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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 an analysis of the U.S. economy over 2008-2014, UI benefit extensions had a contemporaneous output multiplier around 1 or higher. The unemployment rate would have been as much as 0.4pp higher absent these extensions.

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An appendix is available at <http://www.nber.org/data-appendix/w29505>

1 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.¹ More recently, a similar debate has unfolded 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. The unemployment rate would have been as much as 0.4pp 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 disincentive 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-

¹See Summers [2010], Congressional Budget Office [2012], and Blanchard et al. [2013] for examples of commentary emphasizing the potential stimulus from UI.

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 incidence and effects of unemployment, and the cross-sectional distribution of consumption, 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 -0.5: 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 1.2.

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 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 by raising inflation expectations, 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 consumer prices 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 the unemployment rate would have been as much as 0.4pp 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 0.7-2.4, 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 real 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.²

In doing so, my paper contributes to the rapidly growing literature on heterogeneous agent New Keynesian (HANK) models.³ 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. [2021], Heathcote and Perri [2018], McKay and Reis [2021], 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. [2016], and Hagedorn et al. [2019]. 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

²My results here parallel the (much larger) literature studying conventional government spending in New Keynesian models. My analytical results in particular follow the conceptual approach of Woodford [2011], who contrasts the government spending multiplier in a conventional small-scale New Keynesian model in which monetary policy replicates the natural (flexible price) real interest rate; maintains a constant real interest rate; or maintains a constant nominal interest rate. In these cases, the multiplier is below one, equal to one, and greater than one, respectively. My quantitative results parallel those of Christiano et al. [2011], who quantify the government spending multiplier in a medium-scale model of the Great Recession. In section 5, I also quantify the government spending multiplier in my model, demonstrating that it is consistent with the empirical evidence and lending credibility to my analysis of the effects of UI.

³In 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).

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 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. Appendix A outlines the environment more formally, and here I summarize it.

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 $s_0(\theta_0, y_0^e, b_0, r_0)$, a function of labor market tightness θ_0 , real income when employed y_0^e , real 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

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

where the left-hand side is aggregate consumption and the right-hand side is aggregate production, and I have suppressed the arguments of s_0 , c_0^e , and c_0^u for brevity.⁴ 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, $k\theta_0s_0$, where k controls the magnitude of hiring costs in this frictional labor market.⁵ We normalize productivity to one.

Government budget balance implies that

$$p(\theta_0)s_0(\cdot)y_0^e + (1 - p(\theta_0)s_0(\cdot))b_0 = p(\theta_0)s_0(\cdot) - k\theta_0s_0(\cdot), \quad (2)$$

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

Optimal vacancy posting by intermediate good firms requires

$$\mu_0^{-1} \left(1 - \frac{k}{q(\theta_0)} \right) = w_0, \quad (3)$$

where μ_0 denotes the price of final goods relative to intermediate goods, $q(\theta_0)$ is the vacancy-filling probability,⁶ 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 μ_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

$$\frac{1}{u'(c_0^e(\cdot))} (v_0^e(\cdot) - v_0^u(\cdot)) = \frac{\phi}{1 - \phi} (\mu_0^{-1} - w_0), \quad (4)$$

a standard surplus-sharing condition in which ϕ denotes the bargaining power of workers.

⁴This 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.

⁵Since tightness θ_0 is given by the ratio of vacancies to search, $k\theta_0s_0$ equals k times the measure of vacancies, so that k formally corresponds to the measure of recruiters per vacancy as in Shimer [2010]. This interpretation of course makes more sense with incumbent workers as in the quantitative model.

⁶As is standard, this is related to the job-finding probability and tightness according to $q(\theta_0) = \frac{p(\theta_0)}{\theta_0}$.

Conditional on b_0 and r_0 , these constitute 4 equations in 4 unknowns $\{y_0^e, \theta_0, \mu_0, w_0\}$.⁷ 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.⁸

Lemma 1. *As $k \rightarrow 0$ while $\frac{k}{1-\phi}$ remains fixed,*

$$\frac{dy_0}{db_0} \rightarrow \frac{(1 - p(\theta_0)s_0) \left(\frac{\partial c_0^u}{\partial y_0^u} - \frac{\partial c_0^e}{\partial y_0^e} \right) + \left(p(\theta_0)s_0 \frac{\partial c_0^e}{\partial r_0} + (1 - p(\theta_0)s_0) \frac{\partial c_0^u}{\partial r_0} \right) \frac{dr_0}{db_0}}{1 - (c_0^e - c_0^u) - \frac{1}{p(\theta_0)s_0} \frac{\partial c_0^e}{\partial y_0^e} b_0},$$

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. The assumption that $\frac{k}{1-\phi}$ remains fixed in this limit (so workers' bargaining share ϕ is sufficiently close to one) ensures that workers' surplus from employment remains positive even as hiring

⁷By Walras' Law, these conditions imply that the bond market also clears.

⁸The proof of this result, like all other results in this section, is provided in appendix A.

costs vanish. Both assumptions are empirically plausible; in the quantitative model studied later in this paper, k is indeed calibrated to be small and ϕ is calibrated close to one.

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

Proposition 1. *Suppose k is small, ϕ is close to one, 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 $\frac{dy_0}{db_0} > 0$.*

The assumption that agents face a sufficiently tight borrowing constraint in period 0 has the natural implication that the unemployed will be constrained whereas the employed will not. Thus, the unemployed have a higher MPC than the employed, so by Lemma 1 the increase in UI will 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.⁹ 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 $\frac{\partial c_0^e}{\partial r_0}$ 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 μ_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.

⁹The assumption that the initial level of UI is close to optimal is sufficient to sharply sign these general equilibrium responses of wages and search. The optimal level of UI here refers to the value of b_0 which maximizes utilitarian social welfare given flexible prices in period 0.

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 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, 2021], 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, as in my simulation of the Great Recession later in this paper. 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. With these mechanisms in mind, the rest of the paper quantifies the effects of UI extensions in a richer 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_t^b) and shares in firm equity (z_t^f), and a vector of other idiosyncratic states (ζ_t^i) 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 $\Gamma_t(\zeta_t^e | \zeta_t^u)$. Conditional on an employed worker

remaining employed or separating between t and $t+1$, they transition according to $\Gamma_t(\zeta_{t+1}^e|\zeta_t^e)$ and $\Gamma_t(\zeta_{t+1}^u|\zeta_t^e)$, respectively. Finally, among unemployed workers between t and $t+1$ they transition according to $\Gamma_t(\zeta_{t+1}^u|\zeta_t^u)$.

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_t^b, z_t^f) into a worker's total real wealth

$$z_t \equiv z_t^b + \frac{\Pi_t + Q_t}{P_t} z_t^f \quad (5)$$

where Π_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 total wealth z_t alone.

At the beginning of period t , incumbent workers' value functions are

$$\tilde{v}_t^e(z_t; \zeta_t^e) = v_t^e(z_t; \zeta_t^e), \quad (6)$$

and initially unemployed workers' value functions are

$$\begin{aligned} \tilde{v}_t^u(z_t; \zeta_t^u) = \max_{s_t} (p_t(\theta_t; \zeta_t^u) s_t) \int_{\zeta_t^e} v_t^e(z_t; \zeta_t^e) \Gamma_t(\zeta_t^e|\zeta_t^u) d\zeta_t^e \\ + (1 - p_t(\theta_t; \zeta_t^u) s_t) v_t^u(z_t; \zeta_t^u) - \psi(s_t). \end{aligned} \quad (7)$$

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

$$p_t(\theta_t; \zeta_t^u) = \bar{m}_t^{1-\eta} m_t(\zeta_t^u) \theta_t^\eta, \quad (8)$$

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

In the middle of period t , the employed face

$$\begin{aligned} v_t^e(z_t; \zeta_t^e) = \max_{c_t^e, z_{t+1}^e} u(c_t^e) \\ + \beta_t(\zeta_t^e) \left[(1 - \delta_t(\zeta_t^e)) \int_{\zeta_{t+1}^e} \tilde{v}_{t+1}^e(z_{t+1}^e; \zeta_{t+1}^e) \Gamma_t(\zeta_{t+1}^e|\zeta_t^e) d\zeta_{t+1}^e \right. \\ \left. + \delta_t(\zeta_t^e) \int_{\zeta_{t+1}^u} \tilde{v}_{t+1}^u(z_{t+1}^e; \zeta_{t+1}^u) \Gamma_t(\zeta_{t+1}^u|\zeta_t^e) d\zeta_{t+1}^u \right] \text{ s.t.} \\ P_t c_t^e + (1 + i_t)^{-1} P_{t+1} z_{t+1}^e \leq Y_t^e(\zeta_t^e) + P_t z_t, \\ z_{t+1}^e \geq \underline{z}_t, \end{aligned} \quad (9)$$

and the unemployed face

$$\begin{aligned}
v_t^u(z_t; \zeta_t^u) &= \max_{c_t^u, z_{t+1}^u} u(c_t^u) + \beta_t(\zeta_t^u) \int_{\zeta_{t+1}^u} \tilde{v}_{t+1}^u(z_{t+1}^u; \zeta_{t+1}^u) \Gamma_t(\zeta_{t+1}^u | \zeta_t^u) d\zeta_{t+1}^u \text{ s.t.} \\
P_t c_t^u + (1 + i_t)^{-1} P_{t+1} z_{t+1}^u &\leq Y_t^u(\zeta_t^u) + P_t z_t, \\
z_{t+1}^u &\geq \underline{z}_t,
\end{aligned} \tag{10}$$

where each agent's discount factor is $\beta_t(\zeta_t^i)$, 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 \underline{z}_t .

