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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. The unemployment rate would have been as much as 0.4pp higher absent these extensions.

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

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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 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 becomes 0.6 as the nominal and thus real rate rises in response, but not as much as under flexible prices. If monetary policy maintains a fixed nominal interest rate during the period of benefit extensions and follows a Taylor rule thereafter, the output multiplier nearly doubles to 1.1.

Quantitatively, MPC heterogeneity and diminished precautionary saving drive the stimulus from UI when monetary policy is constrained. 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. The goal is not to provide a complete account of the Great Recession, but instead to quantify the effects of UI extensions in a large downturn of this kind. With that said, untargeted macroeconomic time series validate the fit of the model despite the parsimony of focusing on a single driving force. In the simulation, as in the data, the nominal interest rate is at a binding zero lower bound during almost all of 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. I explore the mechanisms underlying this result 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 0.6-1.8, 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, UI extensions would have triggered a monetary policy tightening and the magnitude of transfers themselves would have been smaller (as the recession would have been less severe). 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

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).

terms of employment because, despite a sizeable output multiplier, transfers to the long-term unemployed are small versus output. The model can further explain differences in the precise estimates of researchers as arising from differences in the horizon of UI shocks studied, since these imply differential stimulus through precautionary saving.

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

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

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 $q(\theta_0) = \frac{p(\theta_0)}{\theta_0}$.

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

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

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.

close to one) ensures that workers' surplus from employment remains positive even as hiring 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 $b_t(\zeta_t^u)$.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

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

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 control the elasticities 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

$$i_t = \max \{r + \phi^\Pi \Pi_t^P + \phi^y (y_t/y - 1), 0\}, \quad (29)$$

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 the range reported in 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

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 $\rho^P = (\rho_a^P)^{1/12}$, $(\sigma^P)^2 = (1 - (\rho^P)^2) \frac{(\sigma_a^P)^2}{1 - (\rho_a^P)^2}$, $\sigma^T = \sigma_a^T$.

Moment	Target	Achieved	Parameter	Value
<i>Real rate, wealth, and average MPC</i>				
Real interest rate (ann.)	2%	2.0%	z^g/\bar{a}	-8.3
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
Max UI / mean wage UI recipients	0.6	0.60	$\frac{\zeta}{\bar{w}}$	0.4
Mean HH income w. UI / pre job loss	0.76	0.75	ω_1	0.37
Mean HH income w.o UI / pre job loss	0.55	0.56	ω_2	0.50
<i>Incidence of unemployment</i>				
Unemployment rate	5%	5.0%	ϕ	0.957
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	0.09	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 years immediately preceding the 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 calibrate the remaining parameters to match salient patterns in wealth, income, and unemployment in U.S. data prior to the Great Recession.²³ 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

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.

²³The computational algorithm used to solve the stationary RCE is discussed in appendix F.

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.²⁴ 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} .²⁵ To clear 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 . To match the 60% ratio between the maximum statutory level of UI and the average wage (weighted across states),²⁶ I use the maximum level of benefits \overline{ui} . 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 by Schmieder and von Wachter [2016].²⁷ 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

²⁴I 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.

²⁵The 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, and then compute MPCs by simulating agents over three months including and after receipt.

²⁶In 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.

²⁷As 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.

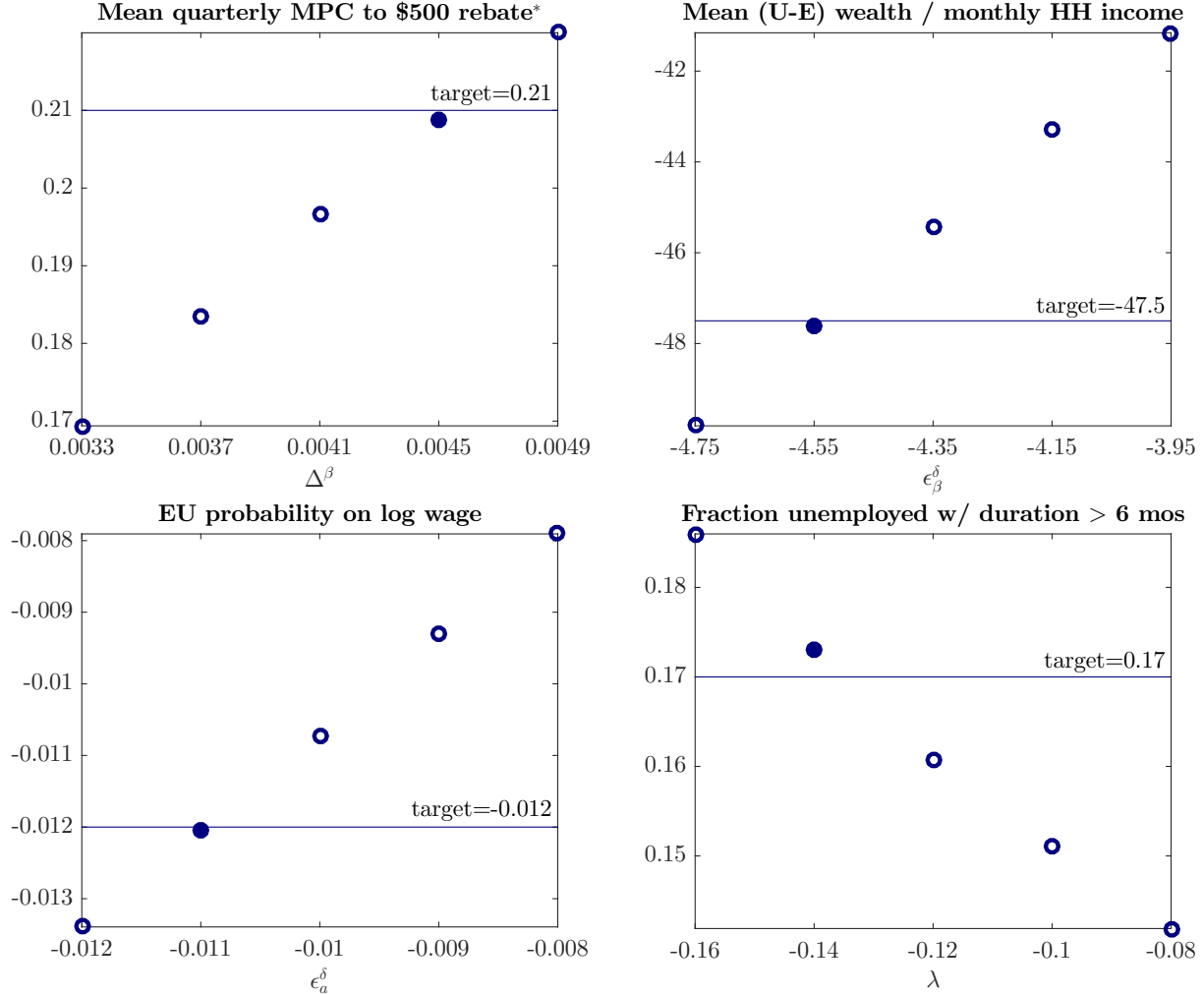


Figure 1: identification of selected parameters in stationary RCE

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).

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.²⁸ Notably, this is consistent with evidence from the SIPP in appendix C that EU probabilities are negatively related to wealth even conditional on income.²⁹ 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 versus employed households.³⁰ 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 only a bit larger than the empirical counterparts.

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

²⁸While 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.

²⁹I 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.

³⁰While 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]	0.27
<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]	26.6%
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.

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.

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.

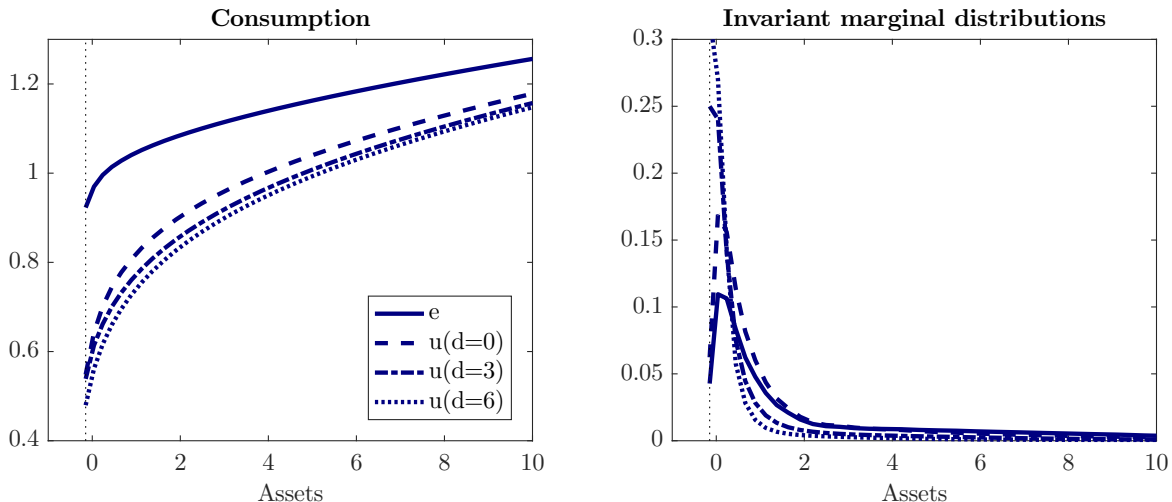


Figure 2: consumption policy functions and marginal wealth distributions in stationary RCE

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.

