-reported in the data but computed in the model for each agent using the change in average consumption over the year following an unanticipated rebate equal to average economy-wide monthly income.
relative to what we observe in the data. However, the model closely matches observed consumption after exhaustion, more important for the experiments which follow because of my primary focus on changes to UI benefit duration affecting the long-term unemployed.

4.3 Long-term unemployed as a “tag” for high MPCs

The structural approach taken in this paper illustrates why, to borrow a phrase from Akerlof [1978], the long-term unemployed are an especially good “tag” for high MPCs: low wealth, and low temporary income relative to permanent income.

This is evident from agents’ consumption policy functions and the marginal distributions over wealth, depicted in Figure 2 for employed agents and unemployed agents in their first month of unemployment \((d = 0)\), in their fourth month \((d = 3)\), and just after the expiration of benefits \((d = 6)\), averaging over all other state variables. The marginal distributions are consistent with the unemployed being drawn disproportionately from the pool of low wealth agents and then further decumulating assets through the spell, a temporary shock. The policy functions are consistent with the temporary income losses associated with unemployment leading agents, even conditional on wealth, to have lower consumption and higher sensitivities to cash on hand. Taken together, Table 3 illustrates that the long-term unemployed have a quarterly MPC out of an unexpected rebate of $500 which is roughly three times that of the employed. In fact, the long-term unemployed have a quarterly MPC which is higher
Group Mean quarterly MPC
Overall 0.22

By wealth
Highest quartile 0.01
2nd quartile 0.12
3rd quartile 0.25
Bottom quartile 0.45

By employment status
Employed 0.20
Unemployed 0.49
Short-term \(d \in \{0, 1, 2\}\) 0.43
Medium-term \(d \in \{3, 4, 5\}\) 0.52
Long-term \(d \geq 6\) 0.66

Table 3: model-generated quarterly MPC to $500 rebate

Note: the $500 rebate is first translated into model scale using average household income of $6,761 from the 2004 SCF. The MPC for each agent is then computed as the change in average consumption over the three months after an unanticipated receipt of this rebate in a given month.

than the bottom quartile of households by wealth, which (recalling the targets in Table 1) are roughly the households with negative wealth balances in the economy.\(^{28}\)

5 Impulse responses to UI shocks

I now study UI policy starting from the stationary RCE. Consistent with the earlier analytical results, UI extensions are contractionary absent nominal rigidity but are expansionary given nominal rigidity and monetary policy which does not raise the interest rate. The latter stimulus is more pronounced when MPCs rise more sharply by duration of unemployment, agents have a higher degree of prudence, or the extensions last for a longer horizon.

5.1 Baseline effects of a three-month extension for one year

I start with an unanticipated extension of UI duration \(\bar{d}_t\) from 6 to 9 months, announced at \(t = 0\) and lasting through \(t = 11\). I assume \(\iota = 1\), so that real wages do not change in response to the shock, and I keep all other macroeconomic parameters fixed, such as \(z^g\), so that changes in UI are fully financed by contemporaneous changes in taxes. I explore the sensitivity to alternative changes in UI policy and parameters in results which follow.

\(^{28}\)The MPCs by wealth are further useful in validating the model given the consistency between the model-implied pattern of MPCs declining in (liquid) wealth and available evidence. For instance, Broda and Parker [2014] find that the roughly half of households reporting less than two months of income available in liquid assets have a quarterly MPC at least double that of households reporting sufficient liquidity.
Table 4: baseline effects of UI

<table>
<thead>
<tr>
<th></th>
<th>Flex prices</th>
<th>Sticky prices</th>
<th>Sticky prices + fixed ( r )</th>
<th>Sticky prices + fixed ( i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output multiplier</td>
<td>-0.6</td>
<td>0.2</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Avg change in unemp. rate</td>
<td>+0.03pp</td>
<td>-0.01pp</td>
<td>-0.06pp</td>
<td>-0.06pp</td>
</tr>
<tr>
<td>%\Delta SW, 12 mo. cons. equiv. (PE)</td>
<td>-0.00%</td>
<td>-0.00%</td>
<td>-0.00%</td>
<td>-0.00%</td>
</tr>
<tr>
<td>%\Delta SW, 12 mo. cons. equiv.</td>
<td>-0.01%</td>
<td>+0.04%</td>
<td>+0.09%</td>
<td>+0.10%</td>
</tr>
</tbody>
</table>

Note: the panels summarize the effects of a one-year extension of UI duration by three months starting from the stationary RCE under flexible prices, sticky prices and an active Taylor rule, sticky prices and a constant real interest rate for 18 months, and sticky prices and a constant nominal interest rate for 18 months. The output multiplier is defined in (30). The average change in unemployment is computed over the year of extended benefits. The change in utilitarian social welfare is computed as in the note to Figure 4. The partial equilibrium (PE) case is defined as in the note to Figure 3.

Since unanticipated shocks lead to a change in the value of firm equity, we must take a stand on the composition of household portfolios at \( t = 0 \). As described in appendix C, I use empirical patterns in household portfolios by wealth to initialize these portfolios.\(^{29}\)

I use a partial equilibrium / general equilibrium decomposition to understand the results. I compute the partial equilibrium impulse using agents’ re-optimized consumption and search behavior in response to the UI shock, holding fixed the initial value of firm equity, the path of labor market tightness, and the path of real interest rates, and only updating taxes to balance the government budget given the change in worker search effort and thus employment. The resulting impulse is consistent with partial equilibrium analyses in public finance, as in Baily [1978] and Chetty [2006], which accounts for the fiscal externality associated with changes in search. I then characterize the full general equilibrium response accounting for the endogenous adjustment of firm equity, tightness, and real rates.

The partial equilibrium impulse to desired consumption resulting from extended UI reflects the effects of MPC heterogeneity, lower precautionary saving, and moral hazard in search. This impulse is the thin solid line in the first panel of Figure 3. The reallocation of desired consumption from the future to the present is consistent with UI redistributing to higher MPC households and reducing the incentive for all households to precautionary save. Because of moral hazard in search, the change in desired consumption is negative in net present value terms as more households stay unemployed with more generous UI.

Accounting for the responses in tightness and interest rates in general equilibrium, the UI extension leads to lower output and employment under flexible prices. The real interest rate rises to equilibrate the asset (and goods) market, as shown by the thick solid line in the

\(^{29}\)The computational algorithm used to characterize each of the transitional dynamics in this section builds on Guerrieri and Lorenzoni [2017] and Auclert et al. [2020] and is discussed further in appendix F.
Figure 3: effects of UI starting from steady-state

Note: the panels describe the effects of a one-year extension of UI duration by three months starting from the stationary RCE with no other macroeconomic shocks. In the left panel, the partial equilibrium impulse describes the change in aggregate consumption after agents re-optimize consumption and search given the change in UI benefits and taxes (where the latter balances the government budget), holding fixed the initial value of firm equity, the path of tightness, and the path of real interest rates. The general equilibrium impulse describes the change in aggregate consumption (which equals output) accounting for the final response of firm equity, tightness, and real interest rates.

second panel of Figure 3. This undoes the effects of more generous UI on households’ desired consumption-savings plan and, consistent with Hall [2017], reduces vacancy creation by raising the discount rate applied by firms on the surplus from continuing matches. Together with lower worker search effort due to moral hazard, the net effect on aggregate consumption and thus output in the first panel of Figure 3 is negative.\(^{30}\) The first row of Table 4 summarizes the effect on output by the contemporaneous multiplier

\[
\text{output multiplier} \equiv \frac{\sum_{t=0}^{11} \Delta \text{output}_t}{\sum_{t=0}^{11} \Delta \text{UI payments}_t},
\]

where the denominator uses the initial distribution of agents across the state space. The multiplier is -0.6, with the unemployment rate rising by 0.03pp in the year of extended UI.

With nominal rigidity but a standard Taylor rule, real interest rates similarly rise in response to UI extensions. I set the adjustment cost on prices to \(\psi = 300\), so that (given an elasticity of substitution across retailer varieties of \(\epsilon = 11\)) the log-linear New Keynesian Phillips curve has slope on marginal cost \(\frac{1}{\psi} = 0.033\), or 0.1 at a quarterly frequency, consistent with the evidence in Schorfheide [2008].\(^{31}\) I set the coefficients in (29) to \(\phi^\Pi = 1.5\)

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\(^{30}\)Appendix D provides the impulse responses of equilibrium tightness, search, and other variables.

\(^{31}\)This log-linear New Keynesian Phillips curve is identical to that in a model of Calvo pricing with
and $\phi^y = 0.5$, following much of the literature since Taylor [1999]. Monetary policy tightens in response to the increase in UI such that the real interest rate, shown by the dashed line in the second panel of Figure 3, rises. Because real interest rates do not rise as much as in the flexible price case, the resulting output multiplier is positive and the unemployment rate falls, but each of these responses is quite small.

Absent the rise in the real interest rate, UI extensions become considerably expansionary. Suppose first that monetary policy maintains a constant real interest rate for 18 months, after which it follows the Taylor rule. The left panel of Figure 3 demonstrates that aggregate consumption rises substantially. The third column of Table 4 indicates that the UI extension now has an output multiplier of 1.1, generating an average decline in the unemployment rate of 0.06pp. Now suppose that monetary policy maintains a constant nominal interest rate for 18 months before reverting to the Taylor rule. The left panel of Figure 3 demonstrates that the increase in consumption is even higher, and the right panel demonstrates that this is because the real interest rate falls due to an increase in inflation expectations at a constant nominal rate. Nonetheless, as both this figure and the last two columns of Table 4 make clear, the latter mechanism is small in these baseline results.

While this paper’s focus is positive, it is also worth noting that raising UI has contrasting normative implications across these environments. The third row of Table 4 indicates that the partial equilibrium change to social welfare is negative, implying that (locally around the current calibration) the welfare cost of the fiscal externality exceeds the gains from consumption insurance. The fourth row indicates that with flexible prices, the general equilibrium change in welfare is even more negative: utilitarian social welfare falls by the equivalent of 0.01% of consumption for all agents in all states over one year. In contrast, with sticky prices and a fixed real or nominal interest rate, utilitarian social welfare rises.

In this last case, the demand stimulus from UI generates broadly shared welfare gains. Figure 4 explores the average change in welfare across the cross-section of agents. The welfare gains are relatively large for the unemployed and low-wage employed, the latter being disproportionately exposed to unemployment risk, consistent with redistribution towards these agents. More interestingly, the welfare gains are relatively larger for the asset-poor employed, regardless of their wage, for whom job loss may be particularly costly. For these agents, the aggregate demand externalities from transfers considerably outweighs the welfare cost from higher taxes when employed.\textsuperscript{32}

\textsuperscript{32}In ongoing and complementary work (Kekre [2021]), I analytically demonstrate that such demand externalities motivate optimally more generous UI when monetary policy is constrained. This builds on Landais et al. [2016a,b]’s analysis of optimal UI over the business cycle and Farhi and Werning [2016]’s analysis of aggregate demand externalities.
Note: the panels describe the welfare effects of a one-year extension of UI duration by three months starting from the stationary RCE with no other macroeconomic shocks. For each agent, I first compute the change in consumption in each state and date for one year which delivers the same change in welfare as the UI extension. I then average these consumption equivalents across dimensions of the idiosyncratic state space using the relevant marginal distributions. When averaging, I use the same weights at each level of wealth to avoid discontinuities in the graphs. The welfare effects along other dimensions of the idiosyncratic state space are provided in appendix D.

5.2 Roles of MPC heterogeneity and precautionary saving

Alternative calibrations of the steady-state demonstrate that the MPC heterogeneity and reduced precautionary saving drive the aggregate effects of UI extensions when monetary policy is constrained. The re-calibrated parameters are summarized in appendix D.

I first study a version of the model eliminating heterogeneity in separation rates, illustrating the importance of heterogeneity in MPCs. With $\epsilon_\delta = \epsilon_\beta = 0$ and other parameters re-calibrated to match the same targets as the baseline, the first panel of Table 5 indicates that the stationary RCE features a smaller difference in MPCs between the unemployed and employed. The second panel of Table 5 indicates that the stimulus from a three-month extension of UI is diminished. These results suggest that heterogeneity in the incidence of unemployment, which Figure 1 demonstrated was needed to rationalize observed variation in EU flows by income and differences in wealth conditional on these flows, plays a key role in the macroeconomic effects of UI by determining the MPCs of those receiving the transfers.

I next study a version of the model where agents have higher prudence, illustrating the importance of agents’ precautionary saving motive in also determining the macroeconomic effects of UI. Rather than assuming agents have log utility over consumption, I assume agents’ coefficient of relative risk aversion is $\sigma = 4$ and recalibrate the other parameters.
Table 5: sensitivity of effects of UI under sticky prices and fixed \( i \)

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Identical ( \delta )</th>
<th>( \sigma = 4 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarterly MPC, employed</td>
<td>0.20</td>
<td>0.21</td>
<td>0.21</td>
</tr>
<tr>
<td>Quarterly MPC, ST unemployed</td>
<td>0.43</td>
<td>0.35</td>
<td>0.39</td>
</tr>
<tr>
<td>Quarterly MPC, MT unemployed</td>
<td>0.52</td>
<td>0.42</td>
<td>0.46</td>
</tr>
<tr>
<td>Quarterly MPC, LT unemployed</td>
<td>0.66</td>
<td>0.54</td>
<td>0.56</td>
</tr>
<tr>
<td>Coeff. of relative prudence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output multiplier</td>
<td>1.1</td>
<td>0.7</td>
<td>1.3</td>
</tr>
<tr>
<td>Avg change in unemp. rate</td>
<td>-0.06pp</td>
<td>-0.03pp</td>
<td>-0.07pp</td>
</tr>
</tbody>
</table>

Note: the first counterfactual sets \( \epsilon_\alpha^\delta = \epsilon_\beta^\delta = 0 \) and re-calibrates all other parameters to match the same moments as in the baseline. The second counterfactual changes \( \sigma \) and re-calibrates all other parameters to match the same moments as in the baseline. The calibrated parameters in each case are provided in appendix D. In all cases the quarterly MPC is computed for an unexpected $500 rebate.

to match the same targets as the baseline. As indicated in the first panel of Table 5, this implies a higher coefficient of relative prudence under CRRA utility, though it also flattens the profile of MPCs by duration of unemployment. The second panel of Table 5 indicates that the stimulus is nonetheless amplified relative to the baseline, consistent with a larger partial equilibrium precautionary saving response and general equilibrium feedback between unemployment risk and precautionary saving. Evidently, these forces more than compensate for the compressed distribution of MPCs in determining the aggregate effects of UI.

5.3 Sensitivity to magnitude and horizon of policy

The sensitivity to features of the policy sheds further light on the roles of MPC heterogeneity and precautionary saving in driving these equilibrium effects.

I first vary the number of months of unemployment by which UI is extended (holding fixed the one-year horizon over which it is extended). The stimulus from a larger magnitude extension reflects the competing forces of higher MPCs among the marginal recipients of transfers and a smaller fraction of agents affected by the policy change. The left panel of Figure 5 plots the output multiplier associated with duration extensions by 3 to 15 months. It further plots the output multiplier associated with such extensions at \( t = 0 \) and \( t = 11 \) alone (in both cases announced at \( t = 0 \)). On the one hand, the marginal recipients of transfers have higher MPCs as UI is extended by a greater magnitude, explaining why the output multiplier from UI extensions in the 1st month of the simulation alone rise. On the other hand, a smaller fraction of agents are affected by the policy change, reducing the precautionary saving effects of UI and explaining why the output multiplier from UI extensions in the 12th month of the simulation alone fall. Because these forces offset, the
Figure 5: sensitivity to magnitude and horizon given sticky prices and constant $i$

Note: the left panel depicts the output multipliers corresponding to different UI extension magnitudes, in place for one year (circles); in the 1st month of the simulation only (small squares); and in the 12th month of the simulation only (small diamonds). In all cases the output multiplier is computed over a fixed 12-month horizon. The right panel depicts the output multipliers corresponding to different UI extension horizons, in each case extended from 6 to 9 months. In all cases the output multiplier is computed over the horizon of the extension. Shaded markers in both panels depict the baseline three-month extension of UI for one year.

The overall output multiplier from a one-year extension of benefits is remarkably stable with the magnitude of the extension.

I next vary the number of calendar months during which the extension policy is in place (holding fixed the three months by which UI is extended). The stimulus from a longer horizon of extended benefits reflects the competing forces of dynamic amplification through precautionary savings and contractionary effects once monetary policy is no longer accommodative. The right panel of Figure 5 plots the output multiplier associated with UI extensions over horizons of 3 to 27 months. The stimulus first grows as the announced horizon increases, consistent with the dynamic amplification of the stimulus from reduced precautionary saving, higher aggregate demand, and lower unemployment risk. But once UI extensions are expected to persist beyond the period of a constant nominal interest rate, the tightening which accompanies the extensions renders them more contractionary.

5.4 Sensitivity to supply-side responses

Larger supply-side responses only amplify the stimulus from UI when monetary policy is constrained, in contrast to the results with flexible prices or an active Taylor rule.

This is first evident in the case of a lower degree of real wage rigidity. In the second column of Table 6, I lower $\iota$ from its baseline value of 1 to 0.9. In the usual way, this implies
that real wages rise with UI generosity, as this raises workers’ outside option in the Nash bargain. Under flexible prices, this increase in wages leads to a reduction in firm profits and thus firm vacancies, generating a large negative multiplier. With sticky prices, the Taylor rule similarly calls for a larger rise in the nominal interest rate and thus real interest rate, lowering the multiplier. However, with sticky prices and constrained monetary policy, these results are reversed. The increase in real wages directly increases firms’ marginal costs and generates inflation, reducing the ex-ante real interest rate when the nominal interest rate is held fixed. Hence, the stimulus is amplified relative to the baseline.

This mechanism also applies to a larger micro disincentive effect. In the third column of Table 6, I re-calibrate the steady-state to target a micro elasticity of unemployment duration to potential benefit duration of 0.4, exceeding the baseline target of 0.1 and at the high end of U.S. estimates summarized in Schmieder and von Wachter [2016]. The larger disincentive elasticity translates into a larger contractionary effect of UI extensions under flexible prices. In contrast, the stimulus with sticky prices and constrained monetary policy is amplified.

### Table 6: sensitivity of effects of UI to supply-side responses

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Lower real wage rigidity</th>
<th>Higher disincentive elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible prices</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg change in real rate (ann.)</td>
<td>+0.07pp</td>
<td>+0.10pp</td>
<td>+0.06pp</td>
</tr>
<tr>
<td>Output multiplier</td>
<td>-0.6</td>
<td>-3.8</td>
<td>-2.0</td>
</tr>
<tr>
<td>Avg change in unemp. rate</td>
<td>+0.03pp</td>
<td>+0.19pp</td>
<td>+0.11pp</td>
</tr>
<tr>
<td>Sticky prices</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg change in real rate (ann.)</td>
<td>+0.06pp</td>
<td>+0.09pp</td>
<td>+0.07pp</td>
</tr>
<tr>
<td>Output multiplier</td>
<td>0.2</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Avg change in unemp. rate</td>
<td>-0.01pp</td>
<td>-0.01pp</td>
<td>-0.01pp</td>
</tr>
<tr>
<td>Sticky prices + fixed i</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg change in real rate (ann.)</td>
<td>-0.01pp</td>
<td>-0.06pp</td>
<td>-0.01pp</td>
</tr>
<tr>
<td>Output multiplier</td>
<td>1.1</td>
<td>2.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Avg change in unemp. rate</td>
<td>-0.06pp</td>
<td>-0.13pp</td>
<td>-0.07pp</td>
</tr>
</tbody>
</table>

Note: in all cases the changes in the annualized interest rate, output, and unemployment rate are computed over the year of extended benefits.

5.5 Other features of UI policy

In appendix D, I conduct several additional experiments which further elucidate the mechanisms in the model given sticky prices and constraints on monetary policy. I first consider

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33The re-calibrated parameters are summarized in appendix D.
an increase in UI eligibility/take-up, which amplifies the stimulus by expanding the scale of transfers. I then consider debt-financed increases in UI duration, which amplifies the stimulus because the model is non-Ricardian. Finally, I compare the effects of raising the replacement rate to extending UI duration, which underscores that duration extensions have a larger multiplier because long-term unemployment is a “tag” for particularly high MPCs.

6 Evaluation of policy during Great Recession

Armed with these insights from steady-state impulse responses, I now evaluate the effects of UI policy during the Great Recession. I calibrate a sequence of fundamental shocks to replicate the path of unemployment over 2008-2014 given the observed extensions to UI. Monetary policy following a Taylor rule hits the zero lower bound in the simulation, as in the data. I find that, at its peak, the unemployment rate would have been 0.5pp higher were it not for the benefit extensions. The model-implied stimulus is consistent with the upper end of estimates of stimulus in the literature.

6.1 UI policy during Great Recession

The Emergency Unemployment Compensation Act of 2008 (EUC08) was legislated by the U.S. Congress in June 30, 2008 to provide a federally-financed extension of UI across U.S. states through June 2009. Subsequent extensions and re-authorizations, together with the triggering of the Extended Benefits (EB) program, meant that UI duration exceeded 26 weeks in most states through 2013, reaching 99 weeks in some states.