Producers A representative producer hires workers to produce a homogenous intermediate good sold at price P_t^I . In period t , the producer starts with a stock \tilde{p}_t^e of incumbent workers and can hire more workers by posting ν_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 workers across the idiosyncratic state space is relevant for the firm because these states affect workers' productivity, separation rate, and wages; let $\tilde{\varphi}_t^e(z_t; \zeta_t^e)$ denote the distribution of state variables among incumbent workers, and $\frac{m_t(\zeta_t^u) s_t(z_t; \zeta_t^u)}{\bar{s}_t} \tilde{\varphi}_t^u(z_t; \zeta_t^u)$ the distribution of state variables among the pool of unemployed workers matched with the firm. The latter reflects the raw distribution of unemployed workers $\tilde{\varphi}_t^u(\cdot)$ weighted by workers' relative match efficiency $m_t(\zeta_t^u)$ and search effort $s_t(z_t; \zeta_t^u)$ relative to weighted average search

$$\bar{s}_t \equiv \int_{\zeta_t^u} \int_{z_t} m_t(\zeta_t^u) s_t(z_t; \zeta_t^u) \tilde{\varphi}_t^u(z_t; \zeta_t^u) dz_t d\zeta_t^u. \tag{11}$$

Hence, the representative producer faces

$$J_t^I(\tilde{p}_t^e, \tilde{\varphi}_t^e) = \max_{\Pi_t^I, \nu_t, \tilde{p}_{t+1}^e, \tilde{\varphi}_{t+1}^e} \Pi_t^I + (1 + i_t)^{-1} J_{t+1}^I(\tilde{p}_{t+1}^e, \tilde{\varphi}_{t+1}^e) \tag{12}$$

subject to its flow of funds

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

the evolution of its stock of incumbents

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

and the evolution of $\tilde{\varphi}_t^e$ 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_{tj} , retailer j faces Rotemberg [1982] adjustment costs

$$AC_{tj} = \frac{\psi}{2} \left(\frac{P_{tj}}{P_{t-1j}} - 1 \right)^2 \left(\int_0^1 P_{tk} y_{tk} dk \right)$$

given its prior price P_{t-1j} and aggregate nominal output $\int_0^1 P_{tk} y_{tk} dk$. Hence, retailer j faces

$$\begin{aligned} J_{tj}^R(P_{t-1j}) = & \max_{\Pi_{tj}^R, P_{tj}, y_{tj}, x_{tj}} \Pi_{tj}^R + (1 + i_t)^{-1} J_{t+1j}^R(P_{tj}) \text{ s.t.} \\ \Pi_{tj}^R = & P_{tj} y_{tj} - (1 + \tau^R) P_t^I x_{tj} - \frac{\psi}{2} \left(\frac{P_{tj}}{P_{t-1j}} - 1 \right)^2 \left(\int_0^1 P_{tk} y_{tk} dk \right) - T_t^R, \\ & y_{tj} = x_{tj}, \\ & y_{tj} = \left(\frac{P_{tj}}{P_t} \right)^{-\varepsilon} c_t, \end{aligned} \tag{13}$$

where y_{tj} is its production using x_{tj} units of the intermediate good and a linear technology; c_t is the sum of $c_t^i(z_t; \zeta_t^i)$ across the idiosyncratic state space; and τ^R is an ad-valorem tax on inputs, rebated back to retailers via the lump-sum instrument T_t^R .¹⁰ 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_t^g , and its schedule of real UI benefits $b_t(\zeta_t^e)$.¹¹ It balances its budget using a tax on the employed T_t .

Wages and income Finally, a union represents workers of each type ζ_t^e and Nash bargains the wage $W_t^{nb}(\zeta_t^e)$ with producers given a bargaining share ϕ and a utilitarian welfare function

¹⁰I further assume that the price adjustment costs are paid to the government and rebated back via T_t^R , so that the only effect of these costs is on retailers' price-setting decisions, not on resources used.

¹¹Following Woodford [2003], I model the "cashless limit" where money serves only as the unit of account.

over workers of that type having different levels of wealth.¹² In the model's steady-state, the real wage is given by the Nash bargained wage: $w(\zeta_t^e) = \frac{W_t^{nb}(\zeta_t^e)}{P}$. 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

$$\frac{W_t(\zeta_t^e)}{P_t} = \iota w(\zeta_t^e) + (1 - \iota) \frac{W_t^{nb}(\zeta_t^e)}{P_t}, \quad (14)$$

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.¹³ 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

$$Y_t^e(\zeta_t^e) = W_t(\zeta_t^e) - T_t, \quad (15)$$

$$Y_t^u(\zeta_t^u) = P_t b_t(\zeta_t^u). \quad (16)$$

Market clearing As already defined, at the beginning of period t the employment rate is \tilde{p}_t^e and the distributions of incumbent and unemployed workers are $\tilde{\varphi}_t^e(z_t; \zeta_t^e)$ and $\tilde{\varphi}_t^u(z_t; \zeta_t^u)$, respectively. Let p_t^e , $\varphi_t^e(z_t; \zeta_t^e)$, and $\varphi_t^u(z_t; \zeta_t^u)$ denote the analogs in the middle of period t .

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

$$p_t^e \int_{\zeta_t^e} \int_{z_t} z_{t+1}^e(z_t; \zeta_t^e) \varphi_t^e(z_t; \zeta_t^e) dz_t d\zeta_t^e + (1 - p_t^e) \int_{\zeta_t^u} \int_{z_t} z_{t+1}^u(z_t; \zeta_t^u) \varphi_t^u(z_t; \zeta_t^u) dz_t d\zeta_t^u + z_{t+1}^g = \frac{\Pi_{t+1} + Q_{t+1}}{P_{t+1}}, \quad (17)$$

where aggregate dividends and the price of equity satisfy

$$\Pi_t = \Pi_t^I + \int_0^1 \Pi_{tj}^R dj, \quad (18)$$

¹²We assume the union represents newly matched workers and incumbents then receive the same wage.

¹³A similar approach has been used by Costain and Reiter [2005] and Nakajima [2007]. Using a Krusell 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.

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

In the labor market, labor market tightness

$$\theta_t = \frac{\nu_t}{(1 - \tilde{p}_t^e) \bar{s}_t} \quad (20)$$

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

$$\bar{m}_t^{1-\eta} ((1 - \tilde{p}_t^e) \bar{s}_t)^{1-\eta} \nu_t^\eta,$$

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

$$q_t(\theta_t) \equiv \frac{\bar{m}_t^{1-\eta} ((1 - \tilde{p}_t^e) \bar{s}_t)^{1-\eta} \nu_t^\eta}{\nu_t} = \bar{m}_t^{1-\eta} \theta_t^{\eta-1}.$$

Absent heterogeneity in match efficiency ($m_t(\zeta_t^u) = 1$ for all ζ_t^u), this specification of the labor market collapses to the Cobb-Douglas case of that in Pissarides [2000].¹⁴

Goods market clearing is

$$\begin{aligned} p_t^e \int_{\zeta_t^e} \int_{z_t} c_t^e(z_t; \zeta_t^e) \varphi_t^e(z_t; \zeta_t^e) dz_t d\zeta_t^e + \\ (1 - p_t^e) \int_{\zeta_t^u} \int_{z_t} c_t^u(z_t; \zeta_t^u) \varphi_t^u(z_t; \zeta_t^u) dz_t d\zeta_t^u = \int_{\zeta_t^e} \int_{z_t} a_t(\zeta_t^e) \left[\tilde{p}_t^e \tilde{\varphi}_t^e(z_t; \zeta_t^e) + \right. \\ \left. q(\theta_t) \nu_t \int_{\zeta_t^u} \Gamma_t(\zeta_t^e | \zeta_t^u) \frac{m_t(\zeta_t^u) s_t(z_t; \zeta_t^u)}{\bar{s}_t} \tilde{\varphi}_t^u(z_t; \zeta_t^u) d\zeta_t^u \right] dz_t d\zeta_t^e - \bar{a}_t k \nu_t. \end{aligned} \quad (21)$$

Finally, budget balance for the government is characterized by

$$p_t^e T_t + P_t z_t^g = P_t (1 - p_t^e) \int_{\zeta_t^u} \int_{z_t} b_t(\zeta_t^u) \varphi_t^u(z_t; \zeta_t^u) dz_t d\zeta_t^u + (1 + i_t)^{-1} P_{t+1} z_{t+1}^g. \quad (22)$$

¹⁴Shimer [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.

Equilibrium Conditional on policy $\{b_t(\zeta_t^u), z_{t+1}^g, T_t\}$ and the monetary policy rule, as well as exogenous aggregates $\{a_t(\zeta_t^e), \delta_t(\zeta_t^e), m_t(\zeta_t^u), \beta_t(\zeta_t^i), \bar{a}_t, \bar{m}_t, \underline{z}_t\}$ 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

$$\begin{aligned}\zeta_t^e &\equiv (a_t^P, a_t^T, \nu^\beta), \\ \zeta_t^u &\equiv (a_t^P, a_t^T, \nu^\beta, d_t, 1_{UI}),\end{aligned}$$

where $\{a_t^P, a_t^T\}$ are components of productivity, ν^β indexes discount factor heterogeneity, d_t is the duration of unemployment, and 1_{UI} is an indicator for UI eligibility and take-up. The transition probabilities $\Gamma_t(\zeta_t^e|\zeta_t^u)$, $\Gamma_t(\zeta_{t+1}^e|\zeta_t^e)$, $\Gamma_t(\zeta_{t+1}^u|\zeta_t^e)$, and $\Gamma_t(\zeta_{t+1}^u|\zeta_t^u)$ 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

$$a_t(\zeta_t^e) \equiv a_t^P a_t^T. \quad (23)$$

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

$$\begin{aligned}\log a_t^P &= \log \bar{a}_t + \eta_t^P, \\ \eta_t^P &= \rho^P \eta_{t-1}^P + \varepsilon_t^P, \varepsilon_t^P \sim N(0, (\sigma^P)^2), \\ \log a_t^T &\sim N\left(-\frac{1}{2}(\sigma^T)^2, (\sigma^T)^2\right),\end{aligned} \quad (24)$$

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 η_t^P remains fixed.¹⁵

¹⁵Given the specification of UI benefits described later in this section, the latter assumption ensures that an unemployed worker's UI benefits remain constant until they expire.