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.³¹

³¹The 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 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.

Group	Mean quarterly MPC
Overall	0.17
<i>By wealth</i>	
Quintile 5 (highest)	0.01
Quintile 4	0.05
Quintile 3	0.17
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 ($d \geq 6$)	0.59

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

	Flex prices	Sticky prices	Sticky prices + fixed r	Sticky prices + fixed i
Output multiplier	-0.5	0.6	1.1	1.1
Avg change in unemp. rate	+0.02pp	-0.01pp	-0.02pp	-0.02pp

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.³²

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

³²The 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.

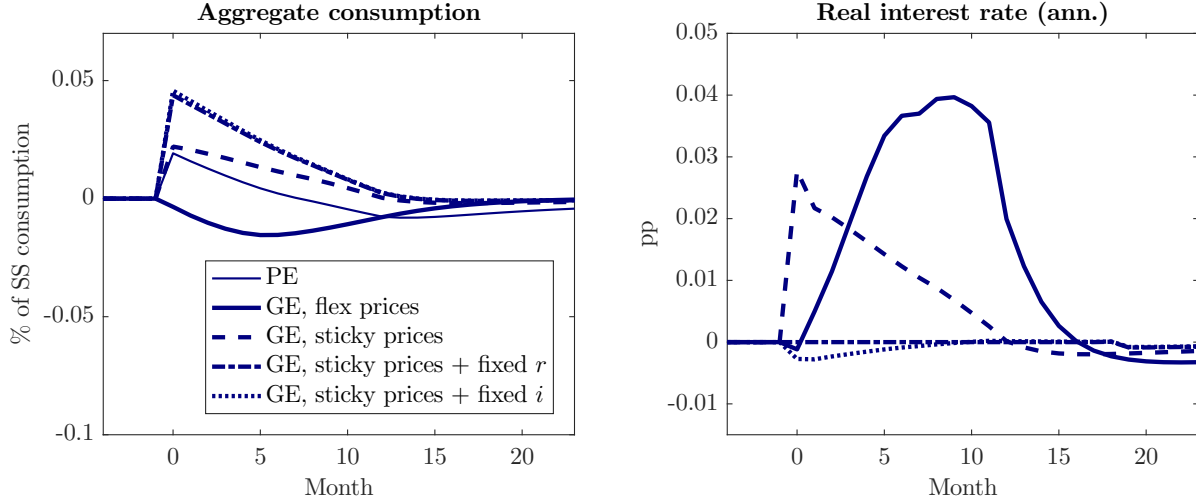


Figure 3: effects of UI starting from steady-state

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.³³ 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 rise — but not as much as above — in response to UI extensions. I set the adjustment cost on prices to $\psi = 360$, 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 $\frac{\epsilon-1}{\psi} = 0.014$. This is equivalent to the log-linear Phillips curve in a model of Calvo pricing with expected price duration 9 months, consistent with the range of estimates surveyed in Nakamura and Steinsson [2013]. I set the coefficients in (29) to $\phi^\Pi = 1.5$ and $\phi^y = 1/12$, 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

³³Appendix 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	0.35
Quarterly MPC, LT unemployed	0.59	0.43
Output multiplier	1.1	0.8
Avg change in unemp. rate	-0.02pp	-0.03pp

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.

real interest rates do not rise by as much as in the flexible price case, the resulting output multiplier becomes positive at 0.6.

Eliminating the rise in the real interest rate, the expansionary effects of UI extensions nearly double. 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, and 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 0.02pp. 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

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 output multiplier from a three-month extension of UI is diminished.³⁴ These results

³⁴The effect on the unemployment rate is slightly amplified, however. This is because the average productivity of the employed is lower than in the baseline, so a larger change in employment is needed to achieve

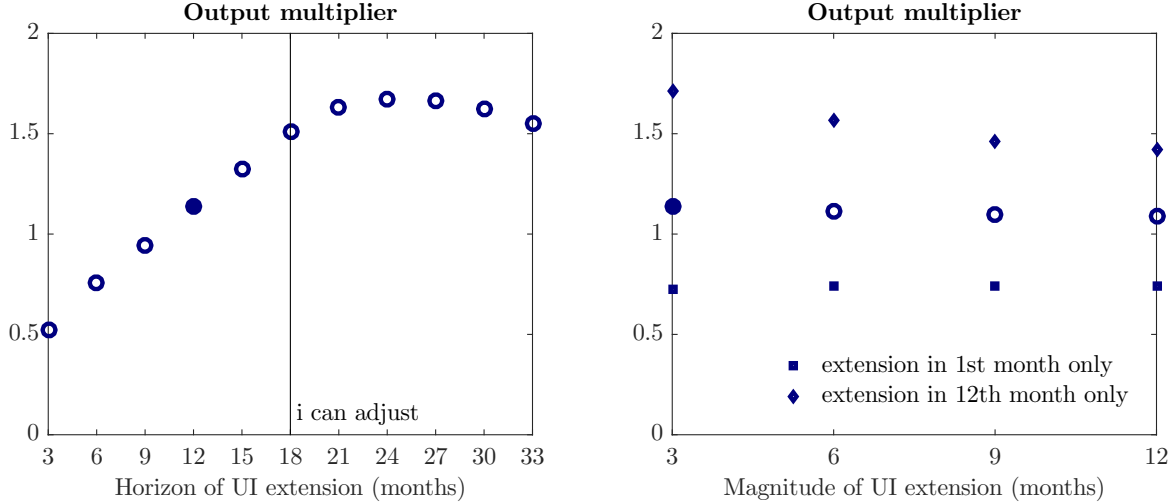


Figure 4: sensitivity to horizon and magnitude given sticky prices and fixed i

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.

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 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 33 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 eventually renders them less expansionary.

Varying the number of months of unemployment by which UI is extended illustrates

a particular change in output.

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.

	Baseline	Lower real wage rigidity	Higher disincentive elasticity
Flexible prices			
Avg change in real rate (ann.)	+0.03pp	+0.04pp	+0.01pp
Output multiplier	-0.5	-5.2	-1.8
Avg change in unemp. rate	+0.02pp	+0.13pp	+0.07pp
Sticky prices			
Avg change in real rate (ann.)	+0.01pp	+0.02pp	+0.02pp
Output multiplier	0.6	0.6	0.6
Avg change in unemp. rate	-0.01pp	-0.01pp	+0.00pp
Sticky prices + fixed i			
Avg change in real rate (ann.)	-0.00pp	-0.01pp	-0.00pp
Output multiplier	1.1	2.2	1.3
Avg change in unemp. rate	-0.02pp	-0.05pp	-0.02pp

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.

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 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

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.

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 and thus real interest rate, though it remains dampened versus flexible prices. 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 0.6-1.4 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.

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

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. The goal is not to provide a complete account of the Great Recession, but instead to quantify the effects of UI extensions in a large downturn of this kind. I calibrate a sequence of shocks to agents' discount factors to replicate the path of unemployment over 2008-2014 given the observed extensions to UI. I compare the observed path of unemployment to counterfactual economies without the observed extensions or without a zero lower bound. I find that the unemployment rate would have been as much as 0.4pp higher were it not for the benefit extensions, and the binding zero lower bound is essential for this result. The model-implied stimulus is consistent with the upper end of estimates of stimulus in the empirical 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.

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.

	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.

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

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.