Based on the Chronology of Federal Unemployment Compensation Laws and median UI benefits by state reported by Farber and Valetta [2013], I simulate 13 shocks to UI policy summarized in Table 7. Each shock is defined by its month of occurrence and the revised path of UI duration from that month onwards. Twelve shocks correspond to new extensions or re-authorizations of EUC08. I date each based on when the legislation was passed by the U.S. Congress, and I define the revised path of UI duration based on the maximum weeks of UI allowed by each piece of legislation.\footnote{The exceptions to the latter are shocks 12 and 13, in which case (from September 2012 onwards) I adjust downward the expected UI duration to match the median realized UI duration across states. As states started letting extended benefits expire or no longer met the necessary “lookback” provisions, the maximum available weeks of UI exceeded the realized measure.} One shock corresponds to the triggering of EB. I date it based on when EB benefits began for the median U.S. state, and I assume for simplicity that EB benefits are reauthorized at the same time and over the same horizon as EUC08 benefits in the subsequent months (until the last EB benefits were paid in August.
Table 7: UI shocks simulated in model based on EUC08 and EB extensions

Note: for all shocks corresponding to EUC08 legislations, if legislation was passed in the first half of the month, it is dated as that month; if it was passed in the second half of the month, it is dated as the following month. UI duration is quoted in number of weeks in practice, so I assume 4.5 weeks per month and round to the nearest month. See text for additional description of how each shock is classified.

In all cases, I assume 4.5 weeks per month and round to the nearest month to obtain UI durations consistent with the model frequency. Figure 6 shows that the realized path of UI duration in my model corresponds closely to the median UI duration across U.S. states.

My implementation tries to strike a balance between realism and parsimony. Importantly, by simulating 13 distinct shocks to UI policy, I capture the fact that the extended UI benefits over 2008-13 were not characterized by perfect foresight in 2008, and instead evolved in real time based on developments in the U.S. labor market and U.S. Congress. At the same time, I abstract from the state-contingency involved in some of the extensions, namely the second through fourth tiers of the EUC08 program as well as the EB program, which depended on the evolution of the unemployment rate in each state. I further abstract from the increase in U.S. government borrowing during this period, instead making the (conservative) assumption that the benefits are financed via contemporaneous taxes on the employed.

### 6.2 Model versus data

I then simulate a sequence of shocks to agents’ average discount factor $\beta_t$ to match the observed path of unemployment from May 2008 through December 2014, conditional on the aforementioned shocks to UI and a value of real wage rigidity $\iota$ calibrated to match the CPI.
Figure 6: realized UI duration in model versus data

Note: vertical line corresponds to initial date of simulation, before which model is in stationary RCE. At any given month of simulation, agents’ expectations regarding future UI duration are described in Table 7. Data is from Farber and Valetta [2013], who report weeks of UI by state. I assume 4.5 weeks per month and round to the nearest month.

during this period. I assume that the average discount factor follows the AR(1) process

\[
\bar{\beta}_t = (1 - \rho^\beta)\bar{\beta} + \rho^\beta (\bar{\beta}_{t-1} - \bar{\beta}) + \epsilon_t^\beta.
\]

and I set \( \rho^\beta = 0.95 \).\(^{35}\) As in section 5, I assume price adjustment costs \( \psi = 300 \) (implying a Calvo-equivalent frequency of price adjustment of 6 months). Monetary policy follows the standard Taylor rule subject to zero lower bound in (29) with \( \phi^\Pi = 1.5 \) and \( \phi^\nu = 0.5 \).

I view discount factor shocks as a way to capture changes in financial conditions which change households’ desired (or required) saving. A shock to the credit constraint \( z \) is another shock in this spirit, and I demonstrate the robustness of my findings to such shocks in appendix E. In appendix E I also characterize the effects of productivity, separation rate, and match efficiency shocks; while these shocks may well have coexisted with shocks to financial conditions during the Great Recession, I focus on a single driving force for parsimony.\(^{36}\)

The calibration proceeds as follows. For a grid of values of real wage rigidity \( \iota \), I calibrate a sequence of shocks \( \{\epsilon_t^\beta\} \) to match unemployment in the data. I choose the unemployment

\(^{35}\)I find that the assumed value of \( \rho^\beta \) has little effect on the results which follow; it simply implies a different magnitude of shocks to rationalize the observed path of unemployment.

\(^{36}\)A large literature has tried to isolate the driving forces behind the Great Recession. This is of course not the contribution of my paper. The ability of discount factor shocks to rationalize the empirical comovements in my model is consistent with the many papers finding a key role for negative demand shocks of this sort in estimated DSGE models of the Great Recession, such as Christiano et al. [2015] and Del Negro et al. [2015].
rate as my calibration target so that the model-implied scale of UI payments is as consistent with the data as possible. Given a sequence of shocks \( \{ \epsilon^\beta_t \} \) calibrated in this way for each value of \( \iota \), I then choose the value of \( \iota \) which minimizes the sum of absolute value differences between the CPI in model and data. I choose the CPI as the key nominal calibration target because expected inflation is what enters into agents’ Euler equations and thus affects aggregate demand while monetary policy is at the zero lower bound.

The computational heart of this algorithm is in calibrating the sequence of discount factor of shocks, conditional on any \( \iota \). This proceeds iteratively: conditional on the distribution of agents over the state space at \( t - 1 \), the calibrated \( \bar{\beta}_{t-1} \), and the expected future path of UI from \( t \) onwards, I calibrate \( \epsilon^\beta_t \) so that in the perfect foresight equilibrium from period \( t \) onwards, the unemployment rate in period \( t \) is consistent with the data in the corresponding period.\(^{37}\) I proceed to period \( t + 1 \) and repeat the steps. Because I re-solve for equilibrium policies, prices, and quantities at each step of this algorithm, I respect the important nonlinearities induced by the zero lower bound. To my knowledge, the solution of such a heterogeneous agent model as it gradually travels “far” from the initial steady-state, with an endogenously time-varying duration at the zero lower bound, is novel to the literature.\(^{38}\)

This algorithm implies \( \iota = 0.95 \), a very high degree of real wage rigidity, and the set of discount factor shocks \( \epsilon^\beta_t \) depicted in the first panel of Figure 7. As is evident, the model requires positive shocks to rationalize the rise and persistence in unemployment in the early part of the sample period, and negative shocks to rationalize its decline toward the end. The simulated unemployment rate is depicted in the second panel, almost identical to the data.

Figure 8 compares other model-generated time-series with the data, all of which are untargeted in the calibration except the CPI.\(^{39}\) The first panel demonstrates that the model generates a binding zero lower bound through (and beyond) 2014, as in the data. The second and third panels plot vacancies relative to the measure of unemployed and the fraction of the unemployed which are long-term unemployed; the model generates substantial movements in both variables, albeit of a smaller magnitude than in the data. The fourth panel plots consumption per capita: the model and data are quite consistent through mid-2011, though

---

\(^{37}\)I again use the empirical patterns in household portfolios described in appendix C to revalue households’ relative wealth given the change in the price of equity on impact of a shock at \( t \).

\(^{38}\)What makes this possible is a simple algorithm to dynamically update the Jacobian used to solve the sequence of equilibrium conditions as the simulation proceeds. I describe this further in appendix F.

\(^{39}\)The data sources are as follows. The nominal interest rate is the effective funds rate reported by the Federal Reserve Board, rounded down to the nearest 25bp. Total non-farm job openings, unemployed persons, unemployment by duration, and average hourly earnings of all private employees are reported by the Bureau of Labor Statistics (BLS). The CPI for all items for all urban consumers is from the Bureau of Economic Analysis (BEA). Consumption per capita is nominal consumption of non-durables plus services (BEA), divided by the product of the GDP deflator (BEA) and total civilian population over 16 (BLS), linearly interpolated from a quarterly to monthly frequency.
Figure 7: discount factor shocks and unemployment

Note: average discount factor assumed to follow an AR(1) process with persistence 0.95. Shocks are chosen each period so that, together with the shocks to UI described in Table 7, unemployment in model matches that in data. Unemployment series is displayed in deviations from steady-state (for model) and April 2008 (in data).

consumption per capita recovers in the model (consistent with unemployment) whereas in the data it falls further below trend.\textsuperscript{40} The fifth and sixth panels focus on nominal wages and prices; the model generates a decline in both quite consistent with the data.

Figure 9 plots an important endogenous outcome in the simulation: the horizon over which agents expect the zero lower bound to bind, which evolves as agents (rationally) forecast the economy’s response to shocks. The early months feature sharply deteriorating expectations, followed by consistent expectations of between one and two years at the zero lower bound until the very end of the simulation, at which point there are relatively stable expectations of an “exit” in 2015. These dynamics are quite consistent with available measures of expectations. For instance, consider the baseline staff projections of the funds rate summarized in the Federal Reserve Greenbook (Tealbook starting in 2010).\textsuperscript{41} By January 2009, the baseline projection was that the funds rate would remain at its 0-25bp target through the end of 2010; in January 2011, the projection was that the funds rate would remain at this level through the first quarter of 2013; in January 2013, the baseline projection was that the funds rate would remain at this level through 2015, when exit indeed occurred.

\textsuperscript{40}I expect that a change in trend growth could rationalize the model with the data in this dimension.

\textsuperscript{41}While the more relevant comparison to our model is the market expectation of the duration at the zero lower bound, as noted in the January 2009 Greenbook it is difficult to gauge expectations from market prices due to heightened term premia. Nonetheless, the evidence suggests that the market also expected a sustained period at the zero lower bound. For instance, by June 2010, the Tealbook reports a modal market forecast of the funds rate exceeding the 0-25bp target only by the second half of 2011.
Figure 8: untargeted macro time-series

Note: series displayed in deviations from steady-state (for model) and April 2008 (in data). In the data, consumption per capita, the nominal wage index, and the nominal price index are detrended at their average growth rates over 1990-2019 (1.7%, 2.6%, and 2.5% per year, respectively).
6.3 Effects of UI extensions

I now characterize the effects of the UI extensions in this environment.

I first compare the model dynamics to a counterfactual economy subject to the same discount factor shocks but with no UI extensions. Figure 10 presents the same endogenous variables as Figures 7 and 8 except for the nominal interest rate; I do not show the latter for brevity because in the counterfactual economy, as in the baseline, the nominal interest rate remains at zero through the middle of 2015.

The first panel of Figure 10 demonstrates that the counterfactual economy sees a larger rise in unemployment. At its peak, the unemployment rate would have been 0.5pp higher were it not for the benefit extensions. Moreover, at no point is the unemployment rate ever higher with benefit extensions. Thus, the model implies that the benefit extensions were not a cause of unemployment persistence during the Great Recession.

The remaining panels of Figure 10 demonstrate that the counterfactual economy is more slack on a number of other dimensions. Labor market tightness and aggregate consumption are lower, while long-term unemployment is higher. These differences are especially pronounced in 2011 — aggregate consumption is almost one percentage point higher in the baseline than the counterfactual in January 2011 — reflecting the especially stimulative effects of the January 2011 reauthorization of UI benefits which I discuss in more detail below. With more economic slack in this counterfactual economy, there is more nominal deflation.

Table 8 considers the effects of each of the 13 shocks in Table 7 in isolation. The effect of each UI shock is computed by comparing the transitional dynamics with the shock to
Unemployment rate

Vacancies / unemployed

Fraction long-term unemployed

Consumption per capita

Average nominal wage

CPI

Figure 10: effects of UI shocks

Note: counterfactual environment maintains the same discount factor shocks in Figure 7.
<table>
<thead>
<tr>
<th>Date</th>
<th>Output multiplier</th>
<th>Avg change in unemployment rate</th>
<th>%Δ SW, 12 mo. cons. equiv.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 7/2008</td>
<td>0.9</td>
<td>-0.05pp</td>
<td>+0.11%</td>
</tr>
<tr>
<td>2 12/2008</td>
<td>1.5</td>
<td>-0.13pp</td>
<td>+0.24%</td>
</tr>
<tr>
<td>3 3/2009</td>
<td>2.6</td>
<td>-0.13pp</td>
<td>+0.26%</td>
</tr>
<tr>
<td>4 5/2009</td>
<td>1.4</td>
<td>-0.07pp</td>
<td>+0.13%</td>
</tr>
<tr>
<td>5 11/2009</td>
<td>0.9</td>
<td>-0.02pp</td>
<td>+0.03%</td>
</tr>
<tr>
<td>6 1/2010</td>
<td>1.0</td>
<td>-0.09pp</td>
<td>+0.11%</td>
</tr>
<tr>
<td>7 3/2010</td>
<td>0.8</td>
<td>-0.05pp</td>
<td>+0.05%</td>
</tr>
<tr>
<td>8 4/2010</td>
<td>1.0</td>
<td>-0.09pp</td>
<td>+0.11%</td>
</tr>
<tr>
<td>9 8/2010</td>
<td>1.1</td>
<td>-0.21pp</td>
<td>+0.31%</td>
</tr>
<tr>
<td>10 1/2011</td>
<td>2.1</td>
<td>-0.33pp</td>
<td>+0.77%</td>
</tr>
<tr>
<td>11 1/2012</td>
<td>1.2</td>
<td>-0.10pp</td>
<td>+0.13%</td>
</tr>
<tr>
<td>12 3/2012</td>
<td>1.6</td>
<td>-0.08pp</td>
<td>+0.13%</td>
</tr>
<tr>
<td>13 1/2013</td>
<td>1.3</td>
<td>-0.21pp</td>
<td>+0.38%</td>
</tr>
</tbody>
</table>

Table 8: effects of each UI shock

Note: see Table 7 for description of each UI shock. Effect of shock in period \( t \) is computed by comparing transitional dynamics with the UI shock to those without the UI shock, assuming no future shocks to UI nor fundamentals from period \( t + 1 \) onwards. Output multiplier and effect on unemployment computed over horizon of UI shock.

those without the shock, assuming no future shocks to UI nor fundamentals from that month onwards. As is evident, all 13 shocks feature a positive output multiplier, around or in excess of 1, and lead to a rise in utilitarian social welfare. There is nonetheless obvious heterogeneity across shocks which underscores the key mechanisms underlying these extensions.

A comparison of shock 1 and 2 demonstrates the key role of the binding zero lower bound. Both shocks extend UI over a one year horizon, but at the time of shock 1 the zero lower bound is only expected to bind for 7 months, whereas at the time of shock 2 it is expected to bind for 16 months. For that reason, shock 2 generates more stimulus.

A comparison of shock 9 and 10 demonstrates the key role of dynamic amplification via reduced precautionary savings and a higher job-finding rate. Both shocks keep the generosity of UI unchanged, but shock 9 pushes out the horizon of the extended benefits by 6 months whereas shock 10 pushes out the horizon of the extended benefits by 13 months. In both cases the zero lower bound is expected to bind through the period of extended benefits. Consistent with Figure 5, shock 10 is thus more stimulative than shock 9.

### 6.4 Role of zero lower bound

I now further characterize the key role of the zero lower bound for the above results.
Figure 11: effects of zero lower bound

Note: counterfactual environments maintain the same discount factor shocks in Figure 7.

I first simulate a counterfactual economy subject to the same discount factor shocks and UI extensions as the baseline model, but without a zero lower bound on the nominal interest rate. The left panel of Figure 11 demonstrates that this counterfactual economy sees a much more modest rise in unemployment than the baseline. The right panel demonstrates that what underlies this result is a substantial decline in the nominal interest rate (below zero), which undoes the recessionary effects of positive discount factor shocks.

I then simulate this same economy except without any UI extensions. The left panel demonstrates that unemployment is barely changed versus the environment with the extensions. The right panel demonstrates that monetary policy endogenously tightens in response to these extensions, explaining why they have a negligible effect on economic activity.

Taken together, the zero lower bound on unemployment plays two key roles. First, it generates a deeper economic recession given the same fundamental shocks, implying a larger pool of workers affected by UI extensions. Second, it explains why monetary policy does not tighten in response to the demand stimulus from extended UI.

6.5 Role of real wage rigidity

I now shed further light on the identification of real wage rigidity and its role in these results.

In Figure 12, I first compare the data and baseline path of nominal wages and the CPI to alternative calibrations with more rigid real wages ($\iota = 1$) and less rigid real wages ($\iota = 0.9$). The latter two cases are generated using alternative sequences of discount factor shocks to match the same unemployment series in Figure 6. As is evident, a lower degree of real wage
rigidity would imply that nominal wages and prices fall by even more during this period.

A potential concern with my identification of real wage rigidity is that this is the only
degree of freedom in the model to rationalize the absence of a substantial nominal deflation
in the data while the economy was at the zero lower bound (given nominal rigidity consis-
tent with micro evidence). An active literature has instead rationalized these dynamics by
appealing to other shocks (such as productivity shocks in Christiano et al. [2015]) or other
frictions (such as financial frictions in Del Negro et al. [2015] and Gilchrist et al. [2017]).
With these features, my estimated degree of real wage rigidity might indeed be different.

What is relevant to assess the effects of UI extensions, however, is the responsiveness
of real wages to changes in UI. While I have followed Hall [2005], Blanchard and Gali [2010],
and much of the literature in having a parsimonious model of real wage rigidity in which a single
parameter ($\iota$) governs the responsiveness to all shocks, one could entertain a specification in
which real wages are more responsive to some shocks than others. It is in this context that I
find my estimated high degree of real wage rigidity especially reasonable. While a definitive
conclusion in the literature has not been reached, many papers exploiting micro variation in
UI have estimated extremely small effects of UI duration on wages (e.g., Card et al. [2007],
Jäger et al. [2020], Lalive [2007], and van Ours and Vodopivec [2008]).

Of course, with more real wage responsiveness to UI, the model implies only greater
stimulus at the zero lower bound. In Figure 13, I plot the baseline, $\iota = 1$, and $\iota = 0.9$
calibrations without the UI extensions. I compare each to the baseline calibration with UI

Figure 12: wages and prices with alternative real wage rigidity $\iota$

Note: series displayed in deviations from steady-state (for model) and April 2008 (in data). Data series
are detrended at their average growth rates over 1990-2019. Model series under alternative values of $\iota$ are
generated using alternative sequences of discount factor shocks to match the same unemployment series in
Figure 6.
Figure 13: counterfactual policy with alternative real wage rigidity $\iota$

Note: model series under alternative values of $\iota$ are generated using alternative sequences of discount factor shocks to match the same unemployment series. For that reason, all three counterfactuals can be compared to the same baseline unemployment series to isolate the effect of UI extensions under alternative values of $\iota$.

extensions, as this is virtually the same across calibrations (because in each case the shocks are calibrated to match the data). As is evident, a lower degree of real wage rigidity would only imply more stimulus from UI extensions, consistent with Table 6. Nonetheless, the case with fully rigid real wages ($\iota = 1$) still features substantial stimulus. Indeed, comparing this to the baseline, we can conclude that the direct effects of UI on aggregate demand, only present because of heterogeneity and incomplete markets, were the most important drivers of the macroeconomic effects of UI extensions during the Great Recession.

6.6 Interpretation of empirical evidence

My analysis complements a growing empirical literature studying UI during this period.

This literature has obtained conflicting results. Boone et al. [2019] and Chodorow-Reich et al. [2019] find small but potentially positive effects of the UI extensions on employment. Hagedorn et al. [2016a], Hagedorn et al. [2016b], and Dieterle et al. [2020] find that the UI extensions lowered employment, with large effects in the first two papers.

The present model implies effects which are consistent with the upper end of estimates of stimulus in this literature. Boone et al. [2019] find that a three-month extension of UI raises the employment-to-population rate between -0.09pp and 0.24pp, while Chodorow-

42In Table 2, these authors find that a 73-week extension of benefits increases employment-to-population by 0.43pp with standard error 0.47. This implies that a 13-week extension of benefits increases employment-to-population by $[0.43 - 1.96 \times 0.47, 0.43 + 1.96 \times 0.47] \times (13/73) = [-0.09, 0.24]$pp. Scaling by (13/73) can
Reich et al. [2019] find that a three-month extension of UI reduces the unemployment rate between -0.06pp and 0.09pp. The upper ends of these confidence intervals are consistent with my baseline results. One reason that my estimates may be at the upper end of these ranges is that the empirical literature has focused on cross-state identification which may understate the increase in consumption on tradeables.

The structural approach in this paper provides three other insights on mechanisms and implications which complement these estimates. First, the modest estimates of stimulus in terms of unemployment are consistent with meaningfully-sized output multipliers, since transfers to the long-term unemployed were a small fraction of overall output even during the Great Recession. Second, differences in identifying variation can rationalize why Boone et al. [2019] may have estimated greater stimulus than Chodorow-Reich et al. [2019]: since the former use differences in UI with an average half-life more than a year while the latter use shocks to UI with an average half-life of three months, the former would be expected to measure greater stimulus from diminished precautionary saving. Third, the estimates of stimulus are consistent with the micro evidence on MPC heterogeneity and precautionary saving used to calibrate and validate my model, and do not rely on an especially large effect through inflation expectations at the zero lower bound.

7 Conclusion

This paper studies UI in general equilibrium with incomplete markets, search frictions, and nominal rigidities. An increase in UI raises aggregate demand if the unemployed have a higher MPC than the employed or if agents have a precautionary saving motive. This raises equilibrium output and employment if monetary policy does not raise the nominal rate. In a quantitative analysis of the U.S. economy over 2008-2014, I find that these mechanisms drove the macroeconomic effects of UI extensions during this period. The observed extensions had a contemporaneous output multiplier around or above 1. At its peak, the unemployment rate would have been 0.5pp higher were it not for the benefit extensions.

At a broader level, the analysis of this paper clarifies an aggregate demand stabilization role of other social insurance and cash transfer programs. As with UI, these programs may be effective “tags” for agents with high MPCs and affect agents’ incentives to precautionary save. I leave the analysis of other programs, and the comparison of UI and these programs to government purchases, to future research.

be justified by my results in Figure 5 that the stimulus from UI is stable across magnitudes of the extension.

43In their discussion of Table 4, the authors argue that their estimates imply a one-month UI duration innovation reduces the unemployment rate by [-0.02,0.03]pp. This implies that a three-month UI duration innovation reduces the unemployment rate by [-0.06,0.09]pp.
References


A Supplementary analytical results

In this section I supplement the analytical results in section 2 of the main text. I first provide formal statements of the additional results described in that section: the stimulus from precautionary saving and dynamic amplification, the robustness to trade in equities and dynamic considerations in vacancy-posting, and the role of a constant nominal rather than real interest rate. I then provide proofs of all analytical results provided in the main text and this appendix.