Heterogeneous discount factors As argued by Carroll et al. [2017] and Krueger et al. [2016a], discount factor heterogeneity can further help in matching the empirical distribution of wealth. I assume that ν^β 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 Δ^β . An agent's period t discount factor is then

$$\beta_t(\zeta_t^i) = \bar{\beta}_t + \nu^\beta \quad (25)$$

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 is

$$\delta_t(\zeta_t^e) = \bar{\delta}_t \left(1 + (\epsilon_a^\delta / \bar{\delta})(\log a_t^P - \log \bar{a}_t) + (\epsilon_\beta^\delta / \bar{\delta})(\log \beta_t(\zeta_t^e) - \log \bar{\beta}_t) \right), \quad (26)$$

where $\bar{\delta}_t$ controls the economy-wide average separation rate and follows an exogenous process. In steady-state, $\bar{\delta}_t = \bar{\delta}$ and thus the parameters ϵ_a^δ and ϵ_β^δ are the semi-elasticity of an agent's separation rate with respect to her productivity and discount factor, respectively.

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 ζ does a newly unemployed worker begin receiving benefits, a state denoted with indicator 1_{UI} .¹⁶

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

$$\bar{m}_t(\zeta_t^u) = \begin{cases} \exp(d_t \lambda) & \text{for } d_t < 8, \\ \exp(7\lambda) & \text{for } d_t \geq 8. \end{cases} \quad (27)$$

¹⁶Using 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.

Here, λ controls duration dependence in match efficiencies. I assume furthermore that match efficiencies are flat after an unemployed agent has been unemployed for 8 months or more.^{17,18}

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 have finite duration and scale with earnings over a base period prior to job loss (up to a cap).¹⁹ 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 $\{a_t^P, a_t^T\}$, discount factor ν^β , duration d_t , and UI eligibility/take-up indicator 1_{UI}

$$b_t(\zeta_t^u) = \begin{cases} \min\{rr_t(1 - \omega_0)w_t(a_t^P, 1, \nu^\beta), \bar{w}i_t\} + \omega_1 w_t(a_t^P, a_t^T, \nu^\beta) & \text{if } 1_{UI} = 1, d_t < \bar{d}_t, \\ \omega_2 w_t(a_t^P, a_t^T, \nu^\beta) & \text{if } 1_{UI} = 0 \text{ or } d_t \geq \bar{d}_t, \end{cases} \quad (28)$$

where the job loser is assumed to have earned a fraction $1 - \omega_0$ of household income prior to job loss; UI policy parameters in period t are replacement rate rr_t , maximum benefit level $\bar{w}i_t$, and duration \bar{d}_t ; and $\{\omega_1, \omega_2\}$ control the level of non-UI income through the spell.²⁰ Higher ω_1 than ω_0 parsimoniously captures the household income implications of an “added worker effect” after job loss (e.g., Lundberg [1985], Stephens [2002]). Higher ω_2 than ω_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

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

¹⁷This 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].

¹⁸An alternative literature has argued that dynamic selection among heterogeneous job-seekers better explains observed duration dependence in job-finding rates (Ahn and Hamilton [2020], 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.

¹⁹UI benefits are also subject to a floor (a minimum weekly benefit amount), but given the discretized income process in my calibration this would not bind at observed values, so I ignore it for simplicity.

²⁰As 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.

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.²¹ 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. I assume $\tau^R = -7.6\%$ so that, anticipating the calibration targets described below, government debt will be roughly 60% of annual output, consistent with total public debt relative to GDP in the years immediately preceding the

²¹Using annual data from the Panel Study of Income Dynamics, these authors estimate a persistent-transitory process of $\rho_a^P = 0.9695$, $(\sigma_a^P)^2 = 0.0384$, $(\sigma_a^T)^2 = 0.0522$. They then translate these estimates to a quarterly frequency; using their same approach, I adjust these to a monthly frequency using $\rho^P = (\rho_a^P)^{1/12}$, $(\sigma^P)^2 = (1 - (\rho^P)^2) \frac{(\sigma_a^P)^2}{1 - (\rho_a^P)^2}$, $\sigma^T = \sigma_a^T$.

Great Recession.²² In most states, regular UI benefits are paid for 6 months, and the weekly benefit amount (among those not hitting the cap) replaces roughly half of wages. I thus set $rr = 50\%$ for $\bar{d} = 6$ months. I set the maximum level of benefits $\bar{ui} = 0.36$ so that it corresponds to roughly 60% of the average wage, consistent with the maximum statutory level of UI weighted across states.^{23,24} Accounting for this cap and the endogenous distribution of unemployed workers, the average effective replacement rate in the model is 45%, quite close to the 47% reported by the U.S. Department of Labor among all UI recipients in the first quarter of 2008.

I calibrate the remaining parameters to match salient patterns in wealth, income, and unemployment in U.S. data prior to the Great Recession.²⁵ 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 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 total net worth, I find that mean wealth equaled 66.0 times average monthly household income, mean wealth of households with an unemployed head was 47.5 months of average household income below that of households with an employed head, and 8% of households had negative wealth.²⁶ I use the average discount factor $\bar{\beta}$ to target mean wealth, the sensitivity of separation rates $\epsilon_{\beta}^{\delta}$ to target the mean difference in wealth by employment status, and the borrowing constraint \underline{z} to target the fraction with negative wealth. To match a 21% mean quarterly MPC out of an unanticipated \$500 rebate among households earning \$75,000 or less annually (the midpoint of the 12%-30% range reported by Parker et al. [2013]), I use the dispersion in discount factors Δ^{β} .²⁷ To clear

²²Government debt to output equals aggregate wealth to output, less the discounted present value of firm profits to output. Absent hiring costs (which will indeed be calibrated to be small, consistent with available evidence), firm profits are retailer profits. Relative to output, these are $1 - \mu^{-1} = 1 - \frac{\epsilon-1}{\epsilon} \frac{1}{1+\tau^R}$. Given $\epsilon = 6$, the targeted aggregate wealth to output, and targeted real interest rate, I thus set τ^R accordingly.

²³Absent hiring costs (which again will be calibrated to be small), real wages would be $\frac{\epsilon-1}{\epsilon} \frac{1}{1+\tau^R}$ times productivity, and the household head would earn a fraction $1 - \omega_0$ of that. I thus set $\bar{ui} = 0.6(1 - \omega_0) \frac{\epsilon-1}{\epsilon} \frac{1}{1+\tau^R} \bar{a}$.

²⁴In the data, I first compute the ratio of the maximum statutory weekly benefit amount to average weekly wage in each state. I then average across states, weighting by UI claimants. All data comes from the U.S. Department of Labor for the first quarter of 2008.

²⁵The computational algorithm used to solve the stationary RCE is discussed in appendix F.

²⁶I study an alternative calibration matching features of the liquid wealth distribution, rather than total wealth distribution, in appendix D. Since I find even larger effects of UI extensions on aggregate demand in that environment, I present the calibration to total wealth in the main text to be conservative.

²⁷The tax rebates under study in Parker et al. [2013] phased out rapidly above \$75,000 annual income among single earner households, and \$150,000 annual income among dual earner households. I use the former threshold to compute the comparable moment in my model so that, if anything, my calibration of MPCs is conservative. I focus on a \$500 rebate as in Kaplan and Violante [2014]. I convert both the \$500 rebate and \$75,000 annual income cutoff into model scale using average monthly household income from the 2004 SCF,

Moment	Target	Achieved	Parameter	Value
<i>Real rate, wealth, and average MPC</i>				
Real interest rate (ann.)	2%	2.0%	z^g/\bar{a}	-8.5
Mean wealth / monthly HH income	66.0	65.5	$\bar{\beta}$	0.99335
Mean (U-E) wealth / monthly HH income	-47.5	-47.6	ϵ_β^δ	-4.55
Fraction HH with negative wealth	0.08	0.05	\underline{z}/\bar{a}	-0.15
Mean quarterly MPC to \$500 rebate*	0.21	0.21	Δ^β	0.0045
<i>Income during unemployment</i>				
Share unemployed receiving UI	0.39	0.42	ζ	0.5
Mean HH income w. UI / pre job loss	0.76	0.77	ω_1	0.38
Mean HH income w.o UI / pre job loss	0.55	0.55	ω_2	0.49
<i>Incidence of unemployment</i>				
Unemployment rate	5%	5.0%	ϕ	0.958
Fraction w/ duration > 6 mos	0.17	0.17	λ	-0.14
EU probability on log wage	-0.012	-0.012	ϵ_a^δ	-0.011
<i>Search and the labor market</i>				
Duration elasticity to benefit duration	0.1	0.10	ξ	15
Vacancies per unemployed worker	0.634	0.634	\bar{m}	0.19
Fraction of monthly wage to hire worker	0.108	0.108	k/\bar{a}	0.044

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.

* Among households earning \leq \$75k ann. income (0.92 times average household income in model).

the asset market at a targeted 2% annualized real interest rate, I use the government's bond position z^g . 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 ζ . Finally, to match the dynamics of household income through unemployment using the SIPP in appendix C, I use ω_1 to target 24% lower income after job loss and ω_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 17% of the unemployed having duration greater than 26 weeks. I use the bargaining power of workers ϕ to target the overall unemployment rate and the duration dependence of match efficiency λ to target the fraction 0.17 of unemployed with duration greater than 6 months. Since much of my analysis will focus on policy affecting UI duration, I use the elasticity of workers' disutility from search ξ to target a micro-elasticity of unemployment duration to potential duration of benefits of 0.1, within the range surveyed

and then compute MPCs by simulating agents over three months including and after receipt.

by Schmieder and von Wachter [2016].²⁸ I use the sensitivity of separation rates ϵ_a^δ 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. [2017], 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 ($\epsilon_\beta^\delta < 0$) to match the mean difference in wealth between the unemployed and employed. Indeed, separation rates which fall only with productivity ($\epsilon_a^\delta < 0$) to match the observed relationship between EU probabilities and wages cannot rationalize this large difference in wealth by employment status.²⁹ Notably, this is consistent with evidence from the SIPP in appendix C that EU probabilities are negatively related to wealth even conditional on income.³⁰ Finally, match efficiencies must fall with duration ($\lambda < 0$) 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 Consumption, unemployment risk, and wealth: data vs. model

The model’s consistency with untargeted moments on consumption, unemployment risk, and wealth 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. More detail on the estimates, including standard errors and sample descriptions, is 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

²⁸As 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.