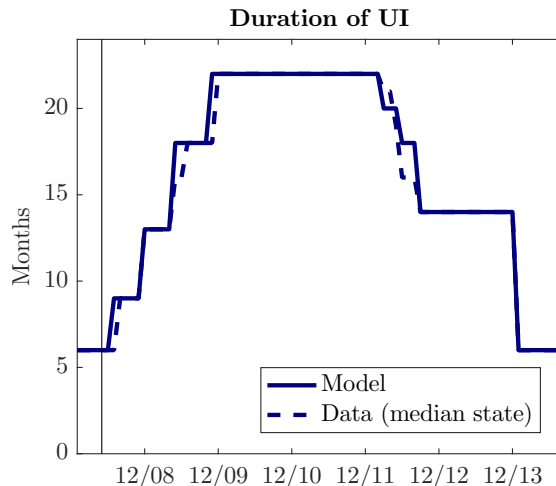


Figure 5: realized UI duration in model versus data

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.

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 $\psi = 360$ (implying a Calvo-equivalent frequency of price adjustment of 9 months). Monetary policy follows the standard Taylor rule subject to zero lower bound in (29) with $\phi^\Pi = 1.5$ and $\phi^y = 1/12$.

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. In particular, these “supply” shocks generate a rise in unemployment together with an increase in inflation. Later in this section, I thus consider

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.

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.

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 squared differences between the final 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 $\iota = 0.94$, 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 demon-

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

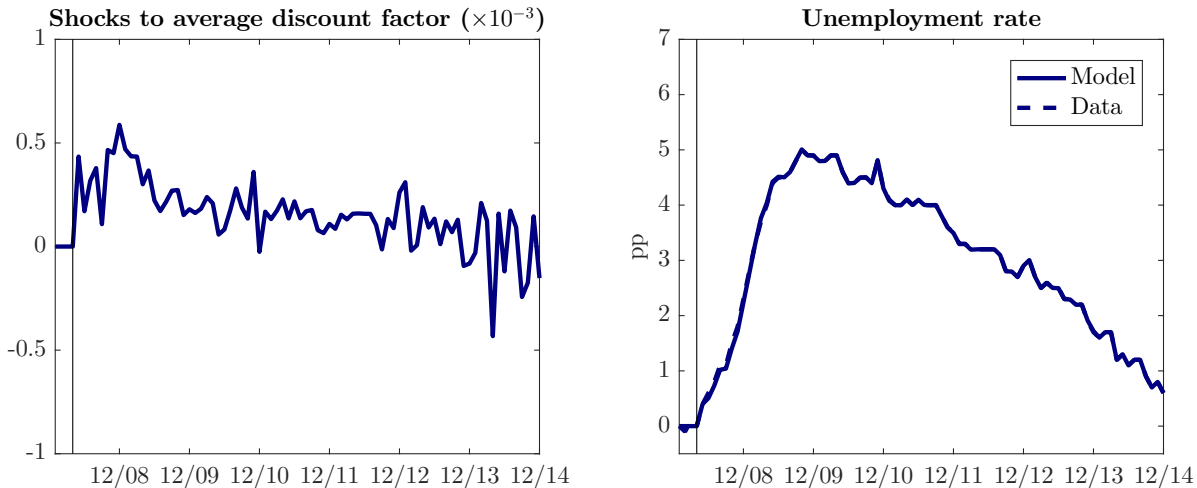


Figure 6: discount factor shocks and unemployment

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).

states that the model generates a binding zero lower bound from late 2008 (as in the data) through late 2013 (earlier than “lift-off” 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 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.⁴⁸ 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.⁴⁹

Figure 8 plots an important endogenous outcome in the simulation: the horizon over

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.

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

⁴⁸Interestingly, nominal wages rise in the first few months of the simulation, as in the data. In the model, this occurs because of selection: the decline in job-finding rates disproportionately affects low-productivity workers who are overrepresented among the unemployed.

⁴⁹In this way, the model rationalizes the “missing disinflation” during this period (see, e.g., Harding et al. [2021] and citations therein).

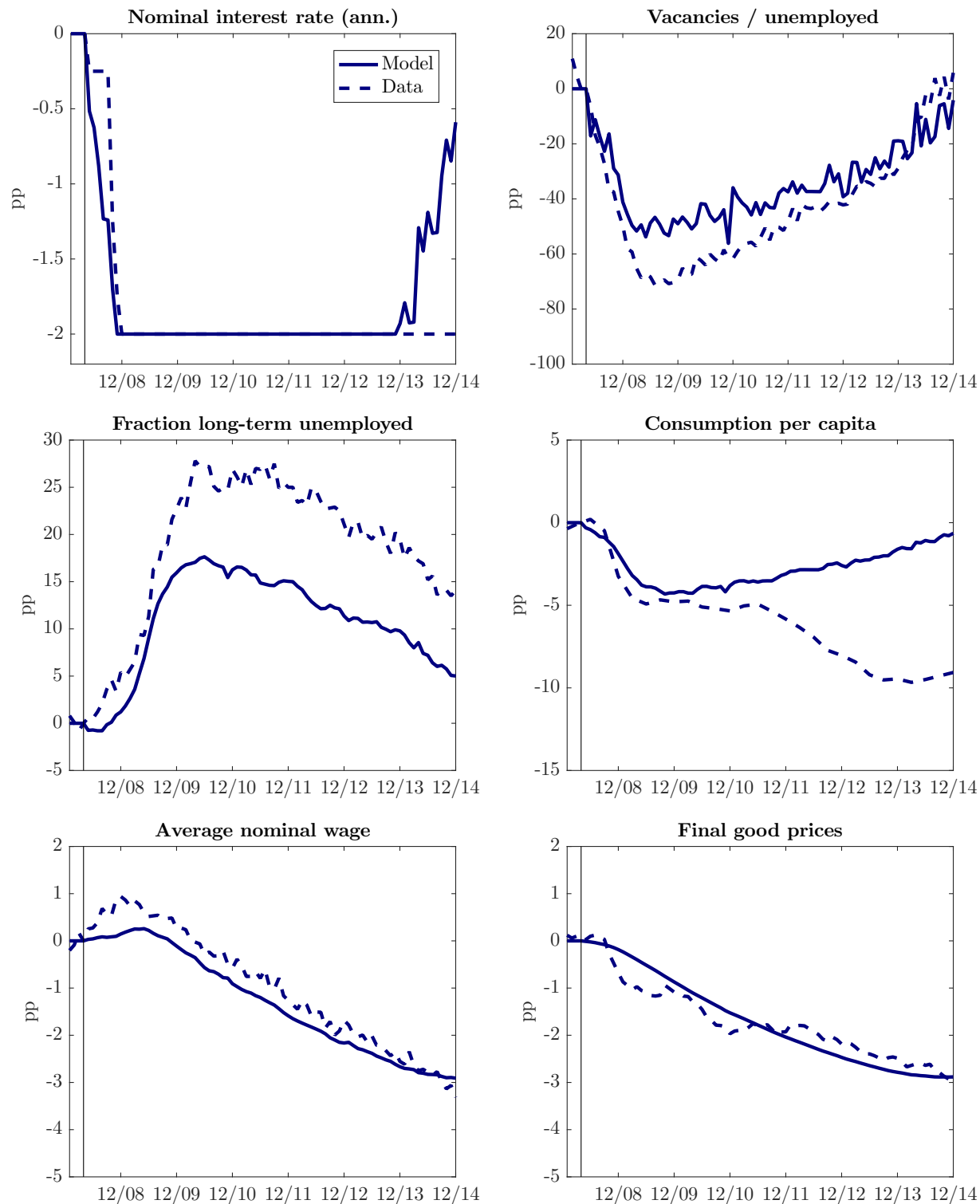


Figure 7: untargeted macro time-series

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).