A.1 Precautionary saving and dynamic amplification

I first characterize the effects of future changes in UI on output.

I consider an infinite horizon extension of the two-period model described in the main text; this infinite horizon extension is itself nested within the quantitative model studied in the balance of the paper. Period 0 is exactly as described in section 2. Now, each period $t \geq 1$ is analogous to period 0: firms post vacancies, workers search, and matches occur randomly; production takes place; and all workers separate. Monopolistically competitive retailers purchase intermediate goods and sell them as differentiated varieties subject to price adjustment costs. Agents trade a one-period real bond. I continue to assume that firm profits are paid only to employed agents each period, and later will relax this assumption. I assume time-separable preferences with constant relative risk aversion $\sigma$. I focus on the dynamics around a steady-state denoted without time subscripts.

Following McKay and Reis [2020], Ravn and Sterk [2017], and Werning [2015], this economy remains analytically tractable by assuming that agents cannot borrow. Only employed agents will thus be “on” their Euler equation and price the bond:

$$u'(c^e_t) = \beta(1 + r_t) \left[ p(\theta_{t+1}) s_{t+1} u'(c^e_{t+1}) + (1 - p(\theta_{t+1}) s_{t+1}) u'(b_{t+1}) \right].$$

Log-differentiating this condition together with market clearing yields the following aggregate Euler equation in the present environment:

**Lemma A.1.** As $k \to 0$,

$$\hat{y}_t = (1 - p(\theta)s)\hat{b}_t - \frac{p(\theta)sc^e}{b} \hat{r}_t + \gamma_1 \left[ \left( 1 + \frac{p(\theta)s}{b} \right) \hat{y}_{t+1} + \gamma_0 (1 - p(\theta)s) \hat{b}_{t+1} \right], \quad (A.1)$$
where \( \dot{\cdot} \) denotes the log differential in a variable and

\[
\begin{align*}
\gamma_{+1} & \equiv \frac{p(\theta) s u'(c^e)}{p(\theta) s u'(c^e) + (1 - p(\theta)s) u'(b)} < 1, \\
\gamma_y & \equiv \frac{u'(b) - u'(c^e)}{-u''(c^e)} \approx (c^e - b) \left[ 1 + \frac{1}{2}(\sigma + 1) \left( 1 - \frac{b}{c^e} \right) \right] > 0, \\
\gamma_b & \equiv \frac{u''(b)}{u''(c^e)} - 1 \approx (\sigma + 1) \left( 1 - \frac{b}{c^e} \right) > 0,
\end{align*}
\]

where the approximate equalities in the last two lines reflect second and first order Taylor approximations around \( b = c^e \), respectively.

The first term on the right-hand side of (A.1) reflects the contemporaneous stimulus from UI on aggregate demand. Because the unemployed are endogenously hand-to-mouth, an increase in UI necessarily raises current output holding fixed interest rates and future income. This result is consistent with Lemma 1; the MPC of employed agents does not enter here (as it did there) because of our assumption of a zero borrowing constraint. In this knife-edge case, a higher MPC of employed agents lowers the initial stimulus to aggregate demand but amplifies the Keynesian cross in exactly offsetting ways.

The second term reflects the equilibrium effect of a change in the real interest rate on aggregate demand. It is the focus of, for instance, Werning [2015] and McKay et al. [2016].

The final set of terms reflect the equilibrium effects of future income on aggregate demand, and are our focus here. Outside the brackets, the term \( \gamma_{+1} \) is below one and reflects the fact that only the employed are unconstrained and thus respond to news about future income. Within the brackets, future output enters with a coefficient larger than one, where the difference (\( \propto \gamma_y \)) is rising in agents’ coefficient of relative prudence \( \sigma + 1 \). Moreover, future UI generosity itself appears with a positive coefficient (\( \propto \gamma_b \)) that is rising in prudence \( \sigma + 1 \). Both of these terms reflect the decline in employed agents’ desired precautionary savings given a future increase in the employment rate and UI.

Armed with the above result, we can interpret the following analog of Proposition 1:

**Proposition A.1.** Suppose \( k \) is small and consider the limit of a zero borrowing constraint. Then:

- If prices are fully flexible (and \( b \) is close to optimal), \( \frac{d y_s}{d b_t} = 0 \) for all \( s < t \) and \( \frac{d y_0}{d b_t} < 0 \).

- If prices are sticky but monetary policy replicates the path of real interest rates absent nominal rigidity, \( \frac{d y_s}{d b_t} \) is identical to that under flexible prices for all \( s \).

- If prices are sticky and monetary policy maintains a constant \( r_s \) through period \( t \), then \( \frac{d y_s}{d b_t} > 0 \) for all \( s \leq t \). Moreover, \( \frac{d y_0}{d b_t} \) is rising with \( t \) if \( b = c^e \) is sufficiently small.
In all cases, $\frac{dy}{db_t} = 0$ for $s > t$.

With fully flexible prices, an expected future increase in UI has no effect on output today. With a unitary separation rate and no equilibrium asset trade, wage determination and search effort are insulated from changes in future income, and thus so is aggregate output. Output falls in the period in which UI is increased — consistent with Proposition 1 — but the real interest rate falls in the prior period so that there is no change in desired consumption in all prior periods. When prices are sticky but monetary policy replicates this path of real interest rates, the same results again obtain.

Conversely, with nominal rigidity and monetary policy maintaining a constant path of real interest rates, the future increase in UI is expansionary today. Consistent with Lemma A.1, we can understand this in two steps: first, the increase in UI is expansionary in the period in which it occurs; second, in prior periods, this stimulates aggregate demand because it raises agents’ permanent income and lowers their income risk.

We can further use Lemma A.1 to understand how the magnitude of stimulus depends on the horizon of the change in UI. On the one hand, because only the employed are unconstrained and respond to changes in future income, the response of aggregate demand to a future increase in UI will be mitigated. This is captured by the term $\gamma_{+1}$ which is less than one. On the other hand, because of the feedback loop between lower income risk, higher aggregate demand, a higher job-finding rate, and thus lower income risk, the response of aggregate demand to a future increase in UI will be amplified. This is captured by the terms $\gamma_y$ and $\gamma_b$ in Lemma A.1, which are rising in the difference between $c^e$ and $b$. Taken together, we can prove that $\frac{dy}{db_t}$ is rising in $t$ if $b$ is sufficiently small relative to $c^e$.

### A.2 Trade in equities and investment

The above results assume that only employed agents receive firm profits and vacancy posting is not a dynamic decision (because workers’ separation rate is one). In this subsection I discuss why these simplifying assumptions are not qualitatively crucial for the results. Quantitatively, they will matter, which is why we allow for trade in equities and separation rates calibrated to the data in the quantitative model.

First consider trade in equities. The infinite horizon model described in the prior subsection remains tractable with trade in equities if we assume that agents are endowed with the same, unitary share, and they are restricted from holding a smaller share than that. In equilibrium, there will thus be no trade in equity but it will still be priced by employed agents. Since there is no aggregate risk, its price will simply reflect the stream of expected profits discounted at the bond interest rate. We can thus continue to summarize employed
agents’ optimal consumption-savings decision via the Euler equation

\[ u'(c^t_e) = \beta(1 + r_t) \left[ p(\theta_{t+1})s_{t+1}u'(c^t_{e+1}) + (1 - p(\theta_{t+1})s_{t+1})u'(c^u_{t+1}) \right]. \]

The key difference from the prior subsection is that now we have in equilibrium

\[ c^u_{t+1} = b_{t+1} + \pi_{t+1}, \]

where \( \pi_{t+1} \) denotes the real profits of firms. As is evident, the response of equilibrium profits to UI will now matter for the aggregate demand response to a change in UI. However, the qualitative forces at play are otherwise unchanged.

I emphasize that in the paper’s quantitative analysis, I not only allow agents to trade equities, but I only impose a non-negativity constraint on the equity position. There is thus active trade in equities, although individual agents’ portfolios are indeterminate in the absence of aggregate risk (and thus can be freely calibrated to match the data).

Now consider a separation rate \( \delta \) below one. In this case, the employment rate becomes an endogenous state variable. It remains the case, however, that UI will continue to stimulate aggregate demand if the unemployed have a higher MPC than the employed or agents engage in precautionary saving. Previous research has demonstrated that lower desired saving can be contractionary when some of the saving is directed towards productive investment. A separation rate below one means that my model indeed features productive investment because hiring a worker raises the economy’s future productive capacity in a frictional labor market. Indeed, the optimal vacancy posting condition becomes

\[ \mu^{-1}_t \left( 1 - \frac{k}{q(\theta_t)} \right) + (1 - \delta)(1 + r_t)^{-1} \mu^{-1}_{t+1} \frac{k}{q(\theta_{t+1})} = w_t, \]

and we see (consistent with Hall [2017]) that an increase in the real interest rate would depress vacancy creation. Conditional on the real interest rate, however, it remains that lower desired saving will raise output. The decline in desired savings must be met by an increase in income rather than decline in investment to clear the asset market.

A.3 Constant \( i \) versus \( r \)

The stimulative effects of UI characterized so far focus on sticky price environments in which monetary policy maintains a constant real interest rate. Of more practical relevance is the case with a constant \textit{nominal} interest rate, as when monetary policy is constrained by the zero lower bound.
When monetary policy maintains a constant nominal interest rate, the effect of a change in UI on inflation will affect the real interest rate and thus aggregate demand. Inflation in turn depends on retailers’ real marginal cost $\mu^{-1}_t$. To characterize the dynamics of real marginal cost, it will be useful to accommodate a more general specification of wages consistent with the quantitative model: suppose real wages are given by the weighted average of the Nash bargained wage and steady-state wage with weights $1 - \iota$ and $\iota$, respectively. Then we obtain the following intermediate result:

**Lemma A.2.** As $k \to 0$,

$$-\frac{k}{q(\theta)} \mu_t \to \chi_y \dot{y}_t + \chi_b \dot{b}_t,$$

where $\chi_b$ is positive and $\chi_y$ is positive if the steady-state level of UI is close to optimal.

Thus, retailers’ real marginal cost $\mu^{-1}_t$ will rise with contemporaneous output and UI generosity provided that the degree of real wage rigidity $\iota > \frac{k}{q(\theta)}$. In the (realistic) case with small hiring costs, this condition will be satisfied at even a small degree of real wage rigidity.

It is intuitive that a rise in output and UI generosity should raise retailers’ real marginal cost by bidding up real wages; what explains the need for some real wage rigidity to obtain this result? This follows from the assumed nature of nominal rigidity: since retailers have sticky prices but intermediate good firms are the ones bargaining with workers, the surplus sharing condition in the absence of any real wage rigidity ($\iota = 0$) requires

$$\frac{1 - \phi}{\phi} \frac{1}{u'(c^e_t)} (u(c^e_t) - u(b_t)) = \mu^{-1}_t \frac{k}{q(\theta)},$$

Hence, a rise in workers’ opportunity cost of employment (fall in the left-hand side) or rise in vacancy posting (rise in the right-hand side) requires that the relative price of intermediate goods $\mu^{-1}_t$ falls. In contrast, with some real wage rigidity, the labor market equilibrium generalizes to

$$\mu^{-1}_t \left( \iota - \frac{k}{q(\theta_t)} \right) = \nu w - (1 - \iota) \frac{1 - \phi}{\phi} \frac{1}{u'(c^e_t)} (u(c^e_t) - u(b_t)),$$

where $w$ denotes the steady-state real wage. Now, when $\iota > \frac{k}{q(\theta)}$, a rise in workers’ opportunity cost of employment (rise in the right-hand side) or rise in vacancy posting (fall in the left-hand side) requires that $\mu^{-1}_t$ rises.

I conjecture that in an alternative model in which retailers directly hire workers, there would be no need to have any real wage rigidity to obtain this result. I maintain the distinction between retailers and intermediate good firms to be consistent with most of the
literature on search frictions in the New Keynesian environment, and because the required
degree of real wage rigidity to obtain this result is small.

We can combine this result with the previous ones to characterize the effects of UI given
a constant nominal interest rate:

**Proposition A.2.** Suppose \( \iota > \frac{k}{q(\theta)} \) and the other conditions in Proposition A.1. Then:

- If prices are sticky and monetary policy maintains a constant nominal interest rate
  through period \( t \), then \( \frac{dy_s}{dt} \) is higher than if monetary policy maintained a constant real
  interest rate through period \( t \) (for any \( s \leq t \)).

- This difference rises as \( \iota \) falls (while maintaining \( \iota > \frac{k}{q(\theta)} \)).

Provided that an increase in UI raises inflation, this lowers the real interest rate at an
unchanged nominal interest rate, thereby further stimulating aggregate output per Lemma
A.1. This feeds back to further stimulate inflation, and so on. This mechanism will be
stronger the more flexible are wages.

### A.4 Proofs of analytical results

#### A.4.1 Lemma 1

**Proof.** In the stated limit, \( k\theta_0 s_0 \to 0 \) and thus output \( y_0 \), employment \( p(\theta_0)s_0 \), and the
income of the employed \( y'_0 \) are defined by

\[
p(\theta_0)s_0 c_0^e(y'_0, r_0) + (1 - p(\theta_0)s_0) c_0^u(b_0, r_0) = y_0,
\]

\[
p(\theta_0)s_0 y'_0 + (1 - p(\theta_0)s_0)b_0 = y_0,
\]

\[
y_0 = p(\theta_0)s_0,
\]

conditional on the generosity of UI \( b_0 \) and real interest rate \( r_0 \). Straightforward differentiation
yields the stated result. \( \square \)

#### A.4.2 Proposition 1

**Proof.** With flexible prices and thus a constant mark-up \( \mu \), in the stated limit \( \{y_0, y'_0, \theta_0\} \)
are defined by

\[
p(\theta_0)s_0(\theta_0, y'_0, b_0)y'_0 + (1 - p(\theta_0)s_0(\theta_0, y'_0, b_0))b_0 = y_0,
\]

\[
y_0 = p(\theta_0)s_0(\theta_0, y'_0, b_0),
\]
\[
\frac{1}{u'(y_0^*)} (u(y_0^*) - u(b_0)) = \mu^{-1} \frac{\kappa}{q(\theta_0)},
\]

where \( \kappa \equiv \frac{k}{1-\sigma} \). Equilibrium search is defined by

\[
s_0(\theta_0, y_0^*, b_0) := p(\theta_0)(u(y_0^*) - u(b_0)) = \psi'(s_0)
\]

given a disutility of search \( \psi(s_0) \), and \( c_0^* = y_0^* \) and \( c_0^0 = b_0 \) in the absence of equilibrium borrowing/lending. Straightforward differentiation of this system yields

\[
\frac{dy_0}{db_0} \frac{b_0}{y_0} = \frac{-\sigma \frac{1-p(\theta_0)}{p(\theta_0)^2} b_0 - \left(1 - \frac{1-\eta}{\eta} \right) + 1}{\frac{1-\eta}{\eta} \frac{1}{1+\xi} - \frac{1}{y_0^*} \frac{1-p(\theta_0)}{p(\theta_0)^2} b_0 - \left(1 - \frac{1-\eta}{\eta} \right) + 1} \frac{u'(y_0^*)}{u(y_0^*) - u(b_0)} \frac{1}{p(\theta_0)^2} b_0,
\]

where \( \sigma \equiv -\frac{u''(y_0^*)}{u'(y_0^*)^2} \), \( \xi \equiv \frac{\psi''(s_0)}{\psi'(s_0)} \), and \( \eta \equiv \frac{\psi'(s_0)\theta_0}{p(\theta_0)} \). The numerator is necessarily negative, while the denominator is not obviously one sign or another. It is for this reason that we focus on changes in UI around the optimal level of UI.

The optimal level of UI solves

\[
\max_{\theta_0, y_0^*, b_0} p(\theta_0) s_0(\theta_0, y_0^*, b_0) u(y_0^*) + (1 - p(\theta_0)) s_0(\theta_0, y_0^*, b_0)) u(b_0) - \psi(s_0(\theta_0), y_0^*, b_0) p(\theta_0) s_0(\theta_0, y_0^*, b_0),
\]

\[
\frac{1}{u'(y_0^*)} (u(y_0^*) - u(b_0)) = \mu^{-1} \frac{\kappa}{q(\theta_0)}.
\]

The constraints imply \( \theta_0 \) and \( y_0^* \) as functions of \( b_0 \). The first order condition then implies

\[
\frac{dp(\theta_0)s_0}{db_0} \frac{b_0}{p(\theta_0)s_0} = \frac{-p(\theta_0)s_0 \frac{1}{1+\xi} \left( u'(y_0^*) \frac{1-p(\theta_0)}{p(\theta_0)^2} b_0 + u'(b_0) b_0 \right) - (1 - p(\theta_0)) s_0(u'(b_0) - u'(y_0^*)) b_0}{p(\theta_0)s_0(u(y_0^*) - u(b_0)) \frac{1}{1+\xi} + \frac{\xi}{1+\xi} u'(c_0^0) b_0},
\]

\[< 0.\]

It then follows from Lemma 1 that \( \frac{dy_0}{db_0} > 0 \).

With sticky prices but a monetary policy rule which implements the same real interest rate as with flexible prices, the allocation is identical to above.

Finally, with sticky prices and a monetary policy rule which maintains a constant \( r_0 \), the result follows immediately from Lemma 1. \( \square \)

---

1To ensure that the equilibrium remains well defined as we consider the limit with \( k \to 0 \), we assume that simultaneously workers’ bargaining power \( \phi \to 1 \), so \( \frac{k}{1-\sigma} = \kappa \) remains finite and positive. Intuitively, this ensures that workers’ surplus from employment remains positive, and thus search effort remains positive, even as hiring costs vanish.
A.4.3 Lemma A.1

Proof. Log-linearizing the Euler equation yields

\[ \sigma \dot{c}_t = -\dot{r}_t + \frac{p(\theta)s(u'(b) - u'(c^e))}{p(\theta)su'(c^e) + (1 - p(\theta)s)u'(b)} \left( \eta \dot{\theta}_{t+1} + \dot{s}_{t+1} \right) + \frac{p(\theta)su'(c^e)}{p(\theta)su'(c^e) + (1 - p(\theta)s)u'(b)} \sigma \dot{c}_{t+1} + \frac{(1 - p(\theta)s)u'(b)}{p(\theta)su'(c^e) + (1 - p(\theta)s)u'(b)} \sigma \dot{b}_{t+1}. \]

Log-linearizing the resource constraint yields

\[ p(\theta)sc\dot{\epsilon}_t + (1 - p(\theta)s)b\dot{b}_t = b \left( \eta \dot{\theta}_t + \dot{s}_t \right) \]

in the \( k \to 0 \) limit. Recall further that in the \( k \to 0 \) limit

\[ \dot{y}_t = \eta \dot{\theta}_t + \dot{s}_t. \]

Combining the last two yields

\[ \dot{c}_t = -\frac{(1 - p(\theta)s)b\dot{b}_t}{p(\theta)sc} + \frac{b}{p(\theta)sc} \dot{y}_t. \]

Substituting this into the first equation and using \( \sigma = -\frac{u''(c^e)c^e}{u'(c^e)} \) yields

\[ \dot{y}_t = (1 - p(\theta)s)\dot{b}_t - \frac{p(\theta)sc}{b} \frac{1}{\sigma} \dot{r}_t + \frac{p(\theta)su'(c^e)}{p(\theta)su'(c^e) + (1 - p(\theta)s)u'(b)} \times \left[ \left( 1 - \frac{p(\theta)su'(b) - u'(c^e)}{u'(c^e)} \right) \dot{y}_{t+1} + \left( \frac{u''(b)}{u''(c^e)} - 1 \right) (1 - p(\theta)s)\dot{b}_{t+1} \right], \]

the claimed result. Then considering \( -\frac{u'(b) - u'(c^e)}{u''(c^e)} \) as a function of \( b \), a second order approximation around \( b = c^e \) yields

\[ -\frac{u'(b) - u'(c^e)}{u''(c^e)} = c^e - b - \frac{1}{2} \frac{u'''(c^e)}{u''(c^e)} (c^e - b)^2 + o(||b - c^e||^3), \]

while up to first order we have

\[ \frac{u''(b)}{u''(c^e)} - 1 = -\frac{u'''(c^e)}{u''(c^e)} (c^e - b) + o(||b - c^e||^2). \]

As \( -\frac{u'''(c^e)c^e}{u''(c^e)} = \sigma + 1 \), we obtain the claimed results. \( \square \)
A.4.4 Proposition A.1

Proof. With flexible prices and thus a constant mark-up $\mu$, in the stated limit $\{y_t, y^e_t, \theta_t\}$ are defined by

$$p(\theta_t)s_t(\theta_t, y^e_t, b_t)y^e_t + (1 - p(\theta_t)s_t(\theta_t, y^e_t, b_t))b_0 = y_t, \quad y_t = p(\theta_t)s_t(\theta_t, y^e_t, b_t),$$

$$\frac{1}{u'(y^e_t)}(u(y^e_t) - u(b_t)) = \mu^{-1}\frac{\kappa}{q(\theta_t)},$$

analogous to the system described in the proof of Proposition 1. It follows that $\frac{dy_s}{db_t} = 0$ for all $s \neq t$ and $\frac{dy_t}{db_t} < 0$, where the proof of the latter is identical to that in Proposition 1.

With sticky prices but a monetary policy rule which implements the same real interest rate as with flexible prices, the allocation is identical to above.