²⁹While 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.

³⁰I 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.

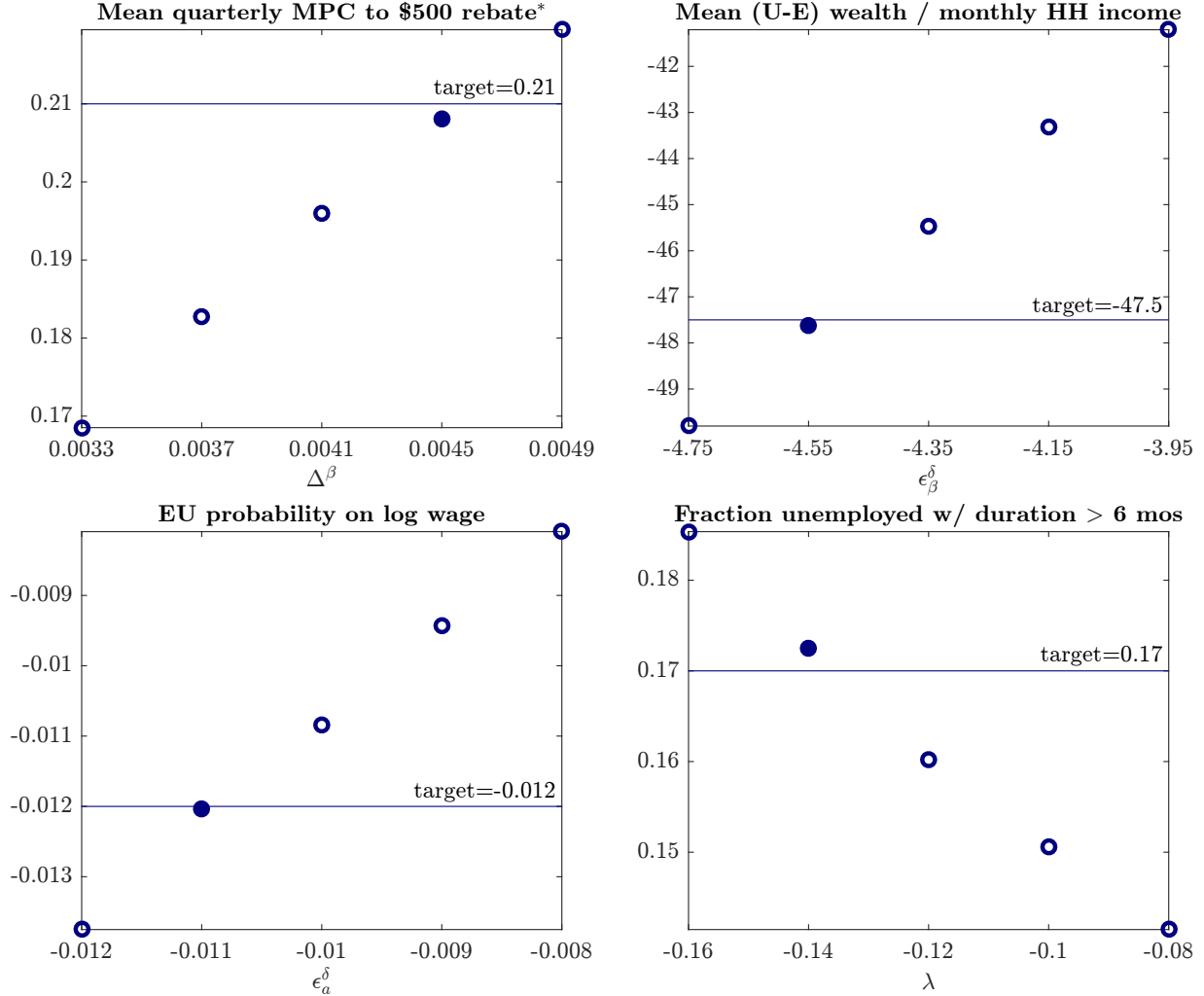


Figure 1: identification of selected parameters in stationary RCE

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 Δ^β : in that case, I also vary $\bar{\beta}$ such that $\bar{\beta} + \Delta^\beta = 0.99785$, 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.

* Among households earning \leq \$75k ann. income (0.92 times average household income in model).

versus employed households.³¹ The results of Ganong and Noel [2019] using data from 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 close to the empirical counterparts.

The model is also consistent with untargeted moments regarding the incidence and effects

³¹While 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.

Moment	Estimate	Source	Model
<i>Consumption sensitivities to income</i>			
Annual MPC unemp. - emp.	0.25	2010 SHIW	0.27
Δ spend. / Δ inc. at UI exhaustion	0.20	Ganong and Noel [2019]	0.24
<i>Incidence and consumption effects of unemployment</i>			
EU prob. on wealth / mo. HH income	-0.0002	2004 Panel SIPP	-0.0001
During UI receipt / pre job loss	0.91	Ganong and Noel [2019]	0.85
After UI exhaustion / pre job loss	0.80	Ganong and Noel [2019]	0.77
<i>Aggregate consumption shares by wealth</i>			
Quintile 5 (highest)	37.2%	Krueger et al. [2016a]	33.5%
Quintile 4	22.4%	Krueger et al. [2016a]	26.5%
Quintile 3	16.8%	Krueger et al. [2016a]	21.1%
Quintile 2	12.4%	Krueger et al. [2016a]	11.2%
Quintile 1 (lowest)	11.3%	Krueger et al. [2016a]	7.7%

Table 2: untargeted moments on MPCs, unemployment risk, and consumption

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.

of unemployment. Exploiting the panel structure of the SIPP, I estimate that one additional month of income in net worth is associated with a 0.02pp decrease in the probability that a household head becomes unemployed one year in the future. In the model, the same increase in net worth is associated with a 0.01pp decline in the probability of unemployment one year in the future. The consequences of unemployment for consumption have been studied 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 their partial equilibrium analysis, agents in the model reduce consumption by more in anticipation of exhaustion relative to what we observe in the data. However, the model more 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.

The model is finally consistent with the relative importance of consumption among households by wealth. Krueger et al. [2016a] sort households in the 2007 PSID into quintiles based on their total level of net worth, and then compute the share of aggregate consumption by households in each group. If anything, the model slightly undershoots the share of aggregate consumption accounted for by households in the bottom two wealth quintiles. Since (as I show in the next subsection) MPCs are strongly associated with wealth, this implies that the model does not overstate the importance of high-MPC households in aggregate consumption.

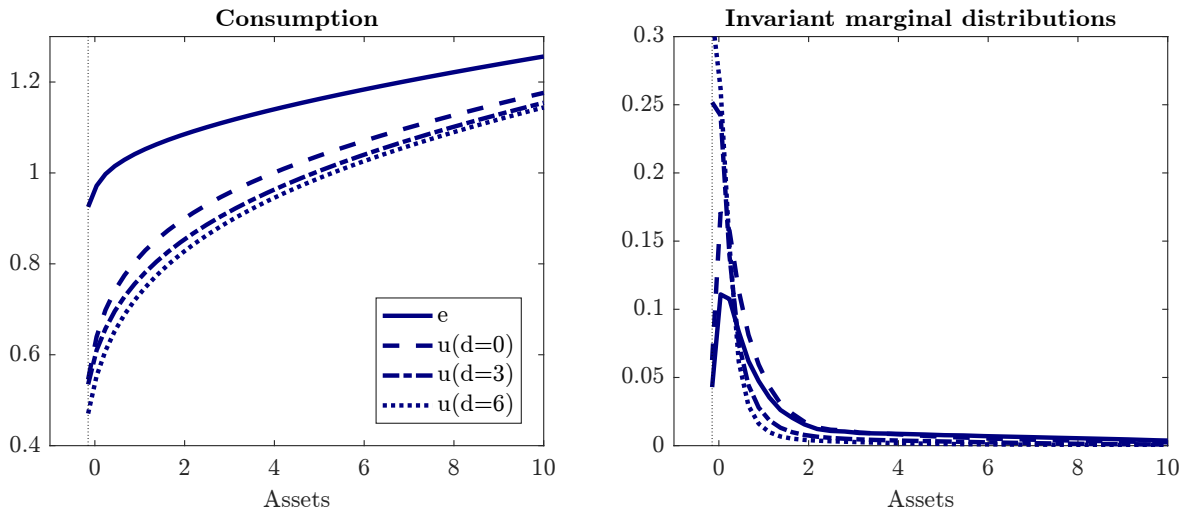


Figure 2: consumption policy functions and marginal wealth distributions in stationary RCE

Note: e denotes employed, u denotes unemployed, and d denotes the number of months an agent has been unemployed in the current spell (not including the current month). The policy functions in the first panel average over all other state variables using the marginal distributions conditional on employment status. The dashed vertical line in both panels marks the borrowing constraint.

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 over three times that of the employed. In fact, the long-term unemployed have a quarterly MPC which is more than one and a half times that of the bottom quintile of households by wealth.³²

³²The MPCs by wealth are further useful in validating the model given the consistency between the model-implied pattern of MPCs declining in 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. The distinction

Group	Mean quarterly MPC
Overall	0.17
<i>By wealth</i>	
Quintile 5 (highest)	0.01
Quintile 4	0.05
Quintile 3	0.18
Quintile 2	0.24
Quintile 1 (lowest)	0.39
<i>By employment status</i>	
Employed	0.16
Unemployed	0.42
Short-term ($d \in \{0, 1, 2\}$)	0.36
Medium-term ($d \in \{3, 4, 5\}$)	0.47
Long-term ($d \geq 6$)	0.60

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

Note: the \$500 rebate is first translated into model scale using average monthly 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.

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 or the extensions last for a longer horizon.