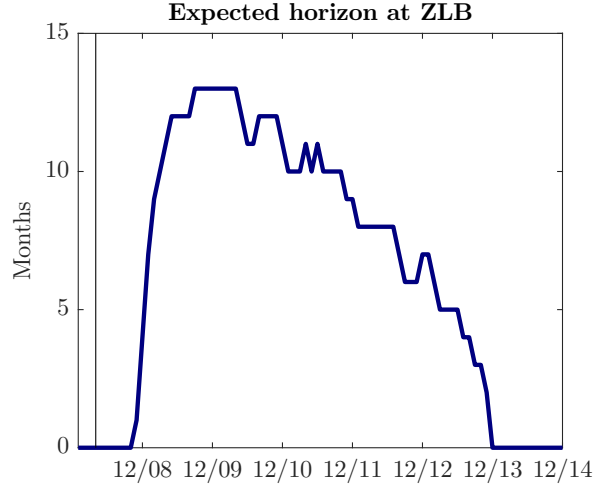


Figure 8: expected horizon at the zero lower bound

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

which agents expect the zero lower bound to bind, which evolves as agents (rationally) forecast the economy’s response to shocks. Through August 2011, the model-implied expectations of roughly one year at the zero lower bound are quite consistent with actual expectations. For instance, as summarized by Swanson and Williams [2014], the Blue Chip survey of forecasters implied an expected number of quarters at the zero lower bound between 2-5 quarters from January 2009 through August 2011. Yield curve data, interpreted for instance through the lens of a shadow rate term structure model as in Bauer and Rudebusch [2016], similarly imply that the zero lower bound was expected to bind for around one year over this same period. In August 2011, the Federal Reserve began forward guidance,⁵⁰ dramatically increasing the market’s expectation of the horizon of zero nominal interest rates. The absence of forward guidance in the model means that it undershoots the expected horizon at the zero lower bound from this point onwards, and indeed the model economy ultimately “lifts off” from the zero lower bound at the end of 2013, whereas in practice this only happened in mid-2015. I do not enrich the model to feature forward guidance for two reasons. First, as described in Table 7, 10 of the 13 extensions to UI in my model all occur before August 2011, so that accounting for forward guidance would have a relatively small effect on my results. Second, accounting for forward guidance would only increase the model-implied stimulus from UI in the remaining 3 extensions, rendering my results conservative.

⁵⁰The Federal Open Market Committee announced that “economic conditions...are likely to warrant exceptionally low levels for the federal funds rate at least through mid-2013.”

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 virtually the entire period of UI extensions.

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 by 2011. With more slack in the counterfactual economy, there is more disinflation.

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 1. There is nonetheless obvious heterogeneity across shocks which underscores the key mechanisms underlying these extensions.

For instance, a comparison of shock 1 and 4 demonstrates the key role of the binding zero lower bound. Both shocks extend UI over a roughly one year horizon, but at the time of shock 1 the zero lower bound is not expected to bind, whereas at the time of shock 4 it is expected to bind over almost the entire period of extended UI. For that reason, shock 4 generates more stimulus.

A comparison of shock 3 and 9 demonstrates the key role of dynamic amplification via reduced precautionary savings and a higher job-finding rate. Both shocks push out the horizon of extended benefits by 6 months, but shock 3 does so 8 months in the future whereas shock 9 does so only 2 months in the future. Consistent with Figure 4, the output multiplier for shock 3 is larger than for 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 in January 2013, agents rationally expected that benefits would expire in December 2013. In the appendix, I consider an alternative scenario in which agents expected benefits to last through 2014, but then they unexpectedly expire in December 2013. The analysis clarifies

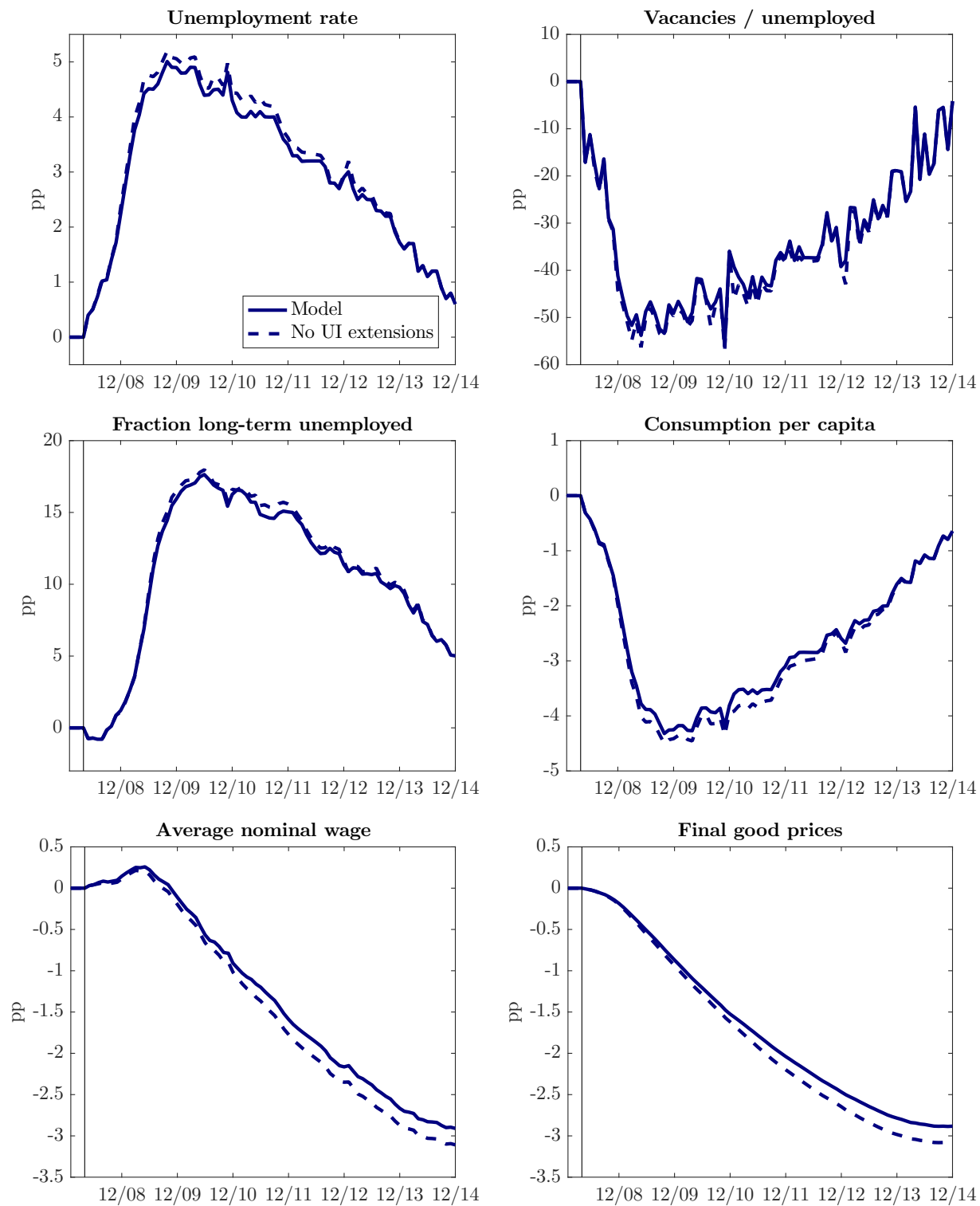


Figure 9: effects of UI shocks

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

	Date	Output multiplier	Avg change in unemployment rate
1	7/2008	0.6	-0.01pp
2	12/2008	0.8	-0.03pp
3	3/2009	1.8	-0.04pp
4	5/2009	1.2	-0.02pp
5	11/2009	0.8	-0.01pp
6	1/2010	1.0	-0.04pp
7	3/2010	0.9	-0.02pp
8	4/2010	1.0	-0.04pp
9	8/2010	1.1	-0.09pp
10	1/2011	1.5	-0.10pp
11	1/2012	1.0	-0.04pp
12	3/2012	1.2	-0.03pp
13	1/2013	1.0	-0.07pp

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.

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.