Finally, with sticky prices and a monetary policy rule which maintains a constant $r_s$ through period $t$, the result that $\frac{dy_0}{db_t} > 0$ follows immediately from Lemma A.1. Moreover, $\frac{dy_0}{db_t}$ is rising in $t$ if

$$\gamma_+ \left(1 + \frac{p(\theta)s}{\gamma_y}b\right) > 1.$$ 

Given the expressions for $\gamma_+$ and $\gamma_y$, it is clear that

$$\lim_{b \to 0} \gamma_+ \left(1 + \frac{p(\theta)s}{\gamma_y}b\right) \to \infty,$$

so that $\frac{dy_0}{db_t}$ is rising in $t$ if $b$ is sufficiently small. It necessarily follows that $\frac{dm}{dt}$ is rising in $t$ if $b$ is sufficiently small. 

A.4.5 Lemma A.2

Proof. Real wages are given by

$$w_t = \iota w + (1 - \iota)w_t^{nb},$$

where the Nash bargained real wage solves

$$\frac{1}{u'(y^e_t)}(u(y^e_t) - u(b_t)) = \frac{\phi}{1 - \phi} \left(\mu^{-1} - w_t^{nb}\right),$$

A9
where I have again used the absence of borrowing/lending in this economy to set \( c^e_t = y^e_t \) and \( c^u_t = b_t \) in equilibrium. Optimal vacancy posting by firms requires

\[
\mu_t^{-1} \left( 1 - \frac{k}{q(\theta_t)} \right) = w_t.
\]

Combining these yields

\[
\mu_t^{-1} \left( \iota - \frac{k}{q(\theta_t)} \right) = \iota w - (1 - \iota) \frac{1 - \phi}{\phi} \frac{1}{u'(y^e_t)} (u(y^e_t) - u(b_t)).
\]

Log-linearizing yields

\[
-\frac{\iota - \frac{k}{q(\theta)}}{\frac{k}{q(\theta)}} \hat{\mu}_t = (1 - \eta) \hat{\theta}_t - (1 - \iota) \left( \sigma \hat{y}^e_t + \frac{u'(y^e_t)y^e}{u(y^e) - u(b)} \hat{y}^e_t - \frac{u'(b)b}{u(y^e) - u(b)} \hat{b}_t \right).
\]

Then log-linearizing

\[
p(\theta_t)(u(y^e_t) - u(b_t)) = \psi'(s_t),
\]

\[
y_t = p(\theta_t)s_t - k\theta_t s_t
\]

and taking the \( k \to 0 \) limit, we have

\[
(1 - \eta) \hat{\theta}_t - (1 - \iota) \left( \sigma \hat{y}^e_t + \frac{u'(y^e_t)y^e}{u(y^e) - u(b)} \hat{y}^e_t - \frac{u'(b)b}{u(y^e) - u(b)} \hat{b}_t \right) \to \chi_y \hat{y}_t + \chi_b \hat{b}_t,
\]

where

\[
\chi_y \equiv \frac{1 - \eta}{\eta} \frac{1}{1 + \xi} - (1 - \iota) \sigma \frac{1}{y^e} \frac{1}{p(\theta)s} b - \left( \frac{1 - \eta}{\eta} \frac{1}{1 + \xi} + 1 - \iota \right) \frac{1}{u(y^e) - u(b)} \frac{1}{p(\theta)s} b,
\]

\[
\chi_b \equiv (1 - \iota) \sigma \frac{1}{y^e} \frac{1}{p(\theta)s} b + \left( \frac{1 - \eta}{\eta} \frac{1}{1 + \xi} + 1 - \iota \right) \left( \frac{u'(y^e)}{u(y^e) - u(b)} \frac{1}{p(\theta)s} b + \frac{u'(b)b}{u(y^e) - u(b)} b \right).
\]

It is clear that \( \chi_b > 0 \). The fact that \( \chi_y > 0 \) is a consequence of our assumption that we are studying local changes in UI around the efficient steady-state. In particular, a straightforward generalization of the argument provided in the proof of Proposition 1 implies that \( \frac{dy}{db} < 0 \) in the flexible price case. As the flexible price allocation implies a constant mark-up \( (\hat{\mu}_t = 0) \), it follows from above that \(-\frac{\chi_b}{\chi_y} < 0\), and thus \( \chi_y > 0 \).

\[\square\]
A.4.6 Proposition A.2

Proof. With quadratic price-setting costs, up to first order around the steady-state we have the standard New Keynesian Phillips curve

\[ \Pi_t^P = -\epsilon - \frac{1}{\psi} \hat{\mu}_t + \beta \Pi_{t+1}^P, \]

where \( \Pi_t^P \) denotes price inflation, \( \epsilon \) is the elasticity of substitution across retailer varieties, and \( \psi \) controls the magnitude of adjustment costs. Up to first order, the Fisher equation implies

\[ \hat{r}_t = \hat{i}_t - \Pi_{t+1}^P. \]

Taken together with the evolution of retailers’ mark-up in Lemma A.2 and the dynamic IS equation in Lemma A.1, it is clear that \( \frac{d\mu}{dt} \) is higher given \( \hat{i}_s = 0 \) rather than \( \hat{r}_s = 0 \) for \( s \leq t \), owing to the additional stimulus to demand via higher inflation expectations and thus a lower real interest rate. Moreover, note that

\[
\frac{d}{dt} \left. \chi_{y,e} \right|_{k \to 0} \propto \frac{1 - \eta}{\eta} \frac{1}{1 + \xi} + \frac{\sigma}{y^e} \frac{1}{p(\theta) s} b + \left( \frac{1 - \eta}{\eta} \frac{1}{1 + \xi} + 1 \right) \frac{u'(y^e)}{u(y^e) - u(b)} \frac{1}{p(\theta) s} b, \]

< 0,

\[
\frac{d}{dt} \left. \chi_{b} \right|_{k \to 0} \propto -\frac{\sigma}{y^e} \frac{1 - p(\theta) s}{p(\theta) s} b - \left( \frac{1 - \eta}{\eta} \frac{1}{1 + \xi} + 1 \right) \left( \frac{u'(y^e)}{u(y^e) - u(b)} \frac{1 - p(\theta) s}{p(\theta) s} b + \frac{u'(b)}{u(y^e) - u(b)} b \right), \]

< 0,

where the first inequality again uses that we are studying local changes around the efficient steady-state. Hence, the smaller is \( \iota \), the larger is the amplification of the stimulus via inflation expectations.

B Supplementary description of equilibrium

In this section I provide additional material accompanying the description of equilibrium in section 3 of the main text. I first describe why agents’ wealth can be summarized by their total wealth in all periods except the initial one. I then characterize agents’ optimality conditions in equilibrium. I finally characterize the conditions under wages are bilaterally efficient for all agents.
B.1 Aggregation of bond and equity wealth

I first describe why we can aggregate agents’ wealth across bonds and firm equity in all periods except the initial one.

Given wealth in bonds $z^b_t$ and shares in firm equity $z^f_t$, an employed agent of type $\zeta^e_t$ faces

$$v^e_t(z^b_t, z^f_t; \zeta^e_t) = \max_{c^e_t, z^e,b_t+1, z^e,f_t+1} u(c^e_t; \zeta^e_t) + \beta_t(\zeta^e_t) \left[ (1 - \delta_t(\zeta^e_t)) \int_{\zeta^e_{t+1}} \tilde{v}^e_{t+1}(z^e,b_{t+1}, z^e,f_{t+1}; \zeta^e_{t+1}) \Gamma_t(\zeta^e_{t+1}|\zeta^e_t)d\zeta^e_{t+1} + \delta_t(\zeta^e_t) \int_{\zeta^u_{t+1}} \tilde{v}^u_{t+1}(z^u,b_{t+1}, z^u,f_{t+1}; \zeta^u_{t+1}) \Gamma_t(\zeta^u_{t+1}|\zeta^u_t)d\zeta^u_{t+1} \right] \text{s.t.}$$

$$P_t c^e_t + (1 + i_t)^{-1} P_{t+1} z^e,b_{t+1} + Q_t z^e,f_{t+1} \leq Y^e_t(\zeta^e_t) + P_t z^b_t + (\Pi_t + Q_t) z^f_t, \quad z^e,b_{t+1} \geq \bar{z}_t, \quad z^e,f_{t+1} \geq 0,$$

and an unemployed agent of type $\zeta^u_t$ faces

$$v^u_t(z^b_t, z^f_t; \zeta^u_t) = \max_{c^u_t, z^u,b_t+1, z^u,f_t+1} u(c^u_t) + \beta_t(\zeta^u_t) \int_{\zeta^u_{t+1}} \tilde{v}^u_{t+1}(z^u,b_{t+1}, z^u,f_{t+1}; \zeta^u_{t+1}) \Gamma_t(\zeta^u_{t+1}|\zeta^u_t)d\zeta^u_{t+1} \text{s.t.}$$

$$P_t c^u_t + (1 + i_t)^{-1} P_{t+1} z^u,b_{t+1} + Q_t z^u,f_{t+1} \leq Y^u_t(\zeta^u_t) + P_t z^b_t + (\Pi_t + Q_t) z^f_t, \quad z^u,b_{t+1} \geq \bar{z}_t, \quad z^u,f_{t+1} \geq 0.$$

Agents’ constraints reflect a bond borrowing constraint at $\bar{z}_t$ as well as short-sale constraint on firm equity.

Given the absence of aggregate risk and assuming that at least one agent is unconstrained in her bond and equity holdings, we then have

$$Q_t = (1 + i_t)^{-1} (\Pi_{t+1} + Q_{t+1}).$$

Hence we can summarize each agent’s total saving as

$$z^i_{t+1} \equiv z^i_{t+1} + \frac{\Pi_{t+1} + Q_{t+1}}{P_{t+1}} z^i_{t+1}$$

subject to the constraint

$$z^i_{t+1} \geq \bar{z}_t.$$
Since we can also collapse the state variables \((z^b_t, z^f_t)\) for any agent into \(z_t\) at all dates except \(t = 0\), when portfolio composition is relevant in response to an unanticipated shock, we obtain the simplified optimization problems in (9) and (10) in the main text.

We can further aggregate asset market clearing in bonds

\[
p^e_t \int_{z^e_t} \int_{z^b_t} \int_{z^f_t} e_{t+1}(z^b_t, z^f_t; \zeta_t^e) \varphi_t^e(z^b_t, z^f_t; \zeta_t^e) d\zeta^b_t d\zeta^f_t d\zeta^e_t
\]

\[
\quad + (1 - p^e_t) \int_{z^e_t} \int_{z^b_t} \int_{z^f_t} u_{t+1}(z^b_t, z^f_t; \zeta_t^u) \varphi_t^u(z^b_t, z^f_t; \zeta_t^u) d\zeta^b_t d\zeta^f_t d\zeta^u_t
\]

\[
\quad + z^u_{t+1} = 0,
\]

and asset market clearing in firm equity

\[
p^e_t \int_{z^e_t} \int_{z^b_t} \int_{z^f_t} e_{t+1}(z^b_t, z^f_t; \zeta_t^e) \varphi_t^e(z^b_t, z^f_t; \zeta_t^e) d\zeta^b_t d\zeta^f_t d\zeta^e_t
\]

\[
\quad + (1 - p^e_t) \int_{z^e_t} \int_{z^b_t} \int_{z^f_t} u_{t+1}(z^b_t, z^f_t; \zeta_t^u) \varphi_t^u(z^b_t, z^f_t; \zeta_t^u) d\zeta^b_t d\zeta^f_t d\zeta^u_t = 1
\]

to obtain the asset market clearing condition (17) described in the main text.

### B.2 Equilibrium conditions

I now characterize the equilibrium.

**Workers** The optimal search effort of unemployed workers facing (7) solves

\[
p_t(\theta_t; \zeta_t, \zeta_t^u) s_t(z_t; \zeta_t^u) \left( \int_{\zeta_t^e} v_t^e(z_t, \zeta_t^e) \Gamma_t(\zeta_t^e | \zeta_t^u) d\zeta_t^e - v_t^u(z_t; \zeta_t^u) \right) = \psi^t(s_t(z_t; \zeta_t^u)). \tag{A.3}
\]

The optimal consumption and savings decisions of agents facing (9) and (10) solve the standard Euler equations

\[
u'(c_t^e(z_t; \zeta_t^e)) \geq \beta_t (1 + r_t) \left[ (1 - \delta_t(\zeta_t^e)) \int_{\zeta_t^e} u'(c_{t+1}^e(z_{t+1}; \zeta_{t+1}^e)) \Gamma_t(\zeta_{t+1}^e | \zeta_t^e) d\zeta_{t+1}^e
\]

\[
\quad + \delta_t(\zeta_t^e) \int_{\zeta_t^u} \bar{v}_{t+1, z}^u(z_{t+1}; \zeta_{t+1}^u) \Gamma_t(\zeta_{t+1}^u | \zeta_t^e) d\zeta_{t+1}^u \right], \tag{A.4}
\]

\[
u'(c_t^u(z_t; \zeta_t^u)) \geq \beta_t (1 + r_t) \int_{\zeta_t^u} \bar{v}_{t+1, z}^u(z_{t+1}; \zeta_{t+1}^u) \Gamma_t(\zeta_{t+1}^u | \zeta_t^u) d\zeta_{t+1}^u, \tag{A.5}
\]

A13
given
\[
\tilde{y}_{t+1}^u(z_{t+1}; \zeta_{t+1}^u) = p_t(\theta_{t+1}; \zeta_{t+1}^u) s_t(z_{t+1}; \zeta_{t+1}^u) \int_{\zeta_{t+1}^u} u'(c_{t+1}(z_{t+1}; \zeta_{t+1}^e)) \Gamma_{t+1}(\zeta_{t+1}^e | \zeta_{t+1}^u) d\zeta_{t+1}^e + (1 - p_t(\theta_{t+1}; \zeta_{t+1}^u)) s_t(z_{t+1}; \zeta_{t+1}^u) u'(c_{t+1}(z_{t+1}; \zeta_{t+1}^u)),
\] (A.6)
where these hold with equality if \( z_{t+1}^i(z_t; \zeta_t^i) > \tilde{z}_t \), and I have defined the real interest rate
\[
1 + r_t \equiv (1 + i_t) \frac{P}{P_{t+1}}.
\]

**Firms** Retailer \( j \) facing (13) optimally sets
\[
P_{tj} = \frac{\varepsilon}{\varepsilon - 1} (1 + \tau R) P_t^l - \frac{\psi}{\varepsilon - 1} \Pi_{tj}^P (1 + \Pi_{P}^j) \left( \int_0^1 \frac{P_{tj} y_{tk} dk}{y_{tj}} \right) + (1 + i_t)^{-1} \frac{\psi}{\varepsilon - 1} \Pi_{t+1+j}^P (1 + \Pi_{P}^{t+1+j}) \left( \int_0^1 \frac{P_{t+1+jk} y_{t+1+k} dk}{y_{t+1+j}} \right)
\]
where \( \Pi_{tj}^P \equiv \frac{P_{tj}}{P_{t+1}} - 1 \) denotes \( j \)-specific inflation. Starting from identical prior prices, the symmetry across retailers implies that \( P_{tj} = P_t \) and thus \( y_{tj} = y_t \) across varieties. Dividing the above condition by \( P_t \) implies the nonlinear Phillips curve
\[
1 = \frac{\varepsilon}{\varepsilon - 1} (1 + \tau R) \mu_t^{-1} - \frac{\psi}{\varepsilon - 1} \Pi_t^P (1 + \Pi_t^P) + (1 + r_t)^{-1} \frac{\psi}{\varepsilon - 1} \Pi_{t+1}^P (1 + \Pi_{t+1}^P) \frac{y_{t+1}}{y_t}
\] (A.7)
where \( \mu_t \equiv \frac{P_t}{P_{t+1}} \) is the gross mark-up.

Finally, it is helpful to write producers’ problem (12) so that the firm only has one state variable, the composite \( \tilde{\phi}_t^e(\zeta_t^e) \equiv \tilde{P}_t^e \int_{z_{t}} \tilde{\phi}_t^e(z_t; \zeta_t^e) dz_t \) giving the measure of workers of type \( \zeta_t^e \) employed by the firm. Then the constraint summarizing the evolution of \( \tilde{\phi}_t^e(\zeta_t^e) \) is
\[
\tilde{\phi}_{t+1}^e(\zeta_{t+1}^e) = \int_{\zeta_t^e} \Gamma_t(\zeta_{t+1}^e | \zeta_t^e) (1 - \delta_t(\zeta_t^e)) \left( \tilde{\phi}_t^e(\zeta_t^e) + q_t(\theta_t) \nu_t \int_{\zeta_t^e} \Gamma_t(\zeta_t^e | \zeta_t^e) \int_{z_{t}} \tilde{\phi}_t^u(z_t; \zeta_t^u) dz_t d\zeta_t^u \right) d\zeta_t^e,
\]
with associated Lagrange multiplier \( \lambda_t^\phi(\zeta_t^e) \). Employing the calculus of variations, producer optimality is characterized by
\[
\int_{\zeta_t^e} \Gamma_t(\zeta_t^e | \zeta_t^e) \int_{z_{t}} \frac{m_t(\zeta_t^u)}{s_t} \tilde{\phi}_t^u(z_{t}; \zeta_t^u) dz_t d\zeta_t^u \right) d\zeta_t^e - \mu_t^{-1} a_t k \frac{q_t(\theta_t)}{\theta_t} = 0,
\] (A.8)
\[
\lambda_t^\phi(\zeta_t^e) = (1 + r_t)^{-1} s_{t+1}^f(\zeta_{t+1}^e),
\] (A.9)
given the real firm surplus from employing a marginal worker of type $\zeta^e_t$ in period $t$

$$s^f_t(\zeta^e_t) \equiv \mu^{-1}_t a_t(\zeta^e_t) - w_t(\zeta^e_t) + (1 - \delta_t(\zeta^e_t)) \int_{\zeta^e_{t+1}} \chi^\phi(\zeta^e_{t+1}) \chi^\delta(\zeta^e_{t+1}) |\zeta^e_t| d\zeta^e_{t+1}, \quad (A.10)$$

where we use the assumed wage protocol in which wages do not depend on individual workers’ wealth.

**Wage determination** Let us first characterize the wage $W_t^{nb}(\zeta^e_t)$ Nash bargained between the representative producer and union on behalf of newly matched workers of type $\zeta^e_t$. The firm’s real surplus from employing a marginal worker of type $\zeta^e_t$ at the arbitrary wage $\hat{W}_t$ in period $t$ and equilibrium wage $P^* w^e(\cdot)$ thereafter is

$$s^f_t(\zeta^e_t; \hat{W}_t) = \mu^{-1}_t a_t(\zeta^e_t) - \frac{\hat{W}_t}{P^*_t} + (1 - \delta_t(\zeta^e_t)) \int_{\zeta^e_{t+1}} \chi^\phi(\zeta^e_{t+1}) \chi^\delta(\zeta^e_{t+1}) |\zeta^e_t| d\zeta^e_{t+1}, \quad (A.11)$$

where $\chi^\phi(\zeta^e_{t+1})$ is characterized by (A.8) and (A.9) and $s^f_t(\zeta^e_t)$ is characterized by (A.10).

The surplus for an unemployed worker with wealth $z_t$ and of type $\zeta^u_t$ who matches with a firm, becomes type $\zeta^e_t$, and receives wage $\hat{W}_t$ in period $t$ and the equilibrium wage $P^* w^e(\cdot)$ thereafter is

$$s^u_t(z_t; \zeta^u_t; \zeta^e_t; \hat{W}_t) = \hat{u}^e_t(z_t; \zeta^e_t; \hat{W}_t) - v^u_t(z_t; \zeta^u_t). \quad (A.12)$$

The surplus of union $\zeta^e_t$ (which aggregates over its members using a utilitarian social welfare function) is thus

$$s^u_t(\zeta^e_t; \hat{W}_t) = \int_{\zeta^u_t} \chi^\gamma(\zeta^u_t) \int_{z_t} s^u_t(z_t; \zeta^u_t; \zeta^e_t; \hat{W}_t) m_t(\zeta^u_t) s_t(z_t; \zeta^u_t) \hat{u}^u(z_t; \zeta^u_t) dz_t d\zeta^u_t.$$

The Nash bargained wage with worker bargaining share $\phi$ solves

$$W^{nb}_t(\zeta^e_t) = \arg\max_{\hat{W}_t} s^u_t(\zeta^e_t; \hat{W}_t) \phi s^f_t(\zeta^e_t; \hat{W}_t) (1 - \phi),$$

which yields the first order condition

$$\frac{1 - \phi}{\phi} \frac{1}{\partial W_t} s^u_t(\zeta^e_t; W^{nb}_t) = -\frac{1}{\partial s^f_t(\zeta^e_t; W^{nb}_t)} s^f_t(\zeta^e_t; W^{nb}_t).$$

We have that

$$\frac{\partial s^f_t(\zeta^e_t; W^{nb}_t)}{\partial W_t} = -\frac{1}{P^*_t},$$

A15
\[
\frac{\partial s^w_t(\zeta^e_t; \hat{W}^nb_t)}{\partial \hat{W}_t} = \int_{\zeta^u_t} \Gamma_t(\zeta^e_t | \zeta^u_t) \int_{z_t} \frac{\partial s^w_t(z_t; \zeta^u_t; \zeta^e_t; \hat{W}^nb_t)}{\partial \hat{W}_t} m_t(\zeta^u_t) s_t(z_t; \zeta^u_t) \tilde{\varphi}^u_t(z_t; \zeta^u_t) dz_t d\zeta^u_t,
\]
\[
\frac{\partial s^w_t(z_t; \zeta^u_t; \zeta^e_t; \hat{W}^nb_t)}{\partial \hat{W}_t} = \frac{1}{P_t} u'(\zeta^e_t(z_t; \zeta^e_t; \hat{W}^nb_t)).
\]

It follows that the Nash bargained wage satisfies

\[
\frac{1 - \phi}{\phi} \int_{\zeta^u_t} \Gamma_t(\zeta^e_t | \zeta^u_t) \int_{z_t} u'(\zeta^e_t(z_t; \zeta^e_t)) \frac{m_t(\zeta^e_t) m_t(z_t; \zeta^e_t)}{s_t} \tilde{\varphi}^u_t(z_t; \zeta^u_t) dz_t d\zeta^u_t \times
\]
\[
\int_{\zeta^u_t} \Gamma_t(\zeta^e_t | \zeta^u_t) \int_{z_t} \left( v^e_t(z_t; \zeta^e_t) - v^u_t(z_t; \zeta^u_t) \right) \frac{m_t(\zeta^u_t) s_t(z_t; \zeta^u_t)}{s_t} \tilde{\varphi}^u_t(z_t; \zeta^u_t) dz_t d\zeta^u_t =
\]
\[
\mu_t^{-1} a_t(\zeta^e_t) - \frac{W^nb_t(\zeta^e_t)}{P_t} + (1 - \delta_t(\zeta^e_t)) \int_{\zeta^e_{t+1}} \lambda^e_t(\zeta^e_{t+1}) \Gamma_t(\zeta^e_{t+1} | \zeta^e_t) d\zeta^e_{t+1}. \quad (A.13)
\]

In steady-state, this characterizes the equilibrium real wage \(w(\zeta^e_t) = \frac{W^nb_t(\zeta^e_t)}{P_t} \). In transitional dynamics following a macroeconomic shock, by (14) the equilibrium real wage satisfies

\[
w_t(\zeta^e_t) = \bar{w}(\zeta^e_t) + (1 - \bar{\iota}) \frac{W^nb_t(\zeta^e_t)}{P_t}.
\]

**Resource and budget constraints** The preceding conditions characterize the equilibrium along with agents’ resource constraints and the market clearing conditions (17)-(22). To fully characterize the real allocation, it only remains to scale the latter conditions by the price level. As in the rest of the paper, I denote these real variables in lower case.