5.1 Roles of nominal rigidity and the monetary policy response

I start with an unanticipated extension of UI duration by three months and lasting one year. This subsection clarifies the key roles of nominal rigidity and the monetary policy response in shaping the resulting macroeconomic effects.

I assume for now $\iota = 1$, so that real wages do not change in response to the shock, and all other macroeconomic parameters are 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.

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

between liquid and illiquid wealth is of course one that my baseline model does not capture, though I provide an alternative calibration to the liquid wealth distribution in appendix D.

	Flex prices	Sticky prices	Sticky prices + fixed r	Sticky prices + fixed i
Output multiplier	-0.5	0.1	1.1	1.2
Avg change in unemp. rate	+0.02pp	+0.00pp	-0.03pp	-0.03pp

Table 4: baseline effects of UI

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.

use empirical patterns in household portfolios by wealth to initialize these portfolios.³³

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 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

³³The computational algorithm used to characterize each of the transitional dynamics in this section builds on Guerrieri and Lorenzoni [2017] and Auclert et al. [2021] and is discussed further in appendix F.

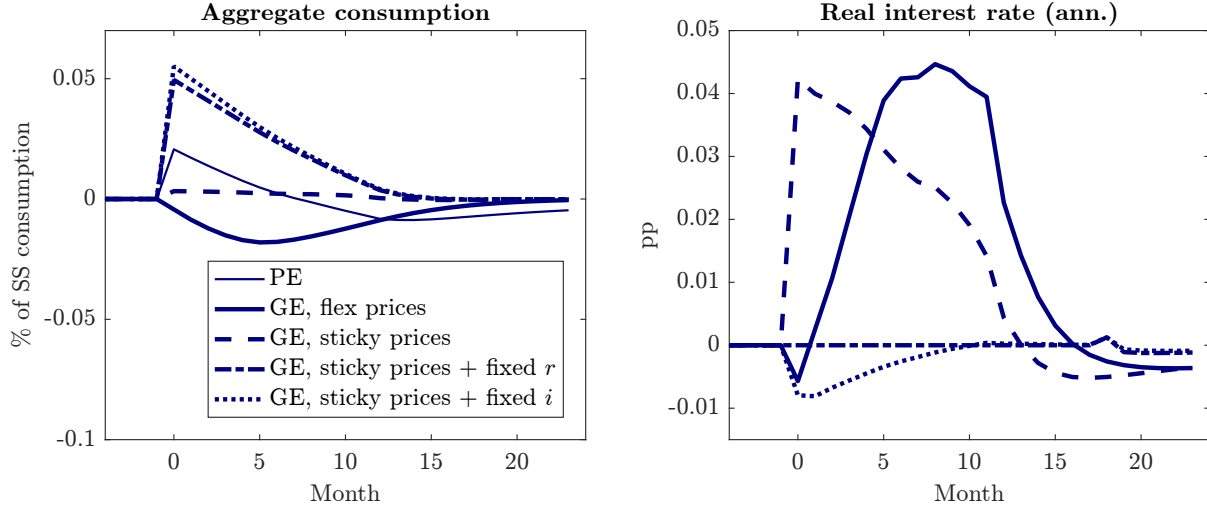


Figure 3: effects of UI starting from steady-state

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.

thus output in the first panel of Figure 3 is negative.³⁴ The first row of Table 4 summarizes the effect on output by the contemporaneous multiplier

$$\text{output multiplier} \equiv \frac{\sum_{t=0}^{11} \Delta \text{output}_t}{\sum_{t=0}^{11} \Delta \text{UI payments}_t}, \quad (30)$$

where the denominator uses the initial distribution of agents across the state space. The multiplier is -0.5, with the unemployment rate rising by 0.02pp 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 $\psi = 150$, so that (given an elasticity of substitution across retailer varieties of $\epsilon = 6$) the log-linear New Keynesian Phillips curve has slope on marginal cost $\frac{\epsilon-1}{\psi} = 0.033$. This is equivalent to the log-linear Phillips curve in a model of Calvo pricing with expected price duration 6 months, consistent with the evidence surveyed in Nakamura and Steinsson [2013]. I set the coefficients in (29) to $\phi^\Pi = 1.5$ and $\phi^y = 1$, 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

³⁴Appendix D provides the impulse responses of equilibrium tightness, search, and other variables.

	Baseline	Identical δ
Quarterly MPC, employed	0.16	0.17
Quarterly MPC, ST unemployed	0.36	0.27
Quarterly MPC, MT unemployed	0.47	0.36
Quarterly MPC, LT unemployed	0.60	0.45
Output multiplier	1.2	0.6
Avg change in unemp. rate	-0.03pp	-0.01pp

Table 5: sensitivity of effects of UI under sticky prices and fixed i

Note: the counterfactual economy sets $\epsilon_a^\delta = \epsilon_\beta^\delta = 0$ and re-calibrates all other parameters to match the same moments as in the baseline, as described in appendix D. In all cases the quarterly MPC is computed for an unexpected \$500 rebate.

exactly as in the flexible price case, the resulting output multiplier is positive, but small.

Absent the rise in the real interest rate, UI extensions become more 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 more 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 0.03pp. If monetary policy instead 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.

5.2 Roles of MPC heterogeneity and precautionary saving

In these results, MPC heterogeneity and reduced precautionary saving drive the aggregate effects of UI extensions when monetary policy is constrained.

I first study an alternative calibration of the model eliminating heterogeneity in separation rates, illustrating the importance of heterogeneity in MPCs. With $\epsilon_a^\delta = \epsilon_\beta^\delta = 0$ and other parameters re-calibrated to match the same targets as the baseline as described in appendix D, 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 indicate 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

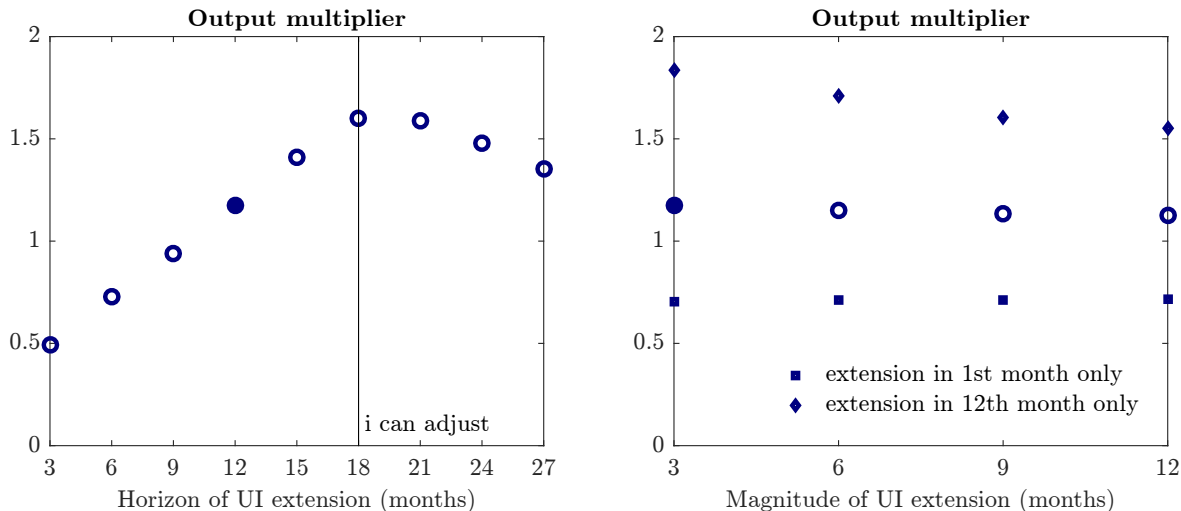


Figure 4: sensitivity to horizon and magnitude given sticky prices and fixed i

Note: the left 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. The right 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. Shaded markers in both panels depict the baseline three-month extension of UI for one year.

of those receiving the transfers.

Returning to focus on the baseline calibration alone, I next vary the number of calendar months during which extended benefits are provided, illustrating the importance of precautionary saving. The first panel of Figure 4 plots the output multiplier associated with extended UI over horizons of 3 to 27 months, holding fixed the three-month duration by which benefits are extended. Over the period in which monetary policy is accommodative (18 months), the stimulus grows as the announced horizon increases. This is consistent with the dynamic amplification of the stimulus from reduced precautionary saving, higher aggregate demand, and lower unemployment risk.³⁵ Of course, once UI extensions are expected to persist beyond the period of a constant nominal interest rate, the tightening which accompanies the extensions renders them less expansionary.

Varying the number of months of unemployment by which UI is extended illustrates an interesting tension between the stimulus via heterogeneous MPCs and precautionary saving.³⁶ The right panel of Figure 4 plots the output multiplier associated with duration

³⁵Output multipliers rising with the horizon of a spending shock can also rise from the inflation expectations channel, but that is not dominant here: almost the same multipliers are obtained if monetary policy maintains a constant real interest rate rather than nominal interest rate over the first 18 months.

³⁶I find a similar tension when considering an alternative calibration of the coefficient of relative risk aversion σ : raising σ raises agents' prudence, but compresses the distribution of MPCs by employment status, such that the effects of UI extensions on output are roughly unchanged from the baseline calibration.

	Baseline	Lower real wage rigidity	Higher disincentive elasticity
Flexible prices			
Avg change in real rate (ann.)	+0.03pp	+0.04pp	+0.02pp
Output multiplier	-0.5	-4.8	-1.8
Avg change in unemp. rate	+0.02pp	+0.14pp	+0.08pp
Sticky prices			
Avg change in real rate (ann.)	+0.03pp	+0.04pp	+0.04pp
Output multiplier	0.1	0.0	0.1
Avg change in unemp. rate	+0.00pp	+0.00pp	+0.02pp
Sticky prices + fixed i			
Avg change in real rate (ann.)	-0.00pp	-0.04pp	-0.01pp
Output multiplier	1.2	2.4	1.5
Avg change in unemp. rate	-0.03pp	-0.07pp	-0.03pp

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

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

extensions by 3 to 12 months, holding fixed a one-year horizon over which benefits are extended. It further plots the output multiplier associated with such extensions at $t = 0$ and $t = 11$ alone (both 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 overall output multiplier from a one-year extension of benefits is remarkably stable with the magnitude of the extension.