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 smaller 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

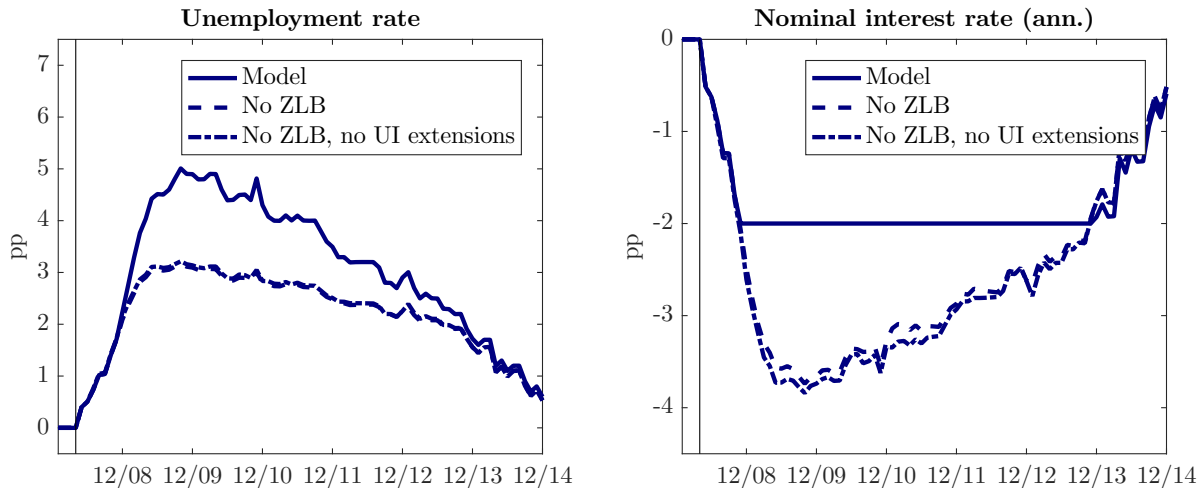


Figure 10: effects of zero lower bound

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

helps to undo 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 close to 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 smaller effects 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 ($\iota = 0.88$). 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

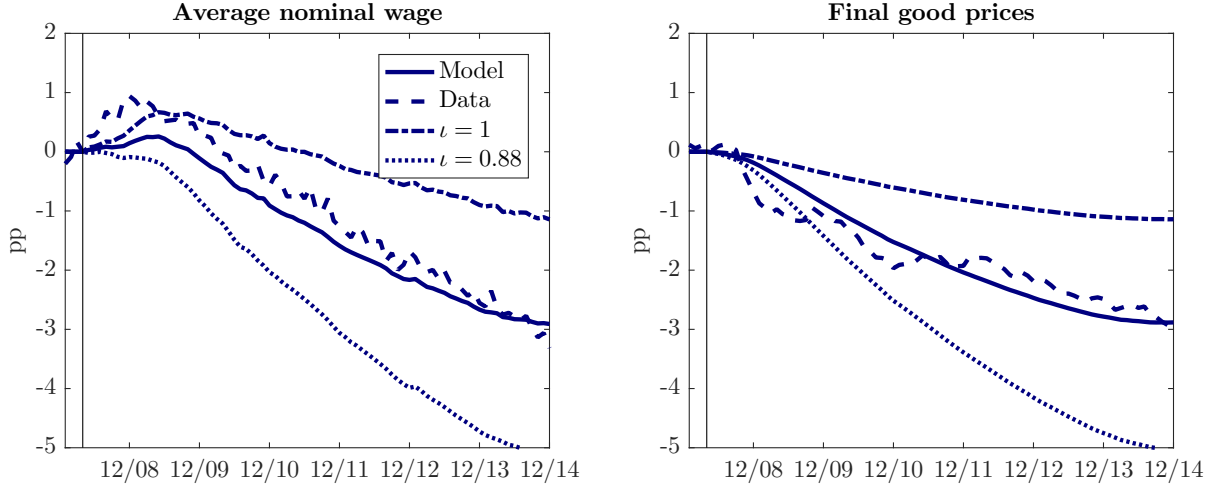


Figure 11: wages and prices with alternative real wage rigidity ι

Note: series displayed in deviations from steady-state (for model) and April 2008 (in data). 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.

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 $\iota = 0.94$. 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,⁵¹ as well as micro evidence on the responsiveness of real wages to changes in UI.⁵² I also continue to estimate a high degree of real wage rigidity when I account

⁵¹Shimer [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).

⁵²While 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

Output multiplier				
	Date	$\iota = 0.88$	Model	$\iota = 1$
1	7/2008	0.6	0.6	0.6
2	12/2008	1.4	0.8	0.6
3	3/2009	2.9	1.8	1.0
4	5/2009	1.7	1.2	0.8
5	11/2009	1.0	0.8	0.8
6	1/2010	1.2	1.0	0.8
7	3/2010	1.0	0.9	0.7
8	4/2010	1.2	1.0	0.8
9	8/2010	1.3	1.1	0.9
10	1/2011	2.3	1.5	0.9
11	1/2012	1.4	1.0	0.8
12	3/2012	1.9	1.2	0.8
13	1/2013	1.4	1.0	0.8

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.

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. Even in this case, I continue to estimate $\iota = 0.94$.

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,⁵³ while Chodorow-Reich et al.

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.

⁵³In Table 2, these authors find that a 73-week extension of benefits increases employment-to-population

[2019] find that a three-month extension of UI reduces the unemployment rate between -0.06pp and 0.09pp.⁵⁴ The positive ranges of these confidence intervals are consistent with my baseline results. One reason that my estimates may be at the positive end of these ranges is that the empirical literature has focused on cross-state identification which may understate the increase in consumption on tradeables.

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

7 Conclusion

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

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.

⁵⁴In 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.

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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Appendix For Online Publication

A Supplementary analytical material

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

A.1 Environment and equilibrium

I first formally set up the simple environment and equilibrium studied in section 2.

Timing In period 0, firms post vacancies, all workers search, and matches occur randomly; production takes place and agents face a standard consumption-savings problem; and then all employed workers separate. In period 1, all workers receive an identical endowment.

Workers All workers start period 0 initially unemployed and search for a job. The representative worker faces

$$\max_{s_0} (p(\theta_0)s_0)v_0^e + (1 - p(\theta_0)s_0)v_0^u - \psi(s_0), \quad (\text{A.1})$$

where s_0 is the worker's choice of search effort, $p(\theta_0)$ is the job-finding probability per unit search, and v_0^e and v_0^u are the value functions of employed and unemployed workers in the middle of the period.

Workers in the middle of the period face a standard consumption-savings problem

$$\begin{aligned} v_0^h &= \max_{c_0^h, z_1^h, c_1^h} u(c_0^h) + \beta u(c_1^h) \text{ s.t.} \\ P_0 c_0^h + (1 + i_0)^{-1} P_1 z_1^h &\leq Y_0^h, \\ P_1 c_1^h &\leq P_1 y_1 + P_1 z_1^h, \\ z_1^h &\geq \underline{z}, \end{aligned} \quad (\text{A.2})$$

where $h \in \{e, u\}$ indexes whether the worker is employed or unemployed, c_t^h is its consumption of a final good in period t , P_t is the final good price at t , z_1^h is the real value of its

savings in a risk-free bond which pays nominal rate i_0 , \underline{z} is a borrowing constraint, Y_0^h is its nominal income in period 0, and y_1 is its endowment of the final good in period 1.

Producers A representative producer hires workers in period 0 to produce a homogenous intermediate good sold at price P_0^I . When it posts ν_0 vacancies, only a fraction $q(\theta_0)$ of these vacancies lead to a match. Managing each vacancy requires that k workers spend time in recruiting rather than production.¹ Thus, the producer faces

$$\Pi_0^I = \max_{\nu_0} P_0^I (q(\theta_0)\nu_0 - k) - W_0 q(\theta_0)\nu_0 \quad (\text{A.3})$$

where W_0 is the nominal wage and we have normalized productivity to one.

Retailers A measure one of retailers purchase the intermediate good in period 0 and sell a differentiated variety to consumers subject to Rotemberg [1982] price adjustment costs. Retailer j faces

$$\begin{aligned} \Pi_{0j}^R = \max_{P_{0j}, y_{0j}, x_{0j}} & P_{0j} y_{0j} - (1 + \tau^R) P_0^I x_{0j} - \frac{\psi}{2} \left(\frac{P_{0j}}{P_{-1j}} - 1 \right)^2 \left(\int_0^1 P_{0k} y_{0k} dk \right) - T_0^R, \\ & y_{0j} = x_{0j}, \\ & y_{0j} = \left(\frac{P_{0j}}{P_0} \right)^{-\varepsilon} c_0, \end{aligned} \quad (\text{A.4})$$

where y_{0j} is its production using x_{0j} units of the intermediate good and a linear technology; $c_0 \equiv p(\theta_0)s_0c_0^e + (1 - p(\theta_0)s_0)c_0^u$ is aggregate consumption of the final good; ε is consumers' elasticity of substitution across varieties, and τ^R is an ad-valorem tax on inputs, rebated back to retailers via the lump-sum instrument T_0^R simply for consistency with the quantitative model. 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 .

Policy The government specifies a real value of UI in period 0 b_0 . It balances its budget that period using a tax on the employed T_0 . We consider various monetary policy rules for the nominal interest rate i_0 and long run price level P_1 as described in the main text.

¹This of course makes more sense with incumbent workers as in the quantitative model.