In particular, workers’ resource constraints imply

\[
c^e_t + (1 + r_t)^{-1} z^e_{t+1} = y^e_t(\zeta^e_t) + z_t, \quad (A.14)
\]
\[
c^u_t + (1 + r_t)^{-1} z^u_{t+1} = y^u_t(\zeta^u_t) + z_t, \quad (A.15)
\]

at each \(t\), where

\[
y^e_t(\zeta^e_t) \equiv w_t(\zeta^e_t) - t_t, \quad (A.16)
\]
\[
y^u_t(\zeta^u_t) \equiv b_t(\zeta^u_t). \quad (A.17)
\]

Since the output of each variety will be the same with identical prices, combining retailers’ linear technology with intermediate goods market clearing and equilibrium in the labor market yields

\[
y_t = p^e_t \int_{z_t} \int_{\zeta^e_t} a_t(\zeta^e_t) \varphi^e_t(z_t; \zeta^e_t) dz_t d\zeta^e_t - \bar{a}_t k \theta_t (1 - \bar{p}^e_t) \bar{s}_t, \quad (A.18)
\]

A16
while final goods market clearing implies
\[
p_t \int_{\zeta_t} \int_{z_t} c_t^e(z_t; \zeta_t^e) \varphi_t^e(z_t; \zeta_t^e) dz_t d\zeta_t^e + (1 - p_t) \int_{\zeta_t^u} \int_{z_t} c_t^u(z_t; \zeta_t^u) \varphi_t^u(z_t; \zeta_t^u) dz_t d\zeta_t^u = y_t. \tag{A.19}
\]

Asset market clearing implies
\[
p_t \int_{\zeta_t^e} \int_{z_t^e} z_{t+1}^e(z_t; \zeta_t^e) \varphi_{t+1}^e(z_t; \zeta_t^e) dz_t d\zeta_t^e + (1 - p_t) \int_{\zeta_t^u} \int_{z_t^u} z_{t+1}^u(z_t; \zeta_t^u) \varphi_{t+1}^u(z_t; \zeta_t^u) dz_t d\zeta_t^u
= -z_{t+1}^g + \pi_{t+1} + q_{t+1}, \tag{A.20}
\]

where the real price of the equity claim is
\[
q_t = (1 + r_t)^{-1} [\pi_{t+1} + q_{t+1}] \tag{A.21}
\]

and real dividends are
\[
\pi_{t+1} = y_{t+1} - p_{t+1} \int_{\zeta_{t+1}^e} w_{t+1}(\zeta_{t+1}^e) \int_{z_{t+1}} \varphi_{t+1}^e(z_{t+1}; \zeta_{t+1}^e) dz_{t+1} d\zeta_{t+1}^e. \tag{A.22}
\]

Finally, budget balance for the government implies
\[
p_t^e t_t + z_t^g = (1 - p_t^e) \int_{\zeta_t^e} \int_{z_t} b_t(\zeta_t^e) \varphi_t(z_t; \zeta_t^e) dz_t d\zeta_t^e + m_t z_{t+1}^g. \tag{A.23}
\]

**B.3 Bilateral efficiency of wages**

Recall the firm and worker surpluses \( s_t^f(\zeta_t^e; \tilde{W}_t) \) and \( s_t^w(z_t; \zeta_t^u; \zeta_t^e; \tilde{W}_t) \) characterized in (A.11) and (A.12), respectively. The real wages \( \{w_t(\zeta_t^e)\} \) are bilaterally efficient for all agents in the economy (absent commitment to long-term contracts) if and only if

\[
\begin{align*}
s_t^f(\zeta_t^e; P_t w_t(\zeta_t^e)) & \geq 0, \tag{A.24} \\
s_t^w(z_t; \zeta_t^u; \zeta_t^e; P_t w_t(\zeta_t^e)) & \geq 0, \tag{A.25}
\end{align*}
\]

for all \( \zeta_t^e \) employed by the firm and all \( \zeta_t^e \) such that \( \Gamma_t(\zeta_t^e|\zeta_t^u) > 0 \), respectively. As wages are Nash bargained in steady-state, (A.24) is naturally satisfied in a neighborhood of steady-state. The assumed absence of disutility from labor and replacement rates less than 100% make it easy to satisfy (A.25). I verify that these conditions are satisfied for all workers in the stationary RCE and in all transitional dynamics described in the main text.
### Table A.1: consumption sensitivities to income by employment status

<table>
<thead>
<tr>
<th>Moment</th>
<th>Mean</th>
<th>Obs.</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual MPC employed</td>
<td>0.47</td>
<td>4,213</td>
<td>2010 SHIW</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual MPC unemployed</td>
<td>0.72</td>
<td>129</td>
<td>2010 SHIW</td>
</tr>
<tr>
<td></td>
<td>(0.027)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two-month ∆ spending at UI exhaustion</td>
<td>-$263</td>
<td>27,740</td>
<td>Ganong and Noel [2019]</td>
</tr>
<tr>
<td></td>
<td>($8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two-month ∆ income at UI exhaustion</td>
<td>-$1,300</td>
<td>27,740</td>
<td>Ganong and Noel [2019]</td>
</tr>
<tr>
<td></td>
<td>($11)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: standard errors are in parentheses. Sampling weights in the 2010 SHIW are used to estimate population-wide means. Statistics around UI exhaustion taken from Appendix Table 8 in Ganong and Noel [2019].

### C  Empirical appendix

In this section I provide further details on the evidence regarding MPCs, wealth, and unemployment risk used to calibrate and evaluate the model in section 4, as well as evidence motivating my calibration of household portfolio shares relevant for transitional dynamics in response to unanticipated shocks.

#### C.1 Moments on MPCs, wealth, and unemployment risk

In this subsection I describe moments informative of MPC heterogeneity by employment status and the precautionary saving responses to changes in UI, used to calibrate and evaluate the quantitative model in 3. I provide further details regarding sample construction and variable definitions at the end of this appendix.

#### C.1.1 Consumption sensitivities to income by employment status

I first compare self-reported MPCs among unemployed versus employed agents, and review research on the spending behavior of long-term unemployed agents in particular around predictable UI benefit exhaustion. The results, summarized in Table A.1, suggest that the unemployed have especially large sensitivities of consumption to income.

The first two rows of Table A.1 imply that self-reported MPCs out of unexpected, transitory income shocks are 25% higher for unemployed versus employed households. I estimate these sample means using the 2010 Survey of Household Income and Wealth (SHIW) administered in Italy, a data source also used by other researchers studying MPCs (e.g., Japelli and Pistaferri [2014]). The advantage of this data source is its rich set of information collected...
alongside estimates of MPCs, including household heads’ contemporaneous employment status used here. A disadvantage is that the reported horizon of spending was not asked in the survey, though as Auclert [2019] notes, the consistency of average MPCs with the annual MPCs elicited in a later 2012 survey suggests that respondents had a one-year time frame in mind here. Another disadvantage is of course that the survey was administered in Italy, while I am interested in evidence for the U.S.²

Reassuringly, U.S.-based evidence focused on the unemployed also suggests that they, and the long-term unemployed in particular, have very high consumption sensitivities to income. The third and fourth rows of Table A.1 summarize the average changes in spending and income for UI recipients upon benefit exhaustion found by Ganong and Noel [2019] using data from JPMorgan Chase. These figures imply that upon UI exhaustion, spending falls by 20% of the reduction in household income. While this is not an MPC out of unexpected, transitory income shocks – both because UI exhaustion is predictable and because agents’ expectations regarding the future path of income may also change after one additional month of unemployment — the dramatic change in spending upon exhaustion does suggest considerably high MPCs among the long-term unemployed.

C.1.2 Wealth by employment status

I next document cross-sectional differences in liquid wealth by employment status, summarized in Table A.2. I find that wealth is considerably lower among the unemployed, and the long-term unemployed in particular, versus the employed. Together with prior research finding higher MPCs among low wealth households (e.g., Broda and Parker [2014]), this suggests that MPCs will be higher among this group.

Using the 2004 Survey of Consumer Finances (SCF), the first four columns of Table A.2 demonstrate that the unemployed have considerably lower median and mean wealth than the employed. I focus on two definitions of wealth: liquid, which only includes transaction (checking, saving, money market, call, and prepaid) accounts and directly held bonds, less credit card balances; and total, which includes all components of net worth. I then scale by average monthly income over the past year among households with an employed or unemployed household head ($6,761 in $2004) to ease interpretation as well as the eventual mapping between data and model. Using liquid wealth, the median unemployed agent holds

²A final disadvantage is that MPCs are self-reported rather than estimated from actual spending behavior. In results available on request, I merge the Consumer Expenditure Survey (CE) data on 2001-02 tax rebates assembled by Johnson et al. [2006] and 2008-09 tax rebates assembled by Parker et al. [2013] with the employment status of the household head in the underlying CE interview files. Unfortunately, the standard errors are so large that I am unable to distinguish between a substantially positive, zero, or substantially negative difference between the MPC of households with employed versus unemployed heads.
between 0.2 less months of income than the employed; given the skewness of wealth (especially pronounced for the employed), mean unemployed wealth is 2.7 months of income below that of the employed. Using total wealth, these moments are 11.4 and 47.5 months of income, respectively.

Data from the Survey of Income and Program Participation (SIPP) further suggests that wealth is especially low among long-term unemployed households. Unlike the SCF, the panel structure of the SIPP together with its questions regarding weekly employment status allow me to construct a measure of unemployment duration for each household head at the end of each month. In the 2004 panel, household balance sheet data was collected in the third and sixth waves of the survey. I summarize mean wealth by unemployment duration at the time wealth was surveyed in the last three columns of Table A.2. The mean liquid wealth of long-term unemployed households is 0.5 months of income below that of short-term unemployed households. We must nonetheless interpret such an estimate with caution given the small samples of long-term unemployed and well-known measurement issues in the SIPP (evident, for example, in the smaller mean levels of wealth among the unemployed versus the SCF).

### C.1.3 Wage-EU and wealth-EU relationships

I next document negative relationships between wages and employment-to-unemployment (EU) transition probabilities and between wealth and EU probabilities in Table A.3. This is
likely critical in shaping the precautionary responses to UI, though the direction is unclear without the aid of the structural model in this paper. On the one hand, if low wealth households disproportionately bear unemployment risk, the aggregate importance of their changes in saving may be limited; on the other, job loss may be especially painful for this group, generating large precautionary responses to changes in UI.

The first column of Table A.3 uses 2004-2007 data from the monthly Outgoing Rotation Groups of the Current Population Survey (CPS) to find a tight negative relationship between 1-year-ahead EU probabilities and weekly pay when employed. The CPS interviews households for four months, rotating them out of the panel for eight months before resurveying them. In the fourth month, earnings data is collected for those individuals which report themselves as employed. Consider all individuals $i$ who have their fourth interview in each calendar month $t$, report being employed with positive pay, and remain in the labor force twelve months later. Letting $logpay_{it}$ denote log weekly pay and $1\{u\}_{i,t+12}$ denote an indicator for unemployment in calendar month $t + 12$, I run the specification

$$1\{u\}_{i,t+12} = \alpha_t + \beta logpay_{it} + \epsilon_{it}.$$ 

The fixed effects allow for time-varying average probabilities of an employed individual becoming unemployed over the sample period. The estimated $\hat{\beta} = -0.012$ implies that a 10pp increase in the wage is associated with a 0.12pp decrease in the probability of an individual being unemployed one year in the future. Given an average such probability ranging from

<table>
<thead>
<tr>
<th>2004-07 CPS</th>
<th>2004 SIPP Panel</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1{e}<em>{i,t} \times logpay</em>{it}$</td>
<td>-0.012 (0.0006)</td>
</tr>
<tr>
<td>$1{u}_{i,t+12}$</td>
<td>-0.0009 (0.0005)</td>
</tr>
<tr>
<td>$liqwealth_{it}$</td>
<td>-0.0004 (0.0005)</td>
</tr>
<tr>
<td>$totwealth_{it}$</td>
<td>-0.0002 (0.00005)</td>
</tr>
<tr>
<td>$logearn_{it}$</td>
<td>-0.012 (0.002)</td>
</tr>
<tr>
<td>Time FE</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>158,181</td>
</tr>
</tbody>
</table>

Table A.3: wage-EU and wealth-EU relationships

Note: standard errors reported in parentheses are clustered at the household level in each regression. Observations below the 5th percentile and above the 95th percentile of wealth are dropped in the SIPP regressions to minimize the influence of outliers. Sampling weights in both the CPS and SIPP are used.
1.6% to 2.8% in each month of 2004 through 2006, this is economically meaningful.

The second and third column of Table A.3 use the 2004 panel of the SIPP to estimate a similarly tight negative relationship between 1-year-ahead EU probabilities and wealth when employed. Recall that wealth data was collected for households in waves 3 and 6 of the survey. Consider all household heads $i$ whose interview in one of these waves is in calendar month $t$ and report being employed, provide non-missing wealth and income (the latter described further below), and remain in the labor force twelve months later. Letting $liqwealth_{it}$ and $totwealth_{it}$ denote the two measures of wealth scaled by mean monthly income described in Table A.2 and $1\{u\}_{it+12}$ denote an indicator for unemployment in calendar month $t + 12$, I run the specification

$$1\{u\}_{it+12} = \alpha_{1t} + \beta_{1} liqwealth_{it} + \epsilon_{1it},$$

and analogously for $totwealth$. The estimates imply that one additional month of average income in wealth is associated with a 0.02-0.09pp decrease in the probability of an employed agent being unemployed one year in the future. Given attenuation bias from measurement error of wealth in the SIPP, the true relationships may be even stronger.

The fourth and fifth columns of Table A.3 add income to the previous regressions, demonstrating that the negative EU-wealth relationship survives even after conditioning on income. Earned income is collected in each wave of the SIPP survey. I add log earned income of the household head ($logearn_{it}$) as a dependent variable in the above regressions and, reassuringly, find that its coefficient across specifications is consistent with that on log weekly pay in the CPS regressions. More importantly, even conditional on income, one additional month of average income in wealth is associated with a 0.01-0.04pp decrease in the probability of an employed agent being unemployed one year in the future.

### C.1.4 Income and consumption through unemployment spell

Finally, I describe the reduction in household income and consumption through unemployment in Table A.4. The results of section 2 imply that it is important to replicate these losses in the quantitative analysis as — together with the incidence of unemployment described above and the degree of prudence in agents’ utility — they determine the strength of the precautionary response to changes in UI.

The first and last columns in Table A.4 quantify the average declines in household income and spending among UI recipients during receipt and after exhaustion relative to the period prior to job loss. The decline in income is estimated using Rothstein and Valletta [2017]’s extract of unemployment spells in the 2001 and 2008 SIPP panels. Among household heads who lose their jobs and ultimately exhaust UI, household income falls by an average of 24%
### Table A.4: income and consumption through unemployment spell

<table>
<thead>
<tr>
<th>Moment</th>
<th>Total</th>
<th>Own</th>
<th>UI</th>
<th>Other HH</th>
<th>SNAP +welf.</th>
<th>Soc. Sec.</th>
<th>Spending</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean prior to job loss</td>
<td>1.00</td>
<td>0.67</td>
<td>0.02</td>
<td>0.21</td>
<td>0.03</td>
<td>0.04</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.01)</td>
<td>(0.00)</td>
<td>(0.01)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td></td>
</tr>
<tr>
<td>Mean during UI receipt</td>
<td>0.76</td>
<td>0.02</td>
<td>0.31</td>
<td>0.29</td>
<td>0.05</td>
<td>0.06</td>
<td>0.91</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.00)</td>
<td>(0.01)</td>
<td>(0.02)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td></td>
</tr>
<tr>
<td>Mean after UI exhaustion</td>
<td>0.55</td>
<td>0.08</td>
<td>0</td>
<td>0.29</td>
<td>0.06</td>
<td>0.07</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.01)</td>
<td>(n/a)</td>
<td>(0.02)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>869</td>
<td>869</td>
<td>869</td>
<td>869</td>
<td>869</td>
<td>869</td>
<td>27,740</td>
</tr>
</tbody>
</table>

Note: standard errors reported in parenthesis are clustered at the household level. Period prior to job loss defined as the three months prior to separation for income, and five months prior to first month of UI for spending. Period of UI receipt defined as the three months prior to the last month of UI. Period after UI exhaustion defined as the month after the last month of UI. Sample for income is that in Tables 3 and 4 of Rothstein and Valletta [2017] but restricted to reference persons only. Spending taken from Figure 1B (6+ months unemployed) of Ganong and Noel [2019].

During UI receipt and a further 21% after UI exhaustion. The associated decline in spending has been estimated by a large literature beginning with Gruber [1997]. In their recent work using the JPMorgan Chase panel, Ganong and Noel [2019] estimate that the spending of UI exhaustees falls by 9% during UI receipt and a further 11% after UI exhaustion.

The middle columns of Table A.4 demonstrate that non-UI sources of income are necessary to rationalize these income dynamics during unemployment.\(^3\) Prior to job loss, the household head’s earnings are only two-thirds of total household income. The remainder is largely earnings of other household members, which increase after job loss consistent with an added worker effect. Social Security, the Supplemental Nutrition Assistance Program (SNAP), and other social assistance also provide modest income support throughout unemployment. Taken together, while UI only replaces half of the income lost upon job loss, overall household income falls by less than 50% because of the income support provided by other household members and, to a lesser extent, other transfer programs.

\(^3\)For the average household, the sum of the reported components of total income explain almost all of reported total income, though a few percentage points remains unexplained.
C.2 Portfolio shares

Define the beginning-of-period real market value of equity

\[ \tilde{q}_t \equiv \pi_t + q_t. \]  

(A.26)

In response to an unexpected shock in period \( t \) studied in sections 5 and 6 of the main text, this equity value will change. This will revalue household balance sheets according to their positions in equity. Since the absence of aggregate risk renders the composition of agents’ portfolios indeterminate, I use empirical patterns in household portfolios to map household wealth \( z \) into positions in bonds and equity which add up to \( z \) at the initial (pre-shock) \( \tilde{q}_t \):

\[ z^b_t(z), z^f_t(z) := z^b_t + \tilde{q}_t z^f_t = z. \]

Given these mappings, a household with wealth \( z \) in the initial equilibrium will experience a wealth revaluation

\[ dz = d\tilde{q}_t z^f_t(z) \]
on impact of the shock. In this subsection I describe empirical patterns in household portfolios using the 2004 SCF and how I use them to define the mappings \( z^b_t(z) \) and \( z^f_t(z) \).

The 2004 SCF implies that households have very little exposure to corporate profits at low levels of wealth, but have positive and rising exposure to corporate profits at moderate/high levels of wealth. I construct measures of such exposure using the asset holdings of labor force participants described in Table A.2. For liquid wealth, used as the target for the wealth distribution in the baseline model, I define \( corpexposure1_i \) as the ratio of household \( i \)'s bond position to total liquid wealth, since bonds are the only asset included in this definition involving direct exposure to corporate profits. I then compute the mean of this measure by the 5% quantile of liquid wealth. For total wealth, used in sensitivity analysis in appendix D, I define \( corpexposure2_i \) as the ratio of household \( i \)'s total position in bonds, stocks, mutual funds, quasi-liquid retirement assets, other managed assets, other financial assets, and business equity to total wealth. I then compute the median of this measure by the 5% quantile of total wealth.\(^4\) Figure A.1 demonstrates that both exposure measures are nonlinear, with positive and rising exposure only at moderate/high levels of wealth.