5.3 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 ι 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].³⁷ 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.

5.4 Other features of UI policy and fiscal policy

In appendix D, I conduct several additional experiments which further elucidate the effects of UI extensions in the model given sticky prices and constraints on monetary policy. I first consider an increase in UI eligibility/take-up, which amplifies the stimulus by expanding the scale of transfers. I then consider deficit-financed increases in UI duration, which amplifies the stimulus because the model is non-Ricardian. I then 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.

Finally, in appendix D I study the effects of conventional government purchases, rather than UI (transfers). I augment the model to feature government spending on final goods which enters separably into households’ utility. The model-implied fiscal multiplier (defined analogously to (30)) ranges between 1-1.4 and is on the higher end of that range when monetary policy maintains a constant nominal interest rate (as at the zero lower bound) and government spending is deficit-financed. These magnitudes are in line with estimates of the fiscal multiplier exploiting time-series and cross-sectional variation as surveyed by Ramey [2011] and Chodorow-Reich [2019], respectively. This lends further credibility to my model’s implications for the general equilibrium effects of UI.

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

³⁷The re-calibrated parameters are again summarized in appendix D.

	Date	Revised UI extensions	Relevant legislation/program
1	7/2008	3 months through 6/2009	P.L. 110-252 (EUC08 Tier 1 announced)
2	12/2008	7 months through 11/2009	P.L. 110-449 (EUC08 Tier 2 announced)
3	3/2009	7 months through 5/2010	P.L. 111-5
4	5/2009	12 months through 5/2010	EB starts for median state
5	11/2009	16 months through 5/2010	P.L. 111-92 (EUC08 Tiers 3, 4 announced)
6	1/2010	16 months through 7/2010	P.L. 111-118
7	3/2010	16 months through 8/2010	P.L. 111-144
8	4/2010	16 months through 10/2010	P.L. 111-157
9	8/2010	16 months through 4/2011	P.L. 111-205
10	1/2011	16 months through 5/2012	P.L. 111-312
11	1/2012	16 months through 8/2012	P.L. 112-78
12	3/2012	16 months through 5/2012, 14 months through 8/2012, 8 months through 12/2012	P.L. 112-96
13	1/2013	8 months through 12/2013	P.L. 112-240

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.

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. The unemployment rate would have been as much as 0.4pp 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.³⁸ 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 2012). 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 5 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.³⁹ 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 $\bar{\beta}_t$ 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 ι calibrated to match the dynamics of prices during this period. I assume that the average discount factor follows the AR(1) process

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

and I set $\rho^{\bar{\beta}} = 0.95$.⁴⁰ As in section 5, I assume price adjustment costs $\psi = 150$ (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 $\phi^y = 1$.

³⁸The 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.

³⁹I also view it as conservative: since the output multiplier rises with the horizon of UI extensions when monetary policy maintains a constant nominal interest rate (Figure 4), I expect that I would find even more stimulative effects of the UI extensions if agents were not surprised by future reauthorizations and had instead expected them to continue so long as monetary policy was at the zero lower bound.

⁴⁰I find that the assumed value of $\rho^{\bar{\beta}}$ has little effect on the results which follow; it simply implies a different magnitude of shocks to rationalize the observed path of unemployment.

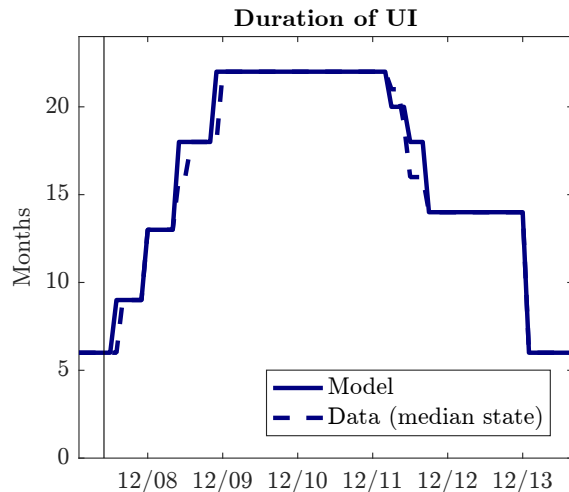


Figure 5: realized UI duration in model versus data

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.

I view discount factor shocks as a way to capture changes in financial conditions which change households' desired (or required) saving.⁴¹ A shock to the credit constraint \underline{z} delivers the same comovements.⁴² In appendix E I also characterize the effects of productivity, separation rate, and match efficiency shocks, which imply distinct comovements from discount factor or credit constraint shocks. Separation rate and match efficiency shocks in particular have the form of "cost-push" shocks, generating a rise in unemployment together with an increase in inflation. Later in this section, I thus consider the sensitivity of my findings to an alternative calibration featuring both discount factor and separation rate shocks; in my baseline calibration, however, I focus on discount factor shocks alone for parsimony.

The calibration proceeds as follows. For a grid of values of real wage rigidity ι , I calibrate a sequence of shocks $\{\epsilon_t^{\bar{\beta}}\}$ to match unemployment in the data. I choose the unemployment 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 $\{\epsilon_t^{\bar{\beta}}\}$ calibrated in this way for each value of ι , I then choose ι to minimize the sum of absolute value differences between the final

⁴¹A 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].

⁴²However, it is quantitatively problematic to match the rapid rise in aggregate unemployment early in the Great Recession via shocks to \underline{z} alone: because the credit constraint shock has little effect on high wealth households, the required size of shocks to \underline{z} would imply some agents have negative consumption. It is for this reason that I focus on discount factor shocks.

goods price index in model and data. I use the final goods price index 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.⁴³

The computational heart of this algorithm is in calibrating the sequence of discount factor of shocks, conditional on any ι . 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 $\epsilon_t^{\bar{\beta}}$ 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.⁴⁴ 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.⁴⁵

This algorithm implies $\iota = 0.975$, a high degree of real wage rigidity, and the set of discount factor shocks $\epsilon_t^{\bar{\beta}}$ depicted in the first panel of Figure 6. 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 7 compares other model-generated time-series with the data, all of which are untargeted in the calibration except the final goods price index.⁴⁶ 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 consumption per capita recovers in the model (consistent with

⁴³I use the core PCE as the data counterpart of final goods prices because the PCE index is the one targeted by the FOMC, and the core index in particular is typically viewed as a more reliable measure of inflation because it excludes volatile food and energy prices.

⁴⁴I 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 .

⁴⁵What 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.

⁴⁶The 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 PCE index excluding food and energy 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.

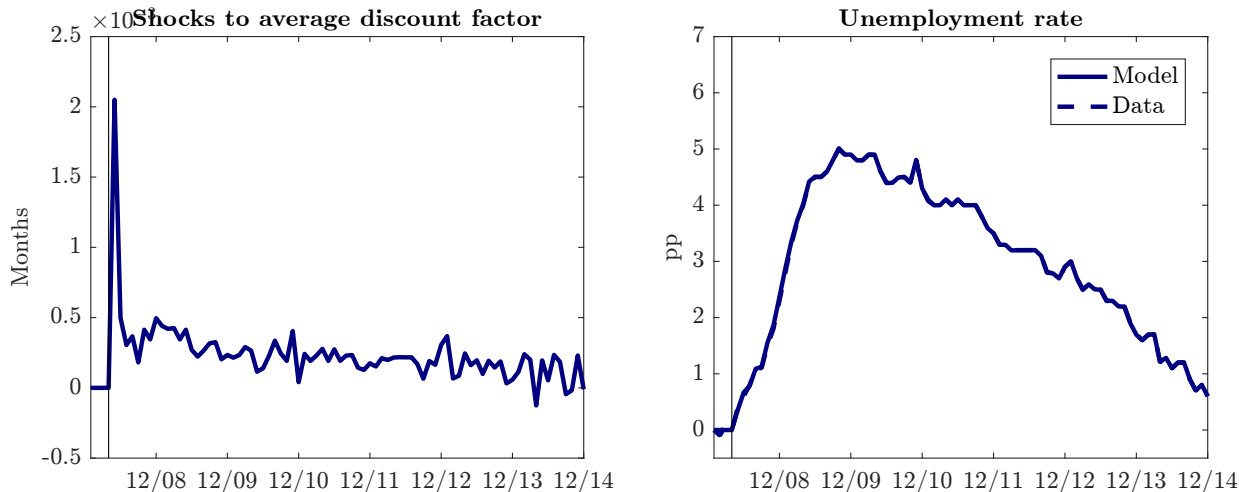


Figure 6: discount factor shocks and unemployment

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).

unemployment) whereas in the data it falls further below trend.⁴⁷ The fifth and sixth panels focus on nominal wages and prices; the model generates a decline in both quite consistent with the data. Notably, the high degree of real wage rigidity ensures that nominal prices only fall by less than $3pp$ below trend by 2014 — amounting to less than $0.5pp$ below trend per year — despite the substantial rise in unemployment during the Great Recession.⁴⁸

Figure 8 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).⁴⁹ By January 2009, the baseline projection was that the funds rate would remain at its $0-25bp$ target

⁴⁷I expect that a change in trend growth could rationalize the model with the data in this dimension.

⁴⁸In this way, the model rationalizes the “missing disinflation” during this period (see, e.g., Harding et al. [2021] and citations therein).

⁴⁹While 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.