Wages and income In period 0, employed workers Nash bargain with producers given a bargaining share ϕ . The bargained wage thus solves

$$\frac{1}{u'(c_0^e)}(v_0^e - v_0^u) = \frac{\phi}{1 - \phi} \left(\frac{P_0^I}{P_0} - \frac{W_0}{P_0} \right). \quad (\text{A.5})$$

For simplicity we assume that employed workers also receive the profits earned by the economy's firms; I emphasize that in the quantitative model, this assumption is not made. Thus, given the bargained wage, this profit allocation rule, and the above policy instruments, agents' incomes in period 0 are

$$Y_0^e = W_0 + \frac{1}{p(\theta_0)s_0} (\Pi_0^I + \Pi_0^R) - T_0, \quad (\text{A.6})$$

$$Y_0^u = P_0 b_0. \quad (\text{A.7})$$

Market clearing In the labor market, labor market tightness is given by

$$\theta_0 = \frac{\nu_0}{s_0} \quad (\text{A.8})$$

and the job-finding and vacancy-filling probabilities by

$$p(\theta_0) = \bar{m}\theta_0^\eta, \quad q(\theta_0) = \frac{p(\theta_0)}{\theta_0}. \quad (\text{A.9})$$

Goods market clearing at each date requires

$$p(\theta_0)s_0c_0^e + (1 - p(\theta_0)s_0)c_0^u = q(\theta_0)\nu_0 - k\nu_0, \quad (\text{A.10})$$

$$p(\theta_0)s_0c_1^e + (1 - p(\theta_0)s_0)c_1^u = y_1. \quad (\text{A.11})$$

Finally, budget balance for the government is characterized by

$$p(\theta_0)s_0T_0 = P_0(1 - p(\theta_0)s_0)b_0. \quad (\text{A.12})$$

By Walras' Law, the bond market clears.

Equilibrium Conditional on UI policy b_0 and monetary policy $\{i_0, P_1\}$ and initial prices $\{P_{-1}\}$, the definition of equilibrium is standard.

The optimality and market clearing conditions reduce to the simple system (1)-(4) studied in the main text. Workers' solution to (A.1) and (A.2) imply the policy and value functions $s_0(\theta_0, y_0^e, b_0, r_0)$, $v_0^e(y_0^e, r_0)$, $c_0^e(y_0^e, r_0)$, $v_0^u(y_0^u, r_0)$, and $c_0^u(y_0^u, r_0)$, where $y_0^e \equiv \frac{Y_0^e}{P_0}$, $y_0^u \equiv \frac{Y_0^u}{P_0} = b_0$,

and $1 + r_0 \equiv (1 + i_0) \frac{P_0}{P_1}$. Goods market clearing (A.10) is identical to (1) once we make use of the definition of tightness (A.8) and (A.9). The resource constraint (2) is implied by the definition of incomes (A.6) and (A.7), the definitions of profits in (A.3) and (A.4), and government budget balance (A.12). The optimal vacancy posting condition (3) directly follows from (A.3), while the Nash bargaining condition (4) is identical to (A.5) where we define the gross mark-up $\mu_0 \equiv \frac{P_0}{P_0^T}$ and real wage $w_0 \equiv \frac{W_0}{P_0}$.

A.2 Precautionary saving and dynamic amplification

I now extend the analysis in section 2 by characterizing the effects of *future* changes in UI on output.

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

Following McKay and Reis [2021], Ravn and Sterk [2017], and Werning [2015], this economy remains analytically tractable by assuming that agents cannot borrow ($\underline{z} = 0$). Only employed agents will thus be “on” their Euler equation and price the bond:

$$u'(c_t^e) = \beta(1 + r_t) [p(\theta_{t+1})s_{t+1}u'(c_{t+1}^e) + (1 - p(\theta_{t+1})s_{t+1})u'(b_{t+1})].$$

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

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

$$\hat{y}_t = (1 - p(\theta)s)\hat{b}_t - \frac{p(\theta)sc^e}{b} \frac{1}{\sigma} \hat{r}_t + \gamma_{+1} \left[\left(1 + \frac{p(\theta)s}{b} \gamma_y \right) \hat{y}_{t+1} + \gamma_b(1 - p(\theta)s)\hat{b}_{t+1} \right], \quad (\text{A.13})$$

where $\hat{\cdot}$ denotes the log differential in a variable and

$$\gamma_{+1} \equiv \frac{p(\theta)su'(c^e)}{p(\theta)su'(c^e) + (1 - p(\theta)s)u'(b)} < 1,$$

$$\gamma_y \equiv \frac{u'(b) - u'(c^e)}{-u''(c^e)} \approx (c^e - b) \left[1 + \frac{1}{2}(\sigma + 1) \left(1 - \frac{b}{c^e} \right) \right] > 0,$$

$$\gamma_b \equiv \frac{u''(b)}{u''(c^e)} - 1 \approx (\sigma + 1) \left(1 - \frac{b}{c^e} \right) > 0,$$

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

The first term on the right-hand side of (A.13) reflects the contemporaneous stimulus from UI on aggregate demand. Because the unemployed are endogenously hand-to-mouth, an increase in UI necessarily raises current output holding fixed interest rates and future income. This result is consistent with Lemma 1; the MPC of employed agents does not enter here (as it did there) because of our assumption of a zero borrowing constraint. In this knife-edge case, a higher MPC of employed agents lowers the initial stimulus to aggregate demand but amplifies the Keynesian cross in exactly offsetting ways.

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

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

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

Proposition A.1. *Suppose k is small, ϕ is close to one, and consider the limit of a zero borrowing constraint. Then:*

- *If prices are fully flexible (and b is close to optimal), $\frac{dy_s}{db_t} = 0$ for all $s < t$ and $\frac{dy_t}{db_t} < 0$.*
- *If prices are sticky but monetary policy replicates the path of real interest rates absent nominal rigidity, $\frac{dy_s}{db_t}$ is identical to that under flexible prices for all s .*
- *If prices are sticky and monetary policy maintains a constant r_s through period t and replicates the path of real interest rates absent nominal rigidity thereafter, then $\frac{dy_s}{db_t} > 0$ for all $s \leq t$. Moreover, $\frac{dy_s}{db_t}$ is rising with t if $\frac{b}{c^e}$ is sufficiently small.*

In all cases, $\frac{dy_s}{db_t} = 0$ for $s > t$.

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

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

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

A.3 Trade in equities and investment

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

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

agents' optimal consumption-savings decision via the Euler equation

$$u'(c_t^e) = \beta(1 + r_t) [p(\theta_{t+1})s_{t+1}u'(c_{t+1}^e) + (1 - p(\theta_{t+1})s_{t+1})u'(c_{t+1}^u)].$$

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

$$c_{t+1}^u = b_{t+1} + \pi_{t+1},$$

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

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

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

$$\mu_t^{-1} \left(1 - \frac{k}{q(\theta_t)} \right) + (1 - \delta)(1 + r_t)^{-1} \mu_{t+1}^{-1} \frac{k}{q(\theta_{t+1})} = w_t, \quad (\text{A.14})$$

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

A.4 Constant i versus r

The stimulative effects of UI characterized so far focus on sticky price environments in which monetary policy maintains a constant real interest rate. Of more practical relevance is the case with a constant *nominal* interest rate, as when monetary policy is constrained by the zero lower bound. When monetary policy maintains a constant nominal rate, the effect of a

change in UI on inflation will affect the real rate and thus aggregate demand.

Returning to the dynamic environment described in section A.2, we can sharply sign the resulting effects. Inflation depends on retailers' real marginal cost μ_t^{-1} . To characterize the dynamics of real marginal cost, it will be useful to accommodate a more general specification of wages consistent with the quantitative model: suppose real wages are given by the weighted average of the Nash bargained wage and steady-state wage with weights $1 - \iota$ and ι , respectively. Then we obtain the following intermediate result:

Lemma A.2. *As $k \rightarrow 0$ while $\frac{k}{1-\phi}$ remains fixed,*

$$-\frac{\iota - \frac{k}{q(\theta)}}{\frac{k}{q(\theta)}} \hat{\mu}_t \rightarrow \chi_y \hat{y}_t + \chi_b \hat{b}_t,$$

where χ_b is positive and χ_y is positive if the steady-state level of UI is close to optimal.