Motivated by these empirical patterns, I assume agents’ portfolios follow a piecewise

\(^4\)The median appears more informative since we are dividing here by measures of wealth, which can be small. I use the mean for the exposure measure based on liquid wealth because the median of this measure is identically zero at all levels of wealth.
log-linear specification. For an agent with wealth \( z \), I assume that

\[
  z^f_t(z) = \begin{cases} 
  0 & \text{if } z \leq z^*_t, \\
  \frac{1}{\bar{q}_t^*} z_t \gamma_t (\log z - \log z^*_t) & \text{if } z > z^*_t
  \end{cases}
\]

is held in firm equity, where \( \bar{q}_t \) refers to the pre-shock price of equity and \( z^*_t, \gamma > 0 \). The remainder \( z^b_t(z) = z - \bar{q}_t z^f_t(z) \) is held in the riskless bond. In the benchmark analysis, I set \( z^*_t \) to be the 75th percentile of the pre-shock wealth distribution, consistent with mean \( \text{corpexposure1} \) only rising meaningfully after the 15th quantile in the first panel of Figure A.1. In the sensitivity analysis using total wealth in appendix D, I set \( z^*_t \) to be the 25th percentile of the pre-shock wealth distribution, consistent with mean \( \text{corpexposure2} \) rising rapidly after the 5th quantile in the second panel of Figure A.1. In both cases, \( \gamma_t \) is then set such that the implied aggregate wealth invested in firm equity is consistent with that in the pre-shock equilibrium.\(^5\)

In the impulse responses starting from steady-state in section 5, the pre-shock equilibrium is simply the stationary RCE. In period \( t \) of the Great Recession simulation in section 6, the pre-shock equilibrium is the one which would prevail absent any shocks from \( t \) onwards.

\(^5\)Computationally, I also assume that agents at the highest 1% of gridpoints in wealth have zero equity to avoid revaluations in wealth far outside the original range. I further check that the bond positions implied by this algorithm respect the borrowing constraint and equity positions respect the short-sale constraint.

Figure A.1: exposure to corporate profits by wealth quantile in 2004 SCF

Note: sample is identical to that in Table A.2 and sampling weights are used. Means by quantile exclude households with exposure measures outside of [-5,5].

![Figure A.1: exposure to corporate profits by wealth quantile in 2004 SCF](image_url)
C.3 Data sources, sample construction, and variable definitons

The prior two subsections drew on public microdata from the 2010 Survey of Household Income and Wealth (SHIW) in Italy, the 2004 Survey of Consumer Finances (SCF), the 2004 panel of the Survey of Income and Program Participation (SIPP), and the 2004-2007 monthly Outgoing Rotation Groups in the Current Population Survey (CPS). Here I provide more detail on the samples and variables in my analysis.

C.3.1 2010 SHIW

The 2010 SHIW microdata covers survey responses of 19,836 individuals from 7,951 households. The responses to two questions are used in the analysis described in the main text. The first question of interest asks about households’ employment status for most of 2010 (B01 on the questionnaire). I define as employed those who respond with code 1–5 (indicating different forms of paid employment such as being a production worker or manager), 6–10 (indicating different forms of self-employment such as being an entrepreneur), or 20 (“other self-employed”). I define as unemployed those who respond with code 12 (“unemployed”). Other codes indicate non-employment such as that of students, homemakers, or retirees.

The second question of interest asks about households’ MPC out of unexpected, transitory income shocks (E14 on the questionnaire), also studied in Japelli and Pistaferri [2014]. It asks: “Imagine you unexpectedly receive a reimbursement equal to the amount your household earns in a month. How much of it would you save and how much would you spend? Please give the percentage you would save and the percentage you would spend.” I define the MPC as respondents’ stated percentage of how much they would spend.

I start my sample with the 7,951 household heads (I focus on household heads since consumption decisions are made at the household level). Of these, 4,342 are either employed or unemployed. This forms the sample for my analysis.

C.3.2 2004 SCF

The 2004 SCF microdata provides detailed balance sheet and income information for 4,519 households.

Ten balances are used in the analysis described in the prior subsections, all of which are available in the summary extract public data: transaction accounts (checking, saving, money market, call, and prepaid accounts); bonds (not including bond funds or saving bonds); directly-held mutual funds (excluding money market mutual funds); stocks; quasi-liquid retirement balances (IRAs, thrift accounts, and future pensions); other managed assets
(trusts, annuities and managed investment accounts with an equity interest); other financial wealth; business equity; credit card debt; and total net worth.

Average monthly income, used to scale each of the balances above, is constructed by computing average household income over the prior calendar year across my sample (the construction of which is described further below) and then dividing by 12.

Finally, I define the employment status for household heads by merging in the full public dataset and examining fields X6670–X6677. This contains the responses to a question about the household head’s present job status; since the respondent is able to provide multiple responses to this question, 8 fields are reported. I define as employed those who respond with code 1 (“working now / self-employed; job accepted and waiting to start work”) to any of X6670–X6677. Of the remaining respondents, I define as unemployed those who respond with code 3 (“unemployed and looking for work”) to any of X6670–X6677. Other codes indicate non-employment such as that of students, homemakers, or retirees.

I start my sample with 4,519 households in the summary extract public data. Of these, 3,454 have household heads which I have coded as either employed or unemployed. This forms the sample for my analysis.

C.3.3 2004 SIPP Panel

The 2004 SIPP Panel microdata follows respondents over 12 waves of surveys at 4 month intervals. I use data on wealth, income, and employment status for respondents over time.

Wealth data at the household level is available in the topical module focused on assets and liabilities asked of respondents in the 3rd and 6th wave of the survey. I use six balances reported in these waves, mapping them to the wealth balances measured in the SCF as follows. First, I use interest-earning assets held in banking institutions and treat this as comparable to transaction account balances in the SCF. Second, I use interest-earning assets held in other institutions and treat this as comparable to bonds in the SCF. Third, I use total unsecured debt and treat this as comparable to credit card debt in the SCF. Fourth, I use total net worth and treat this as comparable to total net worth in the SCF.

Income data at the individual level is available in the core module in each wave of the survey. Respondents are asked to provide their total earned income for the month.

Employment data at the individual level is available in the core module in each wave of the survey. Respondents are asked to provide their employment status for each week of each month of the four months preceding the interview: with a job and working (1); with a job and not on layoff, but absent without pay (2); with a job but on layoff (3); without a job and looking for work or on layoff (4); and without a job, not looking for work, and not on layoff (5). I define respondents’ employment status for each month using their response for
the fourth week of each month: they are in the labor force if their response is 1 through 4; employed if their response is 1 or 2; and unemployed if their response is 3 or 4. Using these measures of employment status each month, I can further construct a measure of unemployment duration at any month of the sample among those who are unemployed.

I start my sample with 69,256 observations of reference persons (which I treat as household heads) with complete interview and asset information surveyed in waves 3 and 6. For the analysis of wealth by employment status in Table A.2, only 32,326 provide complete interview information and have been in the labor force continuously for the prior 12 months, forming the sample for this analysis. For the analysis of wealth-EU relationships in Table A.3, only 44,958 are employed as of the wealth survey date, and of these only 20,970 provide complete interview information and are in the labor force 1 year from their wealth survey date, forming the sample for this analysis.6

C.3.4 2004–2007 CPS

The January 2004 through December 2007 Outgoing Rotation Group (ORG) microdata from the CPS reports the income of respondents alongside their employment status. These surveys occur for respondents in their fourth and eighth interviews with the CPS. Since respondents are interviewed monthly, but rotated out of the survey for eight months after their fourth interview before being rotated back in, the merged ORG files contain a monthly snapshot for each respondent one year apart.

I use the monthly ORG files processed by the Center for Economic and Policy Research (CEPR) as the basis for my analysis, as these researchers layer on a common set of variable names to ease the comparability of data over time. For employment status, I use indicators for employment and unemployment derived by CEPR from the underlying monthly labor force recode in the CPS. For earnings, I use the weekly pay measure provided by CEPR using the weekly earnings recode in the CPS.

I start my sample with 479,210 individuals whose fourth interview takes place between January 2004 through December 2006 (and thus whose eighth interview should be between January 2005 through December 2007). Of these, I am able to match 286,632 to their eighth interview using exact matches on household ID, line number, race, sex, and age (adjusted by one year). 193,277 of these are employed in their fourth interview, 168,786 of these report weekly pay information, 168,454 of these report non-zero pay, and 158,181 of these remain in the labor force in their eighth interview. This forms the sample for my analysis.

I further trim the 5% lowest and 5% highest observations of wealth to minimize the role of outliers in the regression analysis in Table A.3. The existence of observations with identical values of wealth at the relevant cutpoints, but slightly different numbers of such observations for the different definitions of wealth, leads to the variation in sample sizes between 18,874 and 18,875 described in the last row of Table A.3.
D Supplementary results on impulses responses to UI

In this section I supplement the impulse responses to UI shocks starting from the model’s stationary RCE in section 5. I first describe, for my baseline experiment, the dynamics of other macroeconomic aggregates and welfare effects across dimensions of heterogeneity excluded from the main text for brevity. I then provide additional experiments investigating eligibility/take-up, debt finance, and the effect of raising the replacement rate rather than UI duration. I provide the calibration of alternative steady-states studied in the main text. Finally, I characterize the effects of UI in alternative calibrations of the wealth distribution and equilibrium profits of retailers.

D.1 Other macroeconomic aggregates in baseline experiment

Figure A.2 summarizes additional effects of the three-month UI extension for one year beyond those provided in Figure 3 of the main text.

Under flexible prices, the unemployment rate rises and labor market tightness falls during the period of extended UI. As described in the main text, this reflects both a reduction in vacancies and reduction in average search effort among the unemployed ($\bar{s}_t$). The behavior of the nominal interest rate and nominal prices is irrelevant because of the real/nominal dichotomy in this environment.

Under sticky prices, the unemployment rate instead falls and labor market tightness rises during the period of extended UI. The latter reflects an increase in vacancies, despite the decline in worker search, as producers seek to meet the change in demand. The accompanying decline in the retailer markup generates inflation, to which monetary policy responds by raising the nominal interest rate. The rise in the nominal interest rate implies a rise in the real interest rate which mitigates the stimulus from extended UI.

With sticky prices and a constant real interest rate for 18 months, the decline in unemployment and increase in vacancies, tightness, and inflation are all more substantial than the previous case. Given the tighter labor market, workers reduce their search. I expect this effect would be reversed in an alternative model of matching where search falls with tightness, as in Mukoyama et al. [2018]. Nonetheless, I conjecture that the effect on unemployment and output would be little changed: as demonstrated by my analytical results as well as quantitative sensitivities, vacancy creation and thus tightness should adjust to the new search response so that the overall change in employment still ultimately reflects the change in desired demand through redistribution and precautionary saving. Note furthermore that the constant real interest rate requires that the central bank still raise the nominal rate somewhat, because there is positive inflation.
Figure A.2: additional effects of UI starting from steady-state

Note: the panels describe additional effects of a one-year extension of UI duration by three months starting from the stationary RCE with no other macroeconomic shocks.
With sticky prices and a constant nominal interest rate for 18 months, the rise in inflation lowers the real interest rate, further stimulating demand. Thus, all of the responses are slightly amplified relative to the previous case.

### D.2 Welfare effects of UI extensions

In Figure 4 I focused for brevity on the welfare effects of UI extensions by employment status and the persistent component of income for employed agents. Here I present the full decomposition of welfare effects across the idiosyncratic state space.

For unemployed agents, the average welfare effects conditional on duration of unemployment are computed as described in the note to Figure 4.
Figure A.4: welfare effects of UI policy under sticky prices and fixed $i$

Note: the panels describe additional welfare effects of a one-year extension of UI duration by three months starting from the stationary RCE with no other macroeconomic shocks. The welfare effects are computed as described in the note to Figure 4.

ment, eligibility for UI, and discount factor are presented in Figure A.3. Duration has a non-monotonic relationship with the change in welfare, as it is the initially medium-term unemployed who are likely to make use of the benefit extensions who gain the most. Recalling that eligibility and take-up of UI is exogenous conditional on job loss, those able to receive UI naturally gain more than those who cannot. The role of discount factor heterogeneity is small and depends on agents’ level of wealth.

For employed agents, the average welfare effects conditional on transitory income and discount factor are presented in Figure A.4. The role of the former is naturally small, but the latter is comparatively large: the most impatient employed agents gain the most, since they have a higher risk of separating from their job.

The broad welfare gains even among unemployed agents who do not receive UI as well as the employed are further evidence of the positive demand externalities from transfers.

D.3 Other features of UI policy

Other policy features reinforce the mechanisms through which MPC heterogeneity and precautionary saving drive the equilibrium effects in the presence of nominal rigidity and constraints on monetary policy.

Higher eligibility/take-up of UI amplifies the stimulus by expanding the scale of transfers. This is relevant because the fraction of the unemployed who are eligible for and take up UI is countercyclical (Chodorow-Reich and Karabarbounis [2016]). The second column of Table
Table A.5: policy sensitivities under sticky prices and fixed $i$

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Higher eligibility/take-up</th>
<th>Debt financing</th>
<th>$rr$ shock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output multiplier</td>
<td>1.1</td>
<td>1.2</td>
<td>1.2</td>
<td>0.8</td>
</tr>
<tr>
<td>Avg change in unemp. rate</td>
<td>-0.06pp</td>
<td>-0.07pp</td>
<td>-0.06pp</td>
<td>-0.12pp</td>
</tr>
</tbody>
</table>

Note: the first counterfactual features $\zeta = 1$ during the first six months of extended benefits. The second counterfactual features unchanged taxes for first 24 months before adjusting to retire the accumulated debt. The third counterfactual raises the replacement rate by 10pp for one year instead of extending UI duration.

A.5 indicates that if the eligibility/take-up probability $\zeta_t$ increases to 1 during months 0 through 5, the output multiplier and reduction in unemployment are slightly larger.

Debt finance of UI amplifies the stimulus through redistribution because the borrowing constraint breaks Ricardian equivalence in this environment. This is also relevant in practice because extended UI benefits, as with other discretionary fiscal measures, are typically deficit-financed. The third column of Table A.5 summarizes the effects of a year of extended UI holding taxes on the employed fixed for the first 24 months, with the government asset position $z^g_t$ adjusting to balance the budget each period. After $t = 24$, taxes again balance each period’s budget with assets returning to steady-state according to

$$z^g_{t+1} = z^g + \rho^g (z^g_t - z^g)$$

given $\rho^g = 0.95$. The output multiplier is now slightly larger.

Comparing duration to level, we can see the effectiveness of the long-term unemployed as a “tag” in stabilization. The fourth column of Table A.5 keeps UI duration at 6 months but raises the replacement rate among all UI recipients by 10pp for one year. The output multiplier falls relative to duration extensions, consistent with the long-term unemployed having especially high MPCs and long-term unemployment being a particularly costly state of the world against which agents precautionary save. Nonetheless, the aggregate stimulus is higher in the case of the replacement rate increase owing to the larger magnitude of transfers under this policy.

D.4 Alternative calibrations from main text

I now provide more detail on the alternative calibrations studied in the main text.

**Identical $\delta$** Workers’ separation rates in the model vary by their permanent level of productivity and discount factor. These allow the model to match the sensitivity in employment-
Table A.6: targeted moments and calibration results

<table>
<thead>
<tr>
<th>Moment</th>
<th>Target</th>
<th>Achieved</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real rate, wealth, and average MPC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real interest rate (ann.)</td>
<td>2%</td>
<td>2.0%</td>
<td>$\delta/\bar{a}$</td>
<td>-3.47</td>
</tr>
<tr>
<td>Mean wealth / monthly HH income</td>
<td>3.7</td>
<td>3.7</td>
<td>$\bar{\beta}$</td>
<td>0.99374</td>
</tr>
<tr>
<td>Fraction HH with negative wealth</td>
<td>0.26</td>
<td>0.31</td>
<td>$z/\bar{a}$</td>
<td>-0.5</td>
</tr>
<tr>
<td>Mean quarterly MPC to $500$ rebate</td>
<td>0.21</td>
<td>0.22</td>
<td>$\Delta\beta$</td>
<td>0.0045</td>
</tr>
<tr>
<td>Income during unemployment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share unemployed receiving UI</td>
<td>0.39</td>
<td>0.41</td>
<td>$\zeta$</td>
<td>0.5</td>
</tr>
<tr>
<td>Mean HH income w. UI / pre job loss</td>
<td>0.76</td>
<td>0.77</td>
<td>$\omega_1$</td>
<td>0.39</td>
</tr>
<tr>
<td>Mean HH income w.o UI / pre job loss</td>
<td>0.55</td>
<td>0.56</td>
<td>$\omega_2$</td>
<td>0.52</td>
</tr>
<tr>
<td>Incidence of unemployment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unemployment rate</td>
<td>5%</td>
<td>5.1%</td>
<td>$\phi$</td>
<td>0.957</td>
</tr>
<tr>
<td>Fraction w/ duration 4-6 mos</td>
<td>0.14</td>
<td>0.18</td>
<td>$\lambda_0$</td>
<td>1.1</td>
</tr>
<tr>
<td>Fraction w/ duration &gt; 6 mos</td>
<td>0.17</td>
<td>0.20</td>
<td>$\lambda_1$</td>
<td>-0.14</td>
</tr>
<tr>
<td>Search and the labor market</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration elasticity to benefit duration</td>
<td>0.1</td>
<td>0.10</td>
<td>$\xi$</td>
<td>16</td>
</tr>
<tr>
<td>Vacancies per unemployed worker</td>
<td>0.634</td>
<td>0.634</td>
<td>$\bar{m}$</td>
<td>0.19</td>
</tr>
<tr>
<td>Fraction of monthly wage to hire worker</td>
<td>0.108</td>
<td>0.108</td>
<td>$k/\bar{a}$</td>
<td>0.044</td>
</tr>
</tbody>
</table>

Note: relative to the baseline, I assume $\epsilon_\delta = \epsilon_\delta = 0$ and drop the associated targeted moments. The other targets are unchanged from the baseline.

To understand how the quantitative results change with an identical $\delta$ across workers and thus shallower profile of MPCs by duration of unemployment implied by the model.

To understand how the quantitative results change with an identical $\delta$ across workers and thus shallower profile of MPCs by duration of unemployment, I set $\epsilon_\delta = \delta \beta = 0$ and re-calibrate the other parameters of the model to match the same other targets. This yields the parameter choices in Table A.6.

$\sigma = 4$ One of the assumed parameters in the calibration is the coefficient of relative risk aversion $\sigma$, set to 1 in the baseline case. Under CRRA utility this implies a coefficient of relative prudence $\sigma + 1$. The analytical results of section 2 confirm that prudence plays an important role in governing the macroeconomic effects of UI under nominal rigidities by controlling the strength of the precautionary savings response to changes in UI.

To understand how the quantitative results change under a higher coefficient of prudence and thus precautionary savings response, I set $\sigma = 4$ and re-calibrate the parameters of the model to match the same targets. This yields the parameter choices in Table A.7. Note that a lower average discount factor is needed to match the same wealth distribution, as
### Table A.7: calibration results assuming $\sigma = 4$

<table>
<thead>
<tr>
<th>Moment</th>
<th>Target</th>
<th>Achieved</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Real rate, wealth, and average MPC</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real interest rate (ann.)</td>
<td>2%</td>
<td>2.0%</td>
<td>$z^\theta / \bar{a}$</td>
<td>-3.58</td>
</tr>
<tr>
<td>Mean wealth / monthly HH income</td>
<td>3.7</td>
<td>3.8</td>
<td>$\bar{\beta}$</td>
<td>0.971</td>
</tr>
<tr>
<td>Mean (U-E) wealth / monthly HH income</td>
<td>-2.7</td>
<td>-2.8</td>
<td>$\epsilon^\delta$</td>
<td>-0.75</td>
</tr>
<tr>
<td>Fraction HH with negative wealth</td>
<td>0.26</td>
<td>0.27</td>
<td>$z / \bar{a}$</td>
<td>-0.5</td>
</tr>
<tr>
<td>Mean quarterly MPC to $500$ rebate</td>
<td>0.21</td>
<td>0.23</td>
<td>$\Delta^\beta$</td>
<td>0.0269</td>
</tr>
<tr>
<td><strong>Income during unemployment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share unemployed receiving UI</td>
<td>0.39</td>
<td>0.41</td>
<td>$\zeta$</td>
<td>0.5</td>
</tr>
<tr>
<td>Mean HH income w. UI / pre job loss</td>
<td>0.76</td>
<td>0.77</td>
<td>$\omega_1$</td>
<td>0.39</td>
</tr>
<tr>
<td>Mean HH income w/o UI / pre job loss</td>
<td>0.55</td>
<td>0.56</td>
<td>$\omega_2$</td>
<td>0.52</td>
</tr>
<tr>
<td><strong>Incidence of unemployment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unemployment rate</td>
<td>5%</td>
<td>5.0%</td>
<td>$\phi$</td>
<td>0.975</td>
</tr>
<tr>
<td>Fraction w/ duration 4-6 mos</td>
<td>0.14</td>
<td>0.18</td>
<td>$\lambda_0$</td>
<td>1.1</td>
</tr>
<tr>
<td>Fraction w/ duration &gt; 6 mos</td>
<td>0.17</td>
<td>0.20</td>
<td>$\lambda_1$</td>
<td>-0.14</td>
</tr>
<tr>
<td>EU probability on log wage</td>
<td>-0.012</td>
<td>-0.012</td>
<td>$\epsilon^\delta_a$</td>
<td>-0.15</td>
</tr>
<tr>
<td><strong>Search and the labor market</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration elasticity to benefit duration</td>
<td>0.1</td>
<td>0.11</td>
<td>$\xi$</td>
<td>28</td>
</tr>
<tr>
<td>Vacancies per unemployed worker</td>
<td>0.634</td>
<td>0.634</td>
<td>$\bar{m}$</td>
<td>0.18</td>
</tr>
<tr>
<td>Fraction of monthly wage to hire worker</td>
<td>0.108</td>
<td>0.108</td>
<td>$k / \bar{a}$</td>
<td>0.044</td>
</tr>
</tbody>
</table>

Note: relative to the baseline, I set $\sigma = 4$ rather than $\sigma = 1$. The targets are unchanged from the baseline.