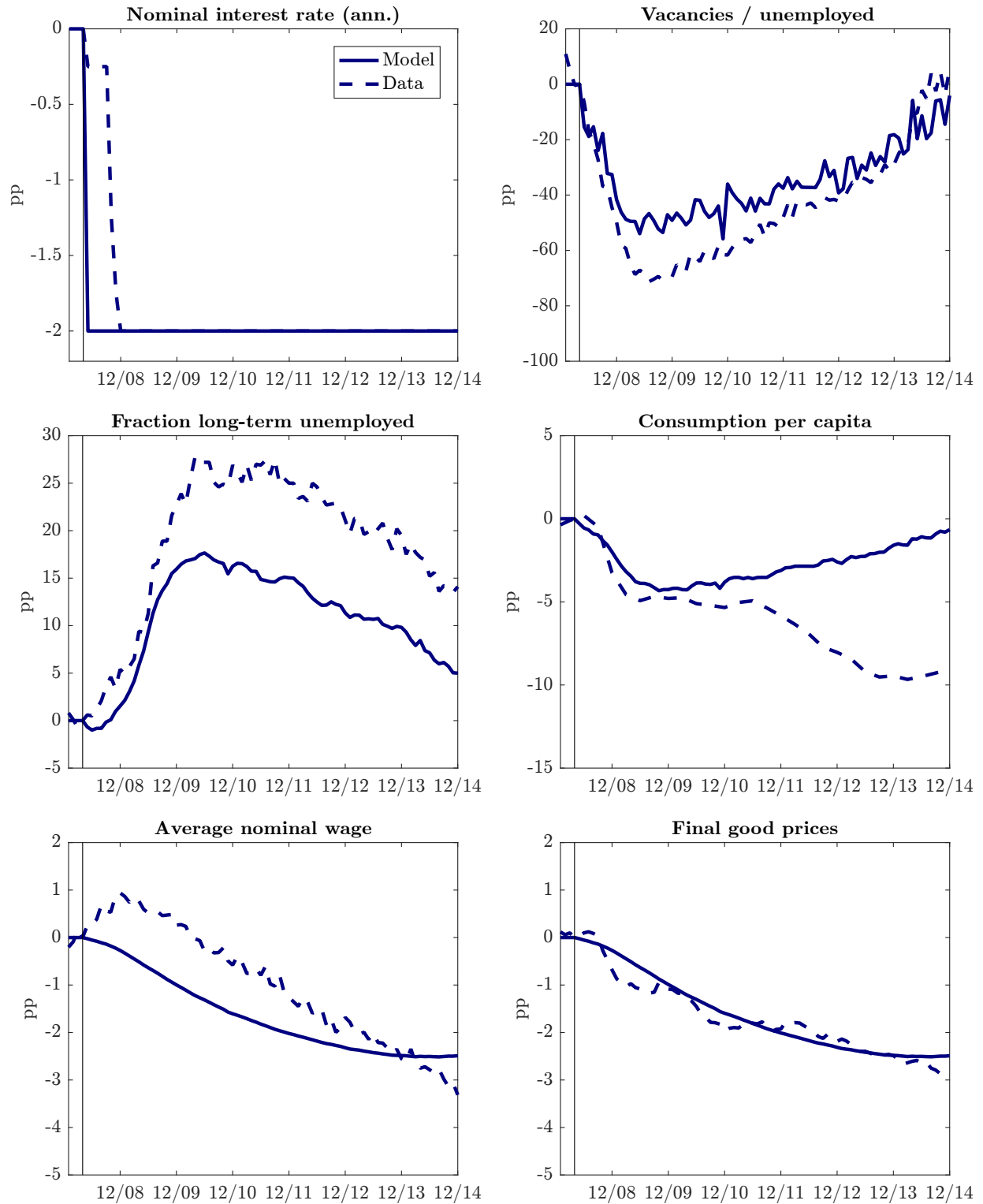


Figure 7: untargeted macro time-series

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 1.9% per year, respectively).

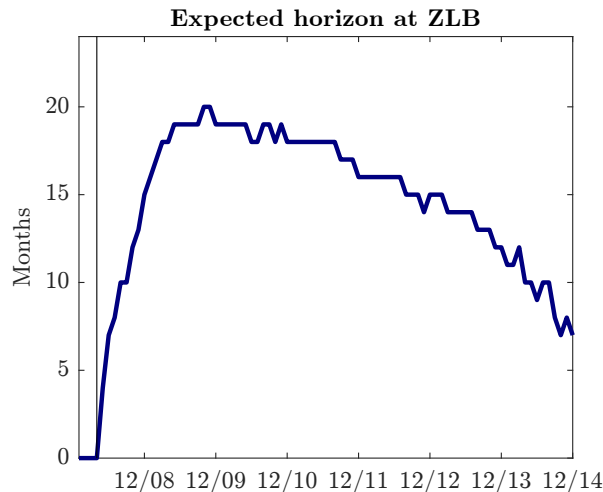


Figure 8: expected horizon at the zero lower bound

Note: model hits the zero lower bound in the first month of the simulation, as depicted in Figure 7.

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.

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 9 presents the same endogenous variables as Figures 6 and 7 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 9 demonstrates that the counterfactual economy sees a larger rise in unemployment. The unemployment rate would have been as much as 0.4pp higher were it not for the benefit extensions. More generally, the model implies that the benefit extensions were not a cause of unemployment persistence during the Great Recession.

The remaining panels of Figure 9 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, 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 disinflation.

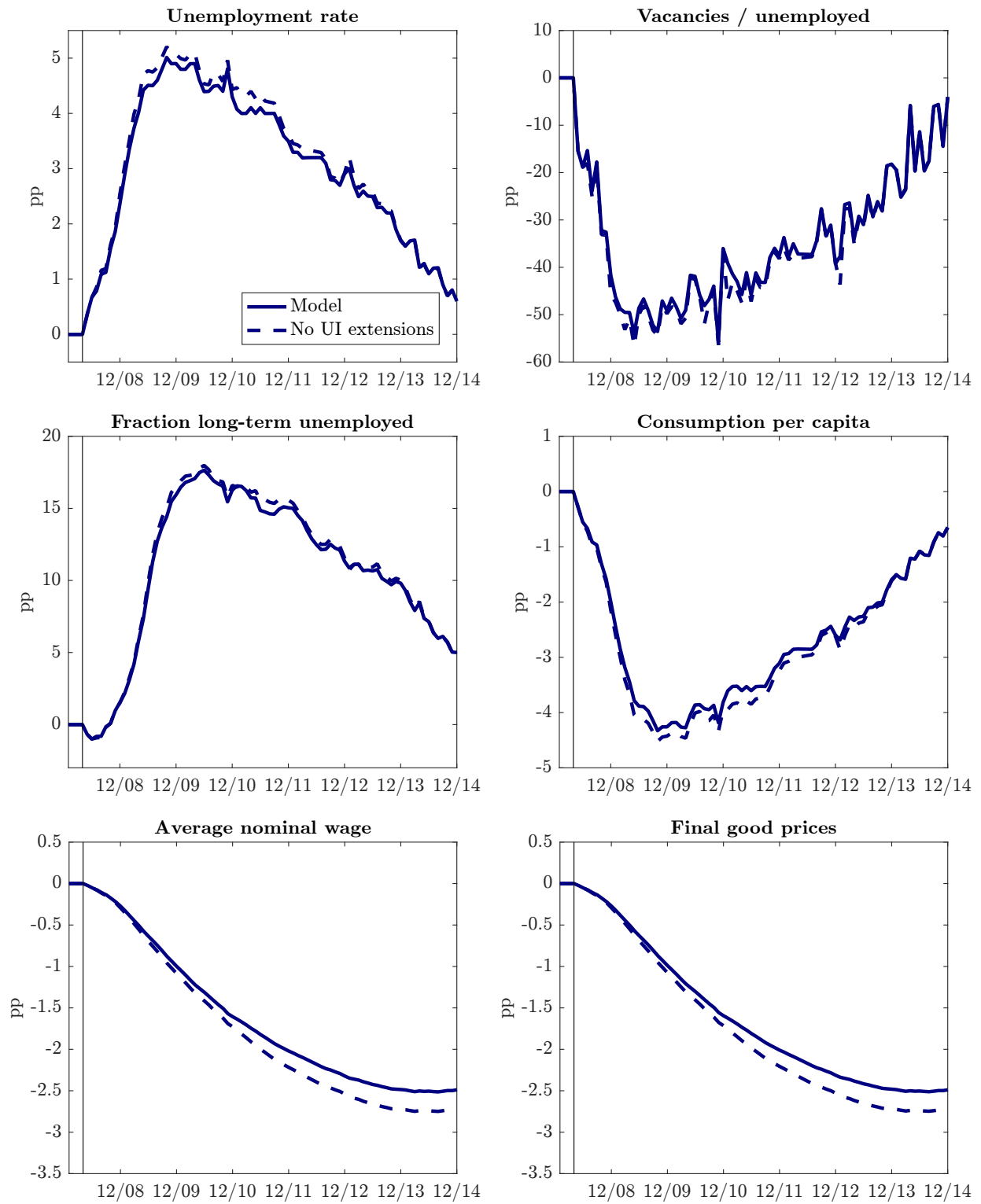


Figure 9: effects of UI shocks

Note: counterfactual environment maintains the same discount factor shocks in Figure 6.

	Date	Output multiplier	Avg change in unemployment rate
1	7/2008	0.7	-0.02pp
2	12/2008	1.4	-0.06pp
3	3/2009	2.4	-0.05pp
4	5/2009	1.2	-0.03pp
5	11/2009	0.8	-0.01pp
6	1/2010	0.9	-0.04pp
7	3/2010	0.8	-0.02pp
8	4/2010	0.9	-0.04pp
9	8/2010	1.0	-0.09pp
10	1/2011	1.8	-0.13pp
11	1/2012	1.1	-0.04pp
12	3/2012	1.5	-0.04pp
13	1/2013	1.1	-0.09pp

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.

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 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. 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 8 months, whereas at the time of shock 2 it is expected to bind for 15 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 4, shock 10 is thus more stimulative than shock 9.