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

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

$$\frac{1-\phi}{\phi} \frac{1}{u'(c_t^e)} (u(c_t^e) - u(b_t)) = \mu_t^{-1} \frac{k}{q(\theta_t)}.$$

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

$$\mu_t^{-1} \left(\iota - \frac{k}{q(\theta_t)} \right) = \iota w - (1 - \iota) \frac{1-\phi}{\phi} \frac{1}{u'(c_t^e)} (u(c_t^e) - u(b_t)),$$

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

I conjecture that in an alternative model in which retailers directly hire workers, there would be no need to have any real wage rigidity to obtain this result. I maintain the

distinction between retailers and intermediate good firms to be consistent with most of the literature on search frictions in the New Keynesian environment, and because the required degree of real wage rigidity to obtain this result is small.

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

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

- *If prices are sticky and monetary policy maintains a constant nominal interest rate through period t , then*
 - *$\frac{dy_t}{db_t}$ is equal to its value if monetary policy maintained a constant real interest rate through period t ;*
 - *for any $s < t$, $\frac{dy_s}{db_t}$ exceeds its value if monetary policy maintained a constant real interest rate through period t ,*

assuming in all cases that policy implements zero inflation and the path of real interest rates absent nominal rigidity after period t .

- *The increase in $\frac{dy_s}{db_t}$ for any $s < t$ rises as ι falls (while maintaining $\iota > \frac{k}{q(\theta)}$).*

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

A.5 Proofs of analytical results

A.5.1 Lemma 1

Proof. In the stated limit, $k\theta_0s_0 \rightarrow 0$ and thus output y_0 , employment $p(\theta_0)s_0$, and the income of the employed y_0^e are defined by

$$\begin{aligned} p(\theta_0)s_0c_0^e(y_0^e, r_0) + (1 - p(\theta_0)s_0)c_0^u(b_0, r_0) &= y_0, \\ p(\theta_0)s_0y_0^e + (1 - p(\theta_0)s_0)b_0 &= y_0, \\ y_0 &= p(\theta_0)s_0, \end{aligned}$$

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

A.5.2 Proposition 1

Proof. With flexible prices and thus a constant mark-up μ , in the stated limit $\{y_0, y_0^e, \theta_0\}$ are defined by

$$\begin{aligned} p(\theta_0)s_0(\theta_0, y_0^e, b_0)y_0^e + (1 - p(\theta_0)s_0(\theta_0, y_0^e, b_0))b_0 &= y_0, \\ y_0 &= p(\theta_0)s_0(\theta_0, y_0^e, b_0), \\ \frac{1}{u'(y_0^e)}(u(y_0^e) - u(b_0)) &= \mu^{-1} \frac{\kappa}{q(\theta_0)}, \end{aligned}$$

where $\kappa \equiv \frac{k}{1-\phi}$, equilibrium search is defined by

$$s_0(\theta_0, y_0^e, b_0) := p(\theta_0)(u(y_0^e) - u(b_0)) = \psi'(s_0)$$

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

$$\frac{dy_0}{db_0} \frac{b_0}{y_0} = \frac{-\sigma \frac{1}{y_0^e} \frac{1-p(\theta_0)s_0}{p(\theta_0)s_0} b_0 - \left(\frac{1-\eta}{\eta} \frac{1}{1+\xi} + 1 \right) \left(\frac{u'(y_0^e)}{u(y_0^e)-u(b_0)} \frac{1-p(\theta_0)s_0}{p(\theta_0)s_0} b_0 + \frac{u'(b_0)}{u(y_0^e)-u(b_0)} b_0 \right)}{\frac{1-\eta}{\eta} \frac{1}{1+\xi} - \sigma \frac{1}{y_0^e} \frac{1}{p(\theta_0)s_0} b_0 - \left(\frac{1-\eta}{\eta} \frac{1}{1+\xi} + 1 \right) \frac{u'(y_0^e)}{u(y_0^e)-u(b_0)} \frac{1}{p(\theta_0)s_0} b_0},$$

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

The optimal level of UI solves

$$\begin{aligned} \max_{\theta_0, y_0^e, b_0} p(\theta_0)s_0(\theta_0, y_0^e, b_0)u(y_0^e) + (1 - p(\theta_0)s_0(\theta_0, y_0^e, b_0))u(b_0) - \psi(s_0(\theta_0, y_0^e, b_0)) \\ p(\theta_0)s_0(\theta_0, y_0^e, b_0)y_0^e + (1 - p(\theta_0)s_0(\theta_0, y_0^e, b_0))b_0 &= p(\theta_0)s_0(\theta_0, y_0^e, b_0), \\ \frac{1}{u'(y_0^e)}(u(y_0^e) - u(b_0)) &= \mu^{-1} \frac{\kappa}{q(\theta_0)}. \end{aligned}$$

The constraints imply θ_0 and y_0^e as functions of b_0 . The first order condition then implies

$$\begin{aligned} \frac{dp(\theta_0)s_0}{db_0} \frac{b_0}{p(\theta_0)s_0} &= \frac{-p(\theta_0)s_0 \frac{1}{1+\xi} \left(u'(y_0^e) \frac{1-p(\theta_0)s_0}{p(\theta_0)s_0} b_0 + u'(b_0)b_0 \right) - (1 - p(\theta_0)s_0)(u'(b_0) - u'(y_0^e))b_0}{p(\theta_0)s_0(u(y_0^e) - u(b_0)) \frac{1}{1+\xi} + \frac{\xi}{1+\xi} u'(c_0^e)b_0}, \\ &< 0. \end{aligned}$$

It then follows from Lemma 1 that $\frac{dr_0}{db_0} > 0$.

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

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

A.5.3 Lemma A.1

Proof. Log-linearizing the Euler equation yields

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

Log-linearizing the resource constraint yields

$$p(\theta)sc^e \hat{c}_t^e + (1 - p(\theta)s)b\hat{b}_t = b \left(\eta \hat{\theta}_t + \hat{s}_t \right)$$

in the $k \rightarrow 0$ limit. Recall further that in the $k \rightarrow 0$ limit

$$\hat{y}_t = \eta \hat{\theta}_t + \hat{s}_t.$$

Combining the last two yields

$$\hat{c}_t^e = -\frac{(1 - p(\theta)s)b}{p(\theta)sc^e} \hat{b}_t + \frac{b}{p(\theta)sc^e} \hat{y}_t.$$

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

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

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

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

while up to first order we have

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

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

A.5.4 Proposition A.1

Proof. With flexible prices and thus a constant mark-up μ , in the stated limit $\{y_s, y_s^e, \theta_s\}$ are defined by

$$\begin{aligned} p(\theta_s)s_s(\theta_s, y_s^e, b_s)y_t^e + (1 - p(\theta_s)s_s(\theta_s, y_s^e, b_s))b_s &= y_s, \\ y_s &= p(\theta_s)s_s(\theta_s, y_s^e, b_s), \\ \frac{1}{u'(y_s^e)}(u(y_s^e) - u(b_s)) &= \mu^{-1} \frac{\kappa}{q(\theta_s)}, \end{aligned}$$

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

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

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

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

Given the expressions for γ_{+1} and γ_y , it is clear that

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

so that $\frac{dy_s}{db_t} \frac{b}{y}$ is rising in t if b is sufficiently small. It necessarily follows that $\frac{dy_s}{db_t}$ is rising in t if b is sufficiently small. \square

A.5.5 Lemma A.2

Proof. Real wages are given by

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

where the Nash bargained real wage solves

$$\frac{1}{u'(y_t^e)} (u(y_t^e) - u(b_t)) = \frac{\phi}{1 - \phi} (\mu_t^{-1} - w_t^{nb}),$$

where I have again used the absence of borrowing/lending in this economy to set $c_t^e = y_t^e$ and $c_t^u = b_t$ in equilibrium. Optimal vacancy posting by firms requires

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

Combining these yields

$$\mu_t^{-1} \left(\iota - \frac{k}{q(\theta_t)} \right) = \iota w - (1 - \iota) \frac{1 - \phi}{\phi} \frac{1}{u'(y_t^e)} (u(y_t^e) - u(b_t)).$$