Precautionary motives play a bigger role in driving wealth accumulation in this calibration.

**Higher target for micro disincentive effect**  
Turning to the supply-side, in the baseline calibration the elasticity of disutility from search $\xi = 16$ is used to target a micro elasticity of 0.1, within the range of estimates for the U.S. provided in the survey of Schmieder and von Wachter [2016]. However, as these authors note, a wide range of estimates for this elasticity have been obtained in the literature, reaching as high as roughly 0.4.

To understand how the quantitative results change under a higher disincentive effect of UI, I instead use $\xi$ to target an elasticity of unemployment duration with respect to benefit duration of 0.4, and re-calibrate the other parameters of the model to match the same targets. This yields the parameter choices in Table A.8. Note that while the supply-side of the model has changed, agents’ consumption behavior is little changed relative to the baseline: the comparable MPCs to those in Table 3 are 21% for the employed, 41% for the short-term unemployed, 50% for the medium-term unemployed, and 64% for the long-term unemployed.
<table>
<thead>
<tr>
<th>Moment</th>
<th>Target</th>
<th>Achieved</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Real rate, wealth, and average MPC</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real interest rate (ann.)</td>
<td>2%</td>
<td>2.0%</td>
<td>z^g/¯a</td>
<td>-3.32</td>
</tr>
<tr>
<td>Mean wealth / monthly HH income</td>
<td>3.7</td>
<td>3.6</td>
<td>β</td>
<td>0.99374</td>
</tr>
<tr>
<td>Mean (U-E) wealth / monthly HH income</td>
<td>-2.7</td>
<td>-2.5</td>
<td>ε^δ_β</td>
<td>-4</td>
</tr>
<tr>
<td>Fraction HH with negative wealth</td>
<td>0.26</td>
<td>0.30</td>
<td>z/¯a</td>
<td>-0.5</td>
</tr>
<tr>
<td>Mean quarterly MPC to $500 rebate</td>
<td>0.21</td>
<td>0.22</td>
<td>Δ^α^β</td>
<td>0.0045</td>
</tr>
<tr>
<td><strong>Income during unemployment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share unemployed receiving UI</td>
<td>0.39</td>
<td>0.42</td>
<td>ζ</td>
<td>0.48</td>
</tr>
<tr>
<td>Mean HH income w. UI / pre job loss</td>
<td>0.76</td>
<td>0.77</td>
<td>ω_1</td>
<td>0.39</td>
</tr>
<tr>
<td>Mean HH income w.o UI / pre job loss</td>
<td>0.55</td>
<td>0.55</td>
<td>ω_2</td>
<td>0.52</td>
</tr>
<tr>
<td><strong>Incidence of unemployment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unemployment rate</td>
<td>5%</td>
<td>5.0%</td>
<td>φ</td>
<td>0.968</td>
</tr>
<tr>
<td>Fraction w/ duration 4-6 mos</td>
<td>0.14</td>
<td>0.18</td>
<td>λ_0</td>
<td>1.1</td>
</tr>
<tr>
<td>Fraction w/ duration &gt; 6 mos</td>
<td>0.17</td>
<td>0.21</td>
<td>λ_1</td>
<td>-0.14</td>
</tr>
<tr>
<td>EU probability on log wage</td>
<td>-0.012</td>
<td>-0.013</td>
<td>ϵ^δ_α</td>
<td>-0.15</td>
</tr>
<tr>
<td><strong>Search and the labor market</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration elasticity to benefit duration</td>
<td>0.4</td>
<td>0.43</td>
<td>ξ</td>
<td>3</td>
</tr>
<tr>
<td>Vacancies per unemployed worker</td>
<td>0.634</td>
<td>0.634</td>
<td>̄m</td>
<td>0.23</td>
</tr>
<tr>
<td>Fraction of monthly wage to hire worker</td>
<td>0.108</td>
<td>0.108</td>
<td>k/¯a</td>
<td>0.044</td>
</tr>
</tbody>
</table>

Table A.8: calibration results targeting higher disincentive effect

Note: relative to the baseline, the targeted micro elasticity of unemployment duration to potential benefit duration is 0.4 rather than 0.1. The other targets are unchanged from the baseline.

**D.5 Sensitivity to wealth distribution and retailer profits**

I finally explore the sensitivity of the effects of UI to the definition of wealth used to calibrate the model, and the steady-state level of retailers’ profits.

**Total wealth rather than liquid wealth**  In the main text I parameterized the model to match the liquid wealth distribution in Table A.2, which includes transaction accounts plus directly held bonds less credit card balances as in Kaplan et al. [2018]. I now assess the sensitivity of the model’s results using a calibration to total wealth instead.

Table A.9 summarizes the calibration results in an analog of Table 1 from the main text. To target a higher average wealth in the economy, this calibration requires ʌβ which is higher than that in the baseline case. This rise in average wealth is driven by the right tail of households; as these households anyway have MPCs close to zero in the baseline calibration, the pattern of average MPCs in the first panel of Table A.11 is only slightly compressed versus the baseline. One important difference from the baseline, however, is that this calibration requires substantially more government borrowing (z^g/¯a = -59.55) to take the other side of
### Table A.9: calibration results targeting total wealth (including illiquid wealth)

<table>
<thead>
<tr>
<th>Moment</th>
<th>Target</th>
<th>Achieved</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real rate, wealth, and average MPC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real interest rate (ann.)</td>
<td>2%</td>
<td>2.0%</td>
<td>z^θ/ā</td>
<td>-59.55</td>
</tr>
<tr>
<td>Mean wealth / monthly HH income</td>
<td>66.0</td>
<td>62.8</td>
<td>β̂</td>
<td>0.993804</td>
</tr>
<tr>
<td>Mean (U-E) wealth / monthly HH income</td>
<td>-47.5</td>
<td>-32.5</td>
<td>εδ̂</td>
<td>-4</td>
</tr>
<tr>
<td>Fraction HH with negative wealth</td>
<td>0.10</td>
<td>0.06</td>
<td>ẑ/ā</td>
<td>-0.2</td>
</tr>
<tr>
<td>Mean quarterly MPC to $500 rebate</td>
<td>0.21</td>
<td>0.21</td>
<td>Δβ̂</td>
<td>0.0045</td>
</tr>
<tr>
<td>Income during unemployment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share unemployed receiving UI</td>
<td>0.39</td>
<td>0.41</td>
<td>ζ</td>
<td>0.5</td>
</tr>
<tr>
<td>Mean HH income w. UI / pre job loss</td>
<td>0.76</td>
<td>0.77</td>
<td>ω1</td>
<td>0.31</td>
</tr>
<tr>
<td>Mean HH income w.o UI / pre job loss</td>
<td>0.55</td>
<td>0.56</td>
<td>ω2</td>
<td>0.47</td>
</tr>
<tr>
<td>Incidence of unemployment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unemployment rate</td>
<td>5%</td>
<td>5.0%</td>
<td>φ</td>
<td>0.951</td>
</tr>
<tr>
<td>Fraction w/ duration 4-6 mos</td>
<td>0.14</td>
<td>0.18</td>
<td>λ0</td>
<td>1.1</td>
</tr>
<tr>
<td>Fraction w/ duration &gt; 6 mos</td>
<td>0.17</td>
<td>0.20</td>
<td>λ1</td>
<td>-0.14</td>
</tr>
<tr>
<td>EU probability on log wage</td>
<td>-0.012</td>
<td>-0.012</td>
<td>εδ̂</td>
<td>-0.15</td>
</tr>
<tr>
<td>Search and the labor market</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration elasticity to benefit duration</td>
<td>0.1</td>
<td>0.06</td>
<td>ξ</td>
<td>30</td>
</tr>
<tr>
<td>Vacancies per unemployed worker</td>
<td>0.634</td>
<td>0.634</td>
<td>m̄</td>
<td>0.19</td>
</tr>
<tr>
<td>Fraction of monthly wage to hire worker</td>
<td>0.108</td>
<td>0.108</td>
<td>k̄/ā</td>
<td>0.045</td>
</tr>
</tbody>
</table>

Note: relative to the baseline, the targeted mean wealth, difference between mean unemployed and mean employed wealth, and fraction of households with negative wealth are based on a broader definition which includes illiquid wealth. The other targets are unchanged from the baseline.

...
### Moment

<table>
<thead>
<tr>
<th>Moment</th>
<th>Target</th>
<th>Achieved</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real rate, wealth, and average MPC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real interest rate (ann.)</td>
<td>2%</td>
<td>2.0%</td>
<td>$z^g/\bar{a}$</td>
<td>-9.67</td>
</tr>
<tr>
<td>Mean wealth / monthly HH income</td>
<td>66.0</td>
<td>64.9</td>
<td>$\bar{\beta}$</td>
<td>0.993805</td>
</tr>
<tr>
<td>Mean (U-E) wealth / monthly HH income</td>
<td>-47.5</td>
<td>-31.1</td>
<td>$\epsilon^\delta_\beta$</td>
<td>-4</td>
</tr>
<tr>
<td>Fraction HH with negative wealth</td>
<td>0.10</td>
<td>0.06</td>
<td>$z/\bar{a}$</td>
<td>-0.2</td>
</tr>
<tr>
<td>Mean quarterly MPC to $500 rebate</td>
<td>0.21</td>
<td>0.21</td>
<td>$\Delta^\beta$</td>
<td>0.0045</td>
</tr>
</tbody>
</table>

### Income during unemployment

| Income during unemployment | Share unemployed receiving UI | 0.39 | 0.41 | $\zeta$ | 0.5 |
| Mean HH income w. UI / pre job loss | 0.76 | 0.78 | $\omega_1$ | 0.39 |
| Mean HH income w.o UI / pre job loss | 0.55 | 0.56 | $\omega_2$ | 0.52 |

### Incidence of unemployment

| Incidence of unemployment | Unemployment rate | 5% | 5.0% | $\phi$ | 0.955 |
| Fraction w/ duration 4-6 mos | 0.14 | 0.18 | $\lambda_0$ | 1.1 |
| Fraction w/ duration > 6 mos | 0.17 | 0.20 | $\lambda_1$ | -0.14 |
| EU probability on log wage | -0.012 | -0.015 | $\epsilon^\delta_a$ | -0.15 |

### Search and the labor market

| Search and the labor market | Duration elasticity to benefit duration | 0.1 | 0.11 | $\xi$ | 16 |
| Vacancies per unemployed worker | 0.634 | 0.634 | $\bar{m}$ | 0.20 |
| Fraction of monthly wage to hire worker | 0.108 | 0.108 | $k/\bar{a}$ | 0.045 |

Table A.10: calibration results targeting total wealth and no retailer subsidy

Note: targets are as in A.9 except we assume no retailer subsidy.

---

**No retailer subsidy**  Eliminating the subsidy offered to retailers raises the economy’s profit share because it raises retailers’ equilibrium mark-up.\(^7\) Indeed, in the baseline model with a subsidy of $\tau^R = -\frac{1}{\epsilon}$, aggregate profits only reflect hiring costs; with a subsidy equal to zero, aggregate profits also reflect profits earned due to positive mark-ups. I now consider the latter case in the context of the calibration to total wealth discussed above, as a substantial fraction of total wealth is indeed firm equity in the data.

In particular, I set $\tau^R = 0$, which implies that the equilibrium gross mark-up is $(1 + \tau^R)_{\epsilon^{-1}} = \frac{11}{10} = 1.1$. Table A.10 summarizes the calibration results in such an environment. The key difference from Table A.9 is that government borrowing is now much more comparable to its value in the baseline.\(^8\) Intuitively, as more of households’ desired saving is absorbed in firm equity, less must be financing government borrowing.

In this environment, the third panel of Table A.11 demonstrates that a three-month

\(^7\)Recall that the subsidy is financed by assessing lump-sum taxes on retailers.

\(^8\)It is also a realistic fraction of total wealth. As the value of equity is $(\pi + q)/\bar{a} = 51.89$, government debt of $-z^g/\bar{a} = 9.67$ is 19% of aggregate wealth. In the Financial Accounts, in 2004 total Treasuries outstanding (FL313161105) plus municipal securities outstanding (FL383162005) were 14% of total U.S. net wealth (FL892090005).
Table A.11: sensitivity to alternative calibrations of wealth and retailer subsidy

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Total wealth</th>
<th>Total wealth + no retailer subsidy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarterly MPC, employed</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>Quarterly MPC, ST unemployed</td>
<td>0.43</td>
<td>0.40</td>
<td>0.41</td>
</tr>
<tr>
<td>Quarterly MPC, MT unemployed</td>
<td>0.52</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Quarterly MPC, LT unemployed</td>
<td>0.66</td>
<td>0.62</td>
<td>0.61</td>
</tr>
<tr>
<td>Sticky prices + constant $r$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output multiplier</td>
<td>1.1</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Avg change in unemp. rate</td>
<td>-0.06pp</td>
<td>-0.04pp</td>
<td>-0.04pp</td>
</tr>
<tr>
<td>Sticky prices + constant $i$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output multiplier</td>
<td>1.1</td>
<td>1.8</td>
<td>1.0</td>
</tr>
<tr>
<td>Avg change in unemp. rate</td>
<td>-0.06pp</td>
<td>-0.08pp</td>
<td>-0.05pp</td>
</tr>
</tbody>
</table>

Note: the first counterfactual matches the total wealth distribution in the SCF, rather than the liquid wealth distribution as in the baseline. The second counterfactual does the same but does not assume any subsidy to retailers. The quarterly MPC is computed for an unexpected $500 rebate. The partial equilibrium output multiplier uses the partial equilibrium stimulus to consumption in the numerator of (30).

...extension of UI for one year generates comparable stimulus to the baseline calibration. This holds not just in the case of a constant real interest rate 18 months, but also in the case of a constant nominal interest rate for 18 months. Intuitively, with a comparable amount of government debt to the baseline calibration, the effects of a change in the real interest rate on government interest payments are now comparable to the baseline.

E Supplementary results for Great Recession

In this section I supplement the Great Recession analysis in section 6 of the main text. I first contrast the effect of discount factor, borrowing constraint, productivity, separation rate, and match efficiency shocks. I then demonstrate the robustness of my findings regarding UI in a simulation with borrowing constraint shocks rather than discount factor shocks.

E.1 Impulse responses to fundamental shocks

I first contrast the impulse responses to discount factor, borrowing constraint, productivity, separation rate, and match efficiency shocks starting from the stationary RCE. I assume that

$$\bar{\beta}_t = (1 - \rho \bar{\beta}) \bar{\beta} + \rho \bar{\beta} (\bar{\beta}_{t-1} - \bar{\beta}) + \epsilon_t \bar{\beta},$$
\[
\begin{align*}
\bar{z}_t &= (1 - \rho \bar{z}) \bar{z} + \rho \bar{z} (\bar{z}_{t-1} - \bar{z}) + \epsilon^\bar{z}_t, \\
\bar{a}_t &= (1 - \rho \bar{a}) \bar{a} + \rho \bar{a} (\bar{a}_{t-1} - \bar{a}) + \epsilon^\bar{a}_t, \\
\bar{\delta}_t &= (1 - \rho \bar{\delta}) \bar{\delta} + \rho \bar{\delta} (\bar{\delta}_{t-1} - \bar{\delta}) + \epsilon^\bar{\delta}_t, \\
\bar{m}_t &= (1 - \rho \bar{m}) \bar{m} + \rho \bar{m} (\bar{m}_{t-1} - \bar{m}) + \epsilon^\bar{m}_t,
\end{align*}
\]
in each case. The persistence of each process is set to 0.95 and the size of each shock is chosen to deliver a 0.05\textit{pp} rise in the unemployment rate on impact. In all cases, the environment features sticky prices, monetary policy following the Taylor rule, and \( \iota = 0.95 \) as calibrated in section 6.

The impulse responses to a positive discount factor shock are provided in Figure A.5. At unchanged prices and a constant nominal interest rate, the increase in desired saving would generate a decline in production and rise in unemployment. This would generate nominal deflation among retailers which can adjust their prices. The central bank responds to the resulting deflation and decline in output by lowering the nominal interest rate, mitigating but not eliminating the decline in economic activity. In this way, a positive discount factor shock can jointly rationalize the rise in unemployment and decline in the nominal interest rate early in the Great Recession. As described in the main text, I view such a shock as capturing the shock to financial conditions during this period more broadly.

The impulse responses to a positive borrowing constraint shock are provided in Figure A.6. The dynamics are qualitatively similar to those after a positive discount factor shock, as both shocks raise households’ desired saving on impact. Quantitatively, however, the effects of a borrowing constraint shock are much less persistent. It is for this reason that relatively “large” borrowing constraint shocks would be needed to rationalize the dynamics of the Great Recession, which I explore in more depth in the next subsection.

The impulse responses to a positive productivity shock are provided in Figure A.7. These responses are qualitatively similar to what would be obtained in a representative agent economy featuring the same nominal and labor market frictions. At an unchanged path of prices and nominal interest rates, consumption demand would be unchanged; with higher productivity, fewer workers are needed to produce the same output, implying an equilibrium rise in unemployment. As the latter is mediated by a decline in relative price of intermediate goods versus final goods, there will be nominal deflation among retailers which can adjust their prices. This in turn causes a decline in the nominal interest rate and thus real interest rate, which stimulates aggregate consumption and mitigates (but does not eliminate) the rise in unemployment. In this way, while productivity shocks can rationalize the rise in unemployment and fall in nominal interest rates at the start of the Great Recession, \textit{positive} such shocks would be needed, and moreover such shocks would imply a consumption \textit{boom}
until the zero lower bound was reached.

The impulse responses to a positive separation rate shock are provided in Figure A.8. A positive separation rate shock acts like a “cost-push” shock in the New Keynesian environment, simultaneously raising unemployment while raising firms’ marginal costs (in recruiting) and thus generating inflation. The latter implies that an inflation targeting central bank will raise the nominal interest rate. Hence, at least given the (standard parameterization of the) monetary policy rule assumed in this paper, separation rate shocks alone cannot rationalize the rise in unemployment and decline in the nominal interest rate early in the Great Recession.

The impulse responses to a negative match efficiency shock are provided in Figure A.9. A negative match efficiency shock directly raises hiring costs for firms and disincentivizes search effort by workers. As a result, it operates like a cost-push shock and has qualitatively the same effects as a positive separation rate shock described above.9

### E.2 Robustness to borrowing constraint shocks

I now demonstrate the robustness of my findings regarding UI during the Great Recession in a simulation with borrowing constraint shocks rather than discount factor shocks.

I first calibrate borrowing constraint shocks analogous to the way I calibrate discount factor shocks in the main text: conditional on the sequence of UI shocks, I iteratively calibrate \{\epsilon^*_z\} to match the dynamics of unemployment from May 2008 onwards, assuming that the economy is in steady-state in April 2008. I set real wage rigidity \( \iota = 0.95 \) so that these results are directly comparable to those in the main text. Figure A.10 summarizes the calibrated shocks through 2009. The left panel illustrates that positive borrowing constraint shocks are needed to rationalize the rise in unemployment during the Great Recession, but — consistent with Figure A.6 — large shocks are needed because the effect of each shock is quite transitory even though the shock itself is quite persistent. The borrowing constraint thus quickly rises above zero in this simulation, as illustrated in the right panel. I view this as unrealistic, and for this reason focus on discount factor shocks — which I interpret as a broader shock to financial conditions — in the main text.

Figure A.11 nonetheless demonstrates that the effect of the UI extensions are quite comparable across this simulation and that provided in the main text. The left panel compares

---

9 It is also revealing to ask what would happen if the slope of match efficiencies by duration of unemployment changed, holding fixed the match efficiency of initially unemployed workers — i.e., a shock to \( \lambda_1 \) in (27), if we made it time-varying. As would be expected, a negative shock (more duration-dependence in job-finding rates) implies a rise in the fraction of long-term agents. More notably, the change in long-term unemployment for any percentage change in overall unemployment is an order of magnitude larger than for any of the other shocks described here.
Figure A.5: discount factor shock

Note: average discount factor assumed to follow an AR(1) process with persistence 0.95. Initial shock chosen to imply a 0.05pp change in unemployment on impact. Environment features sticky prices and the calibrated degree of real wage rigidity $\iota = 0.95$. 
Figure A.6: borrowing constraint shock

Note: borrowing constraint assumed to follow an AR(1) process with persistence 0.95. Initial shock chosen to imply a 0.05$pp$ change in unemployment on impact. Environment features sticky prices and the calibrated degree of real wage rigidity $\iota = 0.95$. 

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Figure A.7: productivity shock

Note: average productivity assumed to follow an AR(1) process with persistence 0.95. Initial shock chosen to imply a 0.05pp change in unemployment on impact. Environment features sticky prices and the calibrated degree of real wage rigidity $\iota = 0.95$. 

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Figure A.8: separation rate shock

Note: separation rate assumed to follow an AR(1) process with persistence 0.95. Initial shock chosen to imply a 0.05pp change in unemployment on impact. Environment features sticky prices and the calibrated degree of real wage rigidity $\iota = 0.95$. 

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Figure A.9: match efficiency shock

Note: match efficiency assumed to follow an AR(1) process with persistence 0.95. Initial shock chosen to imply a 0.05pp change in unemployment on impact. Environment features sticky prices and the calibrated degree of real wage rigidity $\eta = 0.95$. 
Note: borrowing constraint assumed to follow an AR(1) process with persistence 0.95. Shocks are chosen each period so that, together with the shocks to UI described in Table 7, unemployment in model matches that in data.