Appendix E finally provides a case study of the expiration of extended benefits in December 2013. In the analysis above, I assume that upon the final reauthorization of benefits

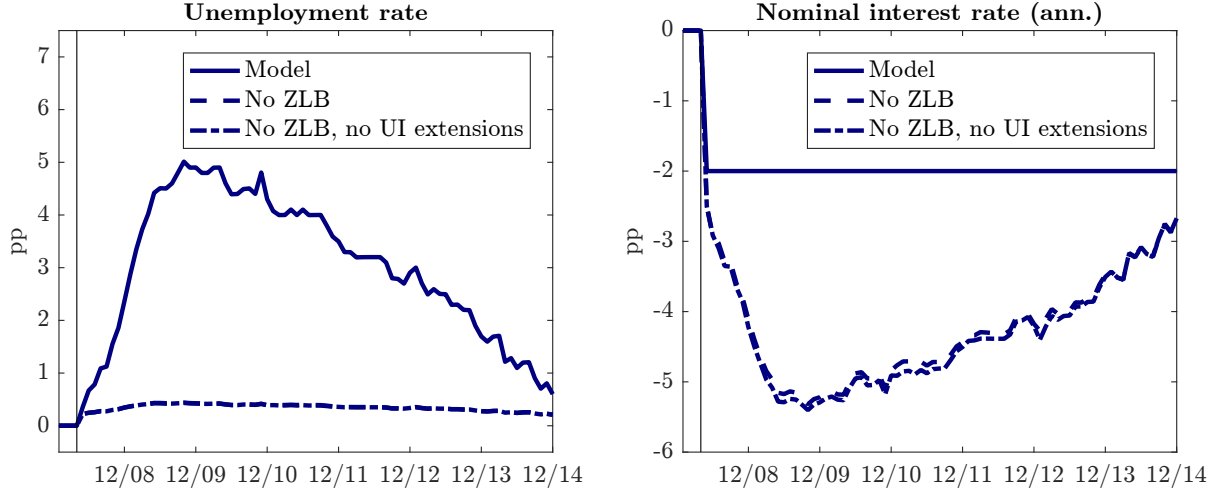


Figure 10: effects of zero lower bound

Note: counterfactual environments maintain the same discount factor shocks in Figure 6.

in January 2013, agents rationally expected that benefits would expire in December 2013. In the appendix, I consider alternative scenarios in which agents expected benefits to last through 2014 or 2015, but then they unexpectedly expire in December 2013. The analysis clarifies first that even if the expiration was unexpected, it need not have been accompanied by a sharp deterioration in the labor market to the extent that favorable fundamental shocks supported the economy at the same time. For instance, when I recalibrate discount factor shocks to match the dynamics of unemployment, the (untargeted) dynamics of vacancies are virtually indistinguishable between my baseline model and the model with unexpected expiration. Of course, this does not mean the expiration is neutral: holding *fixed* the path of discount factor shocks, but comparing the dynamics with unexpected expiration to those in a counterfactual without expiration, I find that the real economy would have recovered faster towards trend in the counterfactual economy. Importantly, however, the horizon over which the zero lower bound lasts puts an upper bound on the degree of stimulus that could be obtained without expiration. In particular, benefit extensions continuing further than the middle of 2015 would have offered essentially no incremental stimulus.

6.4 Role of zero lower bound

I now further characterize the key role of the zero lower bound for the above results.

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 10 demonstrates that this counterfactual economy sees a much

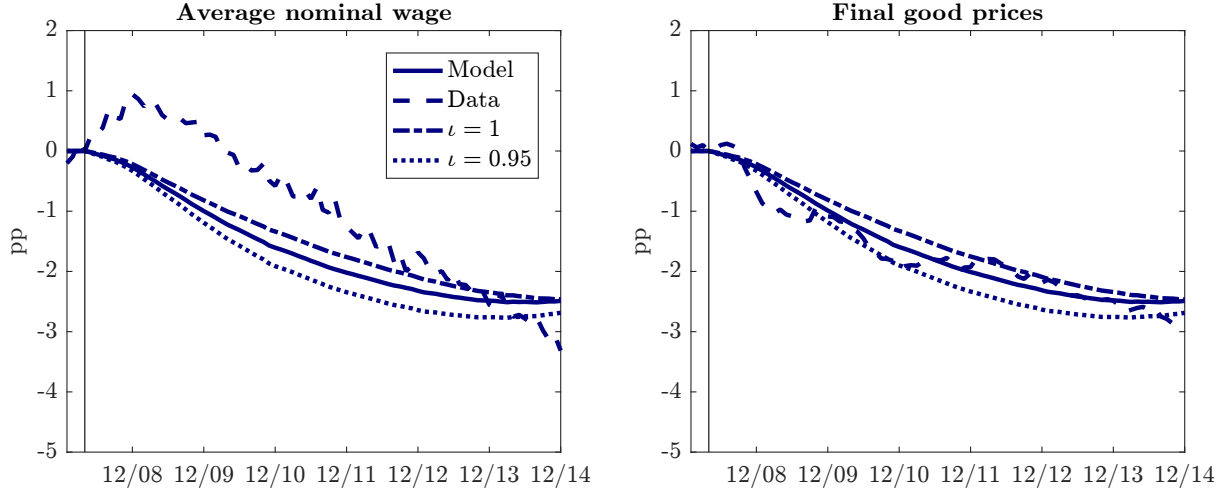


Figure 11: wages and prices with alternative real wage rigidity ι

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 ι are generated using alternative sequences of discount factor shocks to match the same unemployment series in Figure 5.

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 indistinguishable from 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 11, I first compare the data and baseline path of nominal wages and prices to alternative calibrations with more rigid real wages ($\iota = 1$) and less rigid real wages ($\iota = 0.95$). The latter two cases are generated using alternative sequences of discount factor shocks to match the same unemployment series in Figure 5. As is evident, a lower degree of real wage rigidity would imply that nominal wages and prices fall by more during this period. This

makes clear that the model requires a high degree of real wage rigidity to rationalize the absence of substantial deflation despite the rise in unemployment during the Great Recession.

Of course, with more real wage flexibility, the model implies only greater stimulus from UI extensions at the zero lower bound. In Table 9, I compute the output multipliers from each of the 13 UI shocks across these calibrations. As is evident, a lower degree of real wage rigidity only implies more stimulus from UI extensions, consistent with Table 6.

Nonetheless, the case with fully rigid real wages still features substantial stimulus. In fact, the multipliers are more than half of those obtained with $\iota = 0.95$. Since the inflation expectations channel is extremely small when real wages are fully rigid — evident from the comparison of a constant real versus nominal interest rate in Table 4 — I conclude that around my estimated degree of real wage rigidity, the direct effect of UI extensions on aggregate demand are more important than the induced effect through inflation expectations in driving the macroeconomic effects of UI extensions during the Great Recession.

Several other considerations justify the high degree of real wage rigidity in my analysis. While there continues to be substantial debate in the literature, such high degrees of real wage rigidity are well within the range consistent with macro evidence on labor market fluctuations over the business cycle,⁵⁰ as well as micro evidence on the responsiveness of real wages to changes in UI.⁵¹ I also continue to estimate a high degree of real wage rigidity when I account for other driving forces besides demand shocks during the Great Recession: in appendix E, I present an alternative calibration featuring both discount factor and separation rate shocks, where the latter is directly disciplined by the time-series of the aggregate separation rate. Because the separation rate rose early in the Great Recession, and positive separation rate shocks are inflationary, this alternative calibration requires lower real wage rigidity than the baseline model to rationalize the absence of substantial deflation during this period. However, even in this case I estimate $\iota = 0.95$.

⁵⁰Shimer [2010], for instance, also focuses on a degree of (monthly) real wage rigidity around or above 0.95. The comovements between the labor wedge, hours, and consumption/output ratios justify this choice. In the data, the labor wedge and hours are strongly negatively correlated, while the labor wedge and consumption/output ratio are essentially uncorrelated (see his Table 1.1). Absent real wage rigidity in a conventional search model with capital and (only) productivity shocks around a deterministic trend, the labor wedge has a correlation of 0.96 with employment and almost -1 with the consumption/output ratio (see his Table 3.3). Real wage rigidity of 0.993 is needed to bring both close to zero (see his Figure 4.2).

⁵¹While I have followed Hall [2005], Blanchard and Gali [2010], Shimer [2010], and much of the literature in assuming that a single parameter (ι) governs the responsiveness of real wages to all shocks, one could entertain a specification in which real wages are more responsive to some shocks than others. Of most relevance for my results is the responsiveness of real wages to changes in UI. In this context, my estimated high degree of real wage rigidity is especially reasonable: Card et al. [2007], Jäger et al. [2020], Lalive [2007], and van Ours and Vodopivec [2008] have all exploited micro variation in UI and estimated extremely small effects of UI duration on wages.

Output multiplier				
	Date	$\iota = 0.95$	Model	$\iota = 1$
1	7/2008	0.9	0.7	0.6
2	12/2008	1.6	1.4	1.2
3	3/2009	3.0	2.4	1.8
4	5/2009	1.4	1.2	1.0
5	11/2009	0.8	0.8	0.7
6	1/2010	1.0	0.9	0.8
7	3/2010	0.9	0.8	0.7
8	4/2010	1.0	0.9	0.8
9	8/2010	1.1	1.0	0.9
10	1/2011	2.2	1.8	1.4
11	1/2012	1.2	1.1	0.9
12	3/2012	1.8	1.5	1.3
13	1/2013	1.3	1.1	1.0

Table 9: effects of each UI shock with alternative real wage rigidity ι

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 computed over horizon of UI shock.

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. [2016], Hagedorn et al. [2019], 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 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,⁵² while Chodorow-Reich et al. [2019] find that a three-month extension of UI reduces the unemployment rate between -0.06pp and 0.09pp.⁵³ The positive ranges 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

⁵²In 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 be justified by my results in Figure 4 that the stimulus from UI is stable across magnitudes of the extension.

⁵³In 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.

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. The unemployment rate would have been as much as 0.4pp higher were it not for the benefit extensions.

There are two natural directions to build on the analysis of this paper. One direction is to study the positive effects 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, giving these programs an aggregate demand stabilization role in recessions. Another direction is to explore the normative implications of my findings: the effects of UI and other social insurance programs on aggregate demand will naturally affect their optimal generosity over the business cycle, particularly if monetary policy is constrained. I leave the analysis of these exciting questions to future research.

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