Note: counterfactual policy in the first panel maintains the same borrowing constraint shocks in Figure A.10, and in the second panel maintains the same discount factor shocks in Figure 7.

the simulation with borrowing constraint shocks and UI shocks to a counterfactual with only borrowing constraint shocks; the right panel displays the same for the simulation with discount factor shocks in the main text over the same period. As is evident, by late 2009 the unemployment rate would be roughly 0.5pp higher absent the UI extensions in both cases.
F Computational algorithm

In this section I describe the algorithm used to solve and study the model in sections 3-6 of the main text. I first outline the algorithm used to solve for the stationary RCE. I then outline the algorithm used to solve for the transitional dynamics in response to unanticipated macroeconomic shocks. I finally describe the Jacobian matrices used in the latter algorithm, and how I dynamically update them in the Great Recession simulations in section 6.

F.1 Algorithm to solve for the stationary RCE

The goal is to find a fixed point in the real interest rate, real tax on employed workers, labor market tightness, and vector of firm surpluses from employing workers of each type

\{r, t, \theta, s(f(\zeta_e))\}.

This generalizes the algorithm of simpler heterogeneous agent models where only a fixed point in \(r\) needs to be obtained. In the present setting with labor market frictions and government intervention via UI, a conjecture of \(t\) is needed to calculate agents’ real income when employed; a conjecture of \(\theta\) is needed to calculate agents’ search decisions when unemployed; and a conjecture of \(s(f(\zeta_e))\) is needed to calculate equilibrium wages.

The idiosyncratic state space is simplified and approximated as follows. The functional forms of UI (28) and duration dependence in matching (27) together define a duration \(\bar{d} \equiv \max\{\bar{d}, 8\}\) after which unemployed agents face identical problems. It follows that the state space along the duration margin can be limited to \(\{0, 1, \ldots, \bar{d} - 1, \geq \bar{d}\}\). I use the Rouwenhorst procedure as described in Kopecky and Suen [2010] to discretize the persistent component of worker productivity into three values, and I use the Gauss-Hermite procedure to discretize the transitory component of worker productivity into three values. Following (25), the discount factors take on three values \{\(\bar{\beta} - \Delta^{\beta}, \bar{\beta}, \bar{\beta} + \Delta^{\beta}\}\). Finally, I discretize assets using a grid of 201 points, denser near the lower bound \(z^b\).

I then solve for the stationary RCE as follows:

1. Initialize small, positive tolerance levels \(\{\epsilon_{z+1}, \epsilon_t, \epsilon_\theta, \epsilon_s\}\) and step lengths \(\{\Delta_r, \Delta_t, \Delta_\theta, \Delta_s\}\).
2. Conjecture \(\{r, t, \theta, s(f(\zeta_e))\}\).
3. Use (A.9) and (A.10) to compute \(w(\zeta_e)\).
4. Use (A.16) and (A.17) to compute real incomes \(\{y^e(\zeta_e), y^u(\zeta_u)\}\).
5. Iterate workers’ value functions backward using optimality conditions (A.3)-(A.6) and resource constraints (A.14)-(A.15), obtaining approximations of the value functions $\{\hat{v}^e, \hat{v}^u\}$ and policy functions $\{\hat{s}, \hat{c}^e, \hat{c}^u\}$. Here Carroll [2006]’s endogenous gridpoint method substantially speeds up convergence.

6. Iterate the resulting policy functions forward, obtaining approximations of the beginning-of-period distribution $\{\hat{p}^e, \hat{\varphi}^e, \hat{\varphi}^u\}$ and middle-of-period distribution $\{\hat{p}^e, \hat{\varphi}^e, \hat{\varphi}^u\}$.

7. Using the approximated policy functions and ergodic distribution, assess market clearing and consistency conditions and update $\{r', t', \theta', s^f(\zeta^e)\}$ accordingly:

(a) Compute the end-of-period market value of firm equity $q$ using (A.18), (A.21), (A.22) and stationarity.

(b) Compute steady-state net asset demand $\hat{z}_{+1}$, given by the left-hand side less the right-hand side of (A.20).

(c) Compute steady-state taxes $\hat{t}$ solving (A.23).

(d) Compute the firm’s marginal profit from posting a vacancy $\hat{dvacpost}$, given by the left-hand side of (A.10).

(e) Compute workers’ surplus net of firms’ surplus $\hat{dbargain}$, given by the left-hand side less the right-hand side of (A.13).

(f) Set $\{r', t', \theta', s^f(\zeta^e)\}$ based on the deviations in $\{\hat{z}_{+1}, \hat{t}, \hat{dvacpost}, \hat{dbargain}\}$ from $\{0, t, 0, 0\}$:

\[
\begin{align*}
    r' &= \begin{cases} 
    r - \Delta_r \hat{z}_{+1} & \text{if } |\hat{z}_{+1}| > \epsilon_{z_{+1}}, \\
    r & \text{otherwise}
    \end{cases}, \\
    t' &= \begin{cases} 
    t + \Delta_t (\hat{t} - t) & \text{if } |\hat{t} - t| > \epsilon_t, \\
    t & \text{otherwise}
    \end{cases}, \\
    \theta' &= \begin{cases} 
    \theta + \Delta_\theta \hat{dvacpost} & \text{if } |\hat{dvacpost}| > \epsilon_\theta, \\
    \theta & \text{otherwise}
    \end{cases}, \\
    s^f(\zeta^e) &= \begin{cases} 
    s^f(\zeta^e) + \Delta_s \hat{dbargain} & \text{if } |\hat{dbargain}| > \epsilon_s, \\
    s^f(\zeta^e) & \text{otherwise}
    \end{cases}.
\end{align*}
\]

8. If $\{r, t, \theta, s^f(\zeta^e)\} = \{r', t', \theta', s^f(\zeta^e)\}$, stop. Else, return to step 2 with $\{r', t', \theta', s^f(\zeta^e)\}$. 

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F.2 Algorithm to solve for transitional dynamics

When prices are flexible, the goal is to find a fixed point in the sequence

\[{\tilde q_0, \{r_0, t_0, \theta_0, w_0(\zeta^e)\}, \ldots, \{r_T, t_T, \theta_T, w_T(\zeta^e)\}}\]

for \(T\) very large, at which point it is assumed that the initial stationary RCE is again reached. The rationale for iterating over \(\{r_t, t_t, \theta_t, w_t(\zeta^e)\}\) was explained in the prior subsection.\(^{10}\) We also need to iterate over the beginning-of-period-0 market value of equity \(\tilde q_0\), given by

\[\tilde q_0 = \pi_0 + q_0,\]  \hspace{1cm} (A.27)

which is needed to compute agents’ initial capital gain/loss on equity claims given the unanticipated macroeconomic shock.

When prices are sticky, the goal is to find a fixed point in the sequence

\[{\tilde q_0, \{r_0, t_0, \theta_0, \mu_0, w_0(\zeta^e)\}, \ldots, \{r_T, t_T, \theta_T, \mu_T, w_T(\zeta^e)\}}\],

where \(\mu_t \equiv \frac{P_t}{P_{t-}}\) is the gross mark-up of retailers, no longer constant with nominal rigidity.

The idiosyncratic state space remains characterized as in the prior subsection, except for the fact that \(\hat\bar d\) needs to be as large as the maximal duration of UI throughout the simulation.

I then solve for the equilibrium as follows:

1. Initialize a small, positive tolerance level \(\epsilon\).
2. Conjecture \(\{\tilde q_0, \{r_t, t_t, \theta_t, w_t(\zeta^e)\}_{t=0}^T\}\) in the flexible price case or \(\{\tilde q_0, \{m_t, t_t, \theta_t, \mu_t, w_t(\zeta^e)\}_{t=0}^T\}\) in the sticky price case.
3. Under flexible prices, solve for the constant mark-up \(\mu\) consistent with (A.7).
4. Use (A.16)-(A.17) to compute real incomes \(\{y^e_t(\zeta^e), y^u_t(\zeta^u)\}\).
5. Iterate workers’ value functions backward using optimality conditions (A.3)-(A.6) and resource constraints (A.14)-(A.15), obtaining approximations of the value functions \(\{\hat v^e_t, \hat v^u_t\}_{t=0}^T\) and policy functions \(\{\hat s_t, \hat c^e_t, \hat c^u_t\}_{t=0}^T\). Carroll [2006]’s endogenous gridpoint method again speeds up convergence.
6. Re-value agents’ initial wealth given the conjectured \(\tilde q_0\) and assumed equity shares in asset portfolios across the idiosyncratic state space, described further in section C.2.

\(^{10}\)While in the prior subsection we iterated over firm surplus \(s^f(\zeta^e)\) rather than real wages \(w(\zeta^e)\), this was only because in steady-state it is much easier to use (A.9) and (A.10) to solve for \(w(\zeta^e)\) given \(s^f(\zeta^e)\) rather than vice-versa.
7. Using the policy functions from step 5 with the re-valued wealth distribution from step 6, iterate forward to obtain approximations of the beginning-of-period distributions \( \hat{\tilde{p}}_t, \hat{\tilde{\varphi}}^e_t, \hat{\tilde{\varphi}}^u_t \) and middle-of-period distributions \( \hat{\tilde{p}}^e_t, \hat{\tilde{\varphi}}^e_t, \hat{\tilde{\varphi}}^u_t \) at time 0.

8. Using the approximated policy functions and distributions, assess market clearing and consistency conditions and update \( \{ \hat{\tilde{q}}_0, \{ m_t, t_t, \theta_t, w_t(\zeta^e) \}_{t=0}^T \} \) (under flexible prices) or \( \{ \hat{\tilde{q}}_0, \{ m_t, t_t, \theta_t, \mu_t, w_t(\zeta^e) \}_{t=0}^T \} \) (under sticky prices) accordingly:

(a) Compute the end-of-period market value of firm equity by iterating backward on (A.18), (A.21), and (A.22) given \( q_{T+1} = q^{ss} \).

(b) Compute the beginning-of-period-0 market value of firm equity \( \hat{\tilde{q}}_0 \) using (A.27) and \( \hat{\tilde{q}}_0 \) from the previous step.

(c) Compute net asset demand \( \hat{\bar{z}}_{t+1} \), given by the left-hand side less the right-hand side of (A.20).

(d) Compute taxes \( \hat{\tilde{t}}_t \) solving (A.23).

(e) Iterate backwards on (A.9) and (A.10) given \( s_{T+1}^f(\zeta^e) = s_f(\zeta^e) \) to compute \( s_f^l(\zeta^e) \).

Then compute the firm’s marginal profit from posting a vacancy \( \hat{\text{dvacpost}}_t \) given by the left-hand side of (A.10).

(f) Compute real wages \( \hat{\tilde{w}}_t(\zeta^e) \) implied by (14).

(g) Under sticky prices, iterate backwards on price-setting (A.7) to compute \( \{ \Pi^P_t \} \) given \( \Pi^P_{T+1} = 0 \), evaluate the monetary policy rule (29) to compute \( \{ i_t \} \), and then construct \( \hat{\tilde{r}}_t = i_t(1 + \Pi^P_{t+1})^{-1} \).

(h) Under flexible prices:

- If \( ||(\hat{\tilde{q}}_0 - \tilde{q}_0, \{ \hat{\bar{z}}_{t+1}, \hat{\tilde{t}}_t - t_t, \text{dvacpost}_t, \hat{\tilde{w}}_t(\zeta^e) - w_t(\zeta^e) \}_{t=0}^T)|| < \epsilon \), stop.

- Otherwise, let

\[

(\hat{\tilde{q}}_0', \{ m_t', t_t', \theta_t', w_t'(\zeta^e) \}_{t=0}^T)' = (\hat{\tilde{q}}_0, \{ m_t, t_t, \theta_t, w_t(\zeta^e) \}_{t=0}^T)' - H_{\text{flex}}^{-1}(\hat{\tilde{q}}_0 - \tilde{q}_0, \{ \hat{\bar{z}}_{t+1}, \hat{\tilde{t}}_t - t_t, \text{dvacpost}_t, \hat{\tilde{w}}_t(\zeta^e) - w_t(\zeta^e) \}_{t=0}^T)',

\]

where the Jacobian \( H_{\text{flex}} \) is constructed as described in the next subsection.

(i) Under sticky prices:

- If \( ||(\hat{\tilde{q}}_0 - \tilde{q}_0, \{ \hat{\bar{z}}_{t+1}, \hat{\tilde{t}}_t - t_t, \text{dvacpost}_t, \hat{\tilde{r}}_t - r_t, \hat{\tilde{w}}_t(\zeta^e) - w_t(\zeta^e) \}_{t=0}^T)|| < \epsilon \), stop.

- Otherwise, let
With flexible prices, an equilibrium in this algorithm is an estimate of the Jacobian \( H \) associated with the system of market clearing and consistency conditions which characterize an equilibrium, which I describe in the next subsection.

I use the quasi-Newton algorithm to solve for the fixed point in macroeconomic aggregates in the last two steps above. As recommended by Auclert et al. [2020], the use of the quasi-Newton algorithm substantially speeds up convergence versus, for instance, slowly updating the sequence of macroeconomic aggregates using ad-hoc updating rules. A key ingredient in this algorithm is an estimate of the Jacobian \( H \) associated with the system of market clearing and consistency conditions which characterize an equilibrium, which I describe in the next subsection.

### F.3 Jacobians used to solve for transitional dynamics

With flexible prices, an equilibrium \( \{\tilde{q}_0, \{r_t, t_t, \theta_t, w_t(\zeta^e)\}^T_{t=0}\} \) solves the system of equations

\[
\begin{align*}
\dot{\tilde{q}}_0(\tilde{q}_0, \{r_t, t_t, \theta_t, w_t(\zeta^e)\}^T_{t=0}) - \tilde{q}_0 &= 0, \\
\dot{z}_{t+1}(\tilde{q}_0, \{r_t, t_t, \theta_t, w_t(\zeta^e)\}^T_{t=0}) &= 0, \quad \forall t \in \{0, \ldots, T\}, \\
\dot{\hat{t}}(\tilde{q}_0, \{r_t, t_t, \theta_t, w_t(\zeta^e)\}^T_{t=0}) - t_t &= 0, \quad \forall t \in \{0, \ldots, T\}, \\
\text{dvacpost}_t(\tilde{q}_0, \{r_t, t_t, \theta_t, w_t(\zeta^e)\}^T_{t=0}) &= 0, \quad \forall t \in \{0, \ldots, T\}, \\
\hat{w}_t(\zeta^e; \tilde{q}_0, \{r_t, t_t, \theta_t, w_t(\zeta^e)\}^T_{t=0}) - w_t(\zeta^e) &= 0, \quad \forall t \in \{0, \ldots, T\},
\end{align*}
\]

where the variables with hats are functions of the arguments in parenthesis given the algorithm described in the previous subsection. Let the associated Jacobian evaluated at the stationary RCE be denoted \( H_{flex} \). With sticky prices the relevant system of equations is instead

\[
\begin{align*}
\dot{\tilde{q}}_0(\tilde{q}_0, \{r_t, t_t, \theta_t, \mu_t, w_t(\zeta^e)\}^T_{t=0}) - \tilde{q}_0 &= 0, \\
\dot{z}_{t+1}(\tilde{q}_0, \{r_t, t_t, \theta_t, \mu_t, w_t(\zeta^e)\}^T_{t=0}) &= 0, \quad \forall t \in \{0, \ldots, T\}, \\
\dot{\hat{t}}(\tilde{q}_0, \{r_t, t_t, \theta_t, \mu_t, w_t(\zeta^e)\}^T_{t=0}) - t_t &= 0, \quad \forall t \in \{0, \ldots, T\}, \\
\text{dvacpost}_t(\tilde{q}_0, \{r_t, t_t, \theta_t, \mu_t, w_t(\zeta^e)\}^T_{t=0}) &= 0, \quad \forall t \in \{0, \ldots, T\}, \\
\hat{r}_t(\tilde{q}_0, \{r_t, t_t, \theta_t, \mu_t, w_t(\zeta^e)\}^T_{t=0}) - r_t &= 0, \quad \forall t \in \{0, \ldots, T\}, \\
\hat{w}_t(\zeta^e; \tilde{q}_0, \{r_t, t_t, \theta_t, \mu_t, w_t(\zeta^e)\}^T_{t=0}) - w_t(\zeta^e) &= 0, \quad \forall t \in \{0, \ldots, T\}.
\end{align*}
\]

Let the associated Jacobian evaluated at the stationary RCE be denoted \( H_{sticky} \).
I estimate these Jacobians numerically by simply perturbing each of the inputs and parallelizing the computation. These are the Jacobians I use when characterizing all of the impulse responses starting from the stationary RCE in section 5 of the main text and section E.1 of this appendix.

In my simulation of the Great Recession in 6, I find that the steady-state Jacobian cannot be used to solve for the transitional dynamics in response to shocks occurring after the first period. Intuitively, the economy moves sufficiently far away from the stationary RCE of the model that the Jacobian computed around the latter point is no longer useful in computation. However, I find that the following method of updating the Jacobians through the simulation is successful in facilitating convergence in all future periods:

1. Assume the economy is in the deterministic steady-state as of period \(-1\).

2. In period 0, an aggregate shock is realized. Characterize the transitional dynamics using the algorithm in the prior subsection, given the steady-state Jacobian \(H_{\text{sticky}}\).

3. Given the equilibrium from period 1 onwards (with no more shocks), characterize the Jacobian associated with the market clearing and consistency conditions through period \(T\):

\[
\hat{q}_1(q_1, \{r_{1+t}, t_{1+t}, \theta_{1+t}, \mu_{1+t}, w_{1+t}(\zeta_e)\}_{t=0}^{T-1}) - \tilde{q}_1 = 0,
\]

\[
\hat{z}_2(q_1, \{r_{1+t}, t_{1+t}, \theta_{1+t}, \mu_{1+t}, w_{1+t}(\zeta_e)\}_{t=0}^{T-1}) = 0, \ \forall t \in \{0, \ldots, T - 1\},
\]

\[
\hat{t}_{1+t}(q_1, \{r_{1+t}, t_{1+t}, \theta_{1+t}, \mu_{1+t}, w_{1+t}(\zeta_e)\}_{t=0}^{T-1}) - t_{1+t} = 0, \ \forall t \in \{0, \ldots, T - 1\},
\]

\[
\hat{d}_{\text{vacpost}}_{1+t}(q_1, \{r_{1+t}, t_{1+t}, \theta_{1+t}, \mu_{1+t}, w_{1+t}(\zeta_e)\}_{t=0}^{T-1}) = 0, \ \forall t \in \{0, \ldots, T - 1\},
\]

\[
\hat{r}_{1+t}(q_1, \{r_{1+t}, t_{1+t}, \theta_{1+t}, \mu_{1+t}, w_{1+t}(\zeta_e)\}_{t=0}^{T-1}) - r_{1+t} = 0, \ \forall t \in \{0, \ldots, T - 1\},
\]

\[
\hat{w}_{1+t}(q_1, \{r_{1+t}, t_{1+t}, \theta_{1+t}, \mu_{1+t}, w_{1+t}(\zeta_e)\}_{t=0}^{T-1}) - w_{1+t}(\zeta_e) = 0, \ \forall t \in \{0, \ldots, T - 1\}.
\]

This is again done numerically by simply perturbing each of the inputs and parallelizing the computation. Denote this Jacobian \(H_{\text{sticky},1}\), and denote the unemployment rate in the first period of this simulation \(1 - p^e_1\).

4. Compute the change in the Jacobian versus the steady-state, scaled by the change in the unemployment rate versus the steady-state:

\[
dH_{\text{sticky}} \equiv \frac{H_{\text{sticky},1} - (T^{(1)}_1) H_{\text{sticky}} T^{(1)}_1}{(1 - p^e_1) - (1 - p^e)},
\]

where \(T^{(1)}_1\) is a selection matrix which eliminates from \(H_{\text{sticky}}\) all rows pertaining to equilibrium conditions in the last period and all columns pertaining to equilibrium.

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variables in the last period. Thus $(T_1^{(1)})'H_{\text{sticky}}T_1^{(1)}$ is effectively the Jacobian of an economy with one less period in the finite sequence-space representation, and is what we compare to $H_{\text{sticky},1}$.

5. Then solve for the effect of all shocks from period 1 onwards as follows. Initialize $s = 1$.

(a) In period $s$, an aggregate shock is realized. Characterize the transitional dynamics starting from period $s$ onwards using the algorithm in the prior subsection, given the approximated Jacobian

$$H_{\text{sticky},s} = \begin{cases} (T_s^{(1)})'H_{\text{sticky}}T_s^{(1)} + ((1 - p_s^e) - (1 - p_s^e))dH_{\text{sticky}} & \text{if } s = 1, \\ (T_s^{(1)})'H_{\text{sticky}}T_s^{(1)} + ((1 - p_s^e) - (1 - p_s^e))(T_s^{(2)})'dH_{\text{sticky}}(T_s^{(2)}) & \text{if } s > 1, \end{cases}$$

where $T_s^{(1)}$ is a selection matrix which eliminates from $H_{\text{sticky}}$ all rows pertaining to equilibrium conditions in the last $s$ periods and all columns pertaining to equilibrium variables in the last $s$ periods, and $T_s^{(2)}$ is a selection matrix which eliminates from $dH_{\text{sticky}}$ all rows pertaining to equilibrium conditions in the last $s - 1$ periods and all columns pertaining to equilibrium variables in the last $s - 1$ periods.

(b) Increment $s$ by 1 and return to the previous step.

By dynamically updating the Jacobian used in the simulation, I respect the non-linearities induced by the zero lower bound which is expected to bind for various horizons as the simulation proceeds. To my knowledge, this algorithm is novel to the literature. I use the unemployment rate as the key variable to update the Jacobian in steps 4 and 5(a) because I find that it works well for my purposes; in future work, it would be useful to study whether economic theory can more systematically guide the dynamic updating of the Jacobian.

References