Log-linearizing yields

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

Then log-linearizing

$$\begin{aligned} p(\theta_t)(u(y_t^e) - u(b_t)) &= \psi'(s_t), \\ y_t &= p(\theta_t) s_t - k \theta_t s_t \end{aligned}$$

and taking the $k \rightarrow 0$ limit, we have

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

where

$$\begin{aligned} \chi_y &\equiv \frac{1 - \eta}{\eta} \frac{1}{1 + \frac{1}{\xi}} - (1 - \iota) \sigma \frac{1}{y^e} \frac{1}{p(\theta) s} b - \left(\frac{1 - \eta}{\eta} \frac{1}{1 + \xi} + 1 - \iota \right) \frac{u'(y^e)}{u(y^e) - u(b)} \frac{1}{p(\theta) s} b, \\ \chi_b &\equiv (1 - \iota) \sigma \frac{1}{y_0^e} \frac{1 - p(\theta) s}{p(\theta) s} b + \left(\frac{1 - \eta}{\eta} \frac{1}{1 + \xi} + 1 - \iota \right) \left(\frac{u'(y^e)}{u(y^e) - u(b)} \frac{1 - p(\theta) s}{p(\theta) s} b + \frac{u'(b)}{u(y^e) - u(b)} b \right). \end{aligned}$$

It is clear that $\chi_b > 0$. The fact that $\chi_y > 0$ is a consequence of our assumption that we are studying local changes in UI around the efficient steady-state. In particular, a straightforward generalization of the argument provided in the proof of Proposition 1 implies that $\frac{dy_t}{db_t} < 0$ in the flexible price case. As the flexible price allocation implies a constant mark-up

($\hat{\mu}_t = 0$), it follows from above that $-\frac{\chi_b}{\chi_y} < 0$, and thus $\chi_y > 0$. \square

A.5.6 Proposition A.2

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

$$\Pi_s^P = -\frac{\epsilon - 1}{\psi} \hat{\mu}_s + \frac{1}{1 + r} \Pi_{s+1}^P,$$

where Π_s^P denotes price inflation, ϵ is the elasticity of substitution across retailer varieties, and ψ controls the magnitude of adjustment costs. Up to first order, the Fisher equation implies

$$\hat{r}_s = \hat{i}_s - \Pi_{s+1}^P.$$

Hence, given $\Pi_{t+1}^P = 0$, it is clear that the allocation with a constant nominal interest rate at t is identical to that with a constant real interest rate at t , and thus $\frac{dy_t}{db_t}$ is identical in both cases. For all $s < t$, given the evolution of retailers' mark-up in Lemma A.2 and the dynamic IS equation in Lemma A.1, it is clear that $\frac{dy_s}{db_t}$ is higher given a constant nominal interest rate rather than real interest rate through period t , owing to the additional stimulus to demand via higher inflation expectations and thus a lower real interest rate. Moreover, note that

$$\begin{aligned} \left. \frac{d \frac{\chi_y}{\iota - \frac{k}{q(\theta)}}}{dt} \right|_{k \rightarrow 0} &\propto -\frac{1 - \eta}{\eta} \frac{1}{1 + \frac{1}{\xi}} + \sigma \frac{1}{y^e} \frac{1}{p(\theta)s} b + \left(\frac{1 - \eta}{\eta} \frac{1}{1 + \xi} + 1 \right) \frac{u'(y^e)}{u(y^e) - u(b)} \frac{1}{p(\theta)s} b, \\ &< 0, \\ \left. \frac{d \frac{\chi_b}{\iota - \frac{k}{q(\theta)}}}{dt} \right|_{k \rightarrow 0} &\propto -\sigma \frac{1}{y^e} \frac{1 - p(\theta)s}{p(\theta)s} b - \left(\frac{1 - \eta}{\eta} \frac{1}{1 + \xi} + 1 \right) \left(\frac{u'(y^e)}{u(y^e) - u(b)} \frac{1 - p(\theta)s}{p(\theta)s} b + \frac{u'(b)}{u(y^e) - u(b)} b \right), \\ &< 0, \end{aligned}$$

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

B Supplementary description of quantitative model

In this section I provide additional material accompanying the description of the quantitative model in section 3 of the main text. I first describe why agents' wealth can be summarized

by their total wealth in all periods except the initial one. I then characterize agents' optimality conditions in equilibrium. I finally characterize the conditions under which wages are bilaterally efficient for all agents.

B.1 Aggregation of bond and equity wealth

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

Given wealth in bonds z_t^b and shares in firm equity z_t^f , an employed agent of type ζ_t^e faces

$$\begin{aligned}
v_t^e(z_t^b, z_t^f; \zeta_t^e) &= \max_{c_t^e, z_{t+1}^{e,b}, z_{t+1}^{e,f}} u(c_t^e; \zeta_t^e) \\
&+ \beta_t(\zeta_t^e) \left[(1 - \delta_t(\zeta_t^e)) \int_{\zeta_{t+1}^e} \tilde{v}_{t+1}^e(z_{t+1}^{e,b}, z_{t+1}^{e,f}; \zeta_{t+1}^e) \Gamma_t(\zeta_{t+1}^e | \zeta_t^e) d\zeta_{t+1}^e \right. \\
&\quad \left. + \delta_t(\zeta_t^e) \int_{\zeta_{t+1}^u} \tilde{v}_{t+1}^u(z_{t+1}^{e,b}, z_{t+1}^{e,f}; \zeta_{t+1}^u) \Gamma_t(\zeta_{t+1}^u | \zeta_t^e) d\zeta_{t+1}^u \right] \text{ s.t.} \\
P_t c_t^e + (1 + i_t)^{-1} P_{t+1} z_{t+1}^{e,b} + Q_t z_{t+1}^{e,f} &\leq Y_t^e(\zeta_t^e) + P_t z_t^b + (\Pi_t + Q_t) z_t^f, \\
z_{t+1}^{e,b} + \frac{\Pi_{t+1} + Q_{t+1}}{P_{t+1}} z_{t+1}^{e,f} &\geq z_t, \\
z_{t+1}^{e,f} &\geq 0,
\end{aligned}$$

and an unemployed agent of type ζ_t^u faces

$$\begin{aligned}
v_t^u(z_t^b, z_t^f; \zeta_t^u) &= \max_{c_t^u, z_{t+1}^{u,b}, z_{t+1}^{u,f}} u(c_t^u) + \beta_t(\zeta_t^u) \int_{\zeta_{t+1}^u} \tilde{v}_{t+1}^u(z_{t+1}^{u,b}, z_{t+1}^{u,f}; \zeta_{t+1}^u) \Gamma_t(\zeta_{t+1}^u | \zeta_t^u) d\zeta_{t+1}^u \text{ s.t.} \\
P_t c_t^u + (1 + i_t)^{-1} P_{t+1} z_{t+1}^{u,b} + Q_t z_{t+1}^{u,f} &\leq Y_t^u(\zeta_t^u) + P_t z_t^b + (\Pi_t + Q_t) z_t^f, \\
z_{t+1}^{u,b} + \frac{\Pi_{t+1} + Q_{t+1}}{P_{t+1}} z_{t+1}^{u,f} &\geq z_t, \\
z_{t+1}^{u,f} &\geq 0.
\end{aligned}$$

Agents' constraints reflect a borrowing constraint \underline{z}_t as well as short-sale constraint on firm equity.

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

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

Hence we can summarize each agent's total saving as

$$z_{t+1}^i \equiv z_{t+1}^{i,b} + \frac{\Pi_{t+1} + Q_{t+1}}{P_{t+1}} z_{t+1}^{i,f}$$

subject to the constraint

$$z_{t+1}^i \geq \underline{z}_t.$$

Since we can also collapse the state variables (z_t^b, z_t^f) for any agent into z_t at all dates except $t = 0$, when portfolio composition is relevant in response to an unanticipated shock, we obtain the simplified optimization problems in (9) and (10) in the main text.

We can further aggregate asset market clearing in bonds

$$\begin{aligned} p_t^e \int_{\zeta_t^e} \int_{z_t^f} \int_{z_t^b} z_{t+1}^{e,b}(z_t^b, z_t^f; \zeta_t^e) \varphi_t^e(z_t^b, z_t^f; \zeta_t^e) dz_t^b dz_t^f d\zeta_t^e \\ + (1 - p_t^e) \int_{\zeta_t^u} \int_{z_t^f} \int_{z_t^b} z_{t+1}^{u,b}(z_t^b, z_t^f; \zeta_t^u) \varphi_t^u(z_t^b, z_t^f; \zeta_t^u) dz_t^b dz_t^f d\zeta_t^u + z_{t+1}^g = 0, \end{aligned}$$

and asset market clearing in firm equity

$$\begin{aligned} p_t^e \int_{\zeta_t^e} \int_{z_t^f} \int_{z_t^b} z_{t+1}^{e,f}(z_t^b, z_t^f; \zeta_t^e) \varphi_t^e(z_t^b, z_t^f; \zeta_t^e) dz_t^b dz_t^f d\zeta_t^e \\ + (1 - p_t^e) \int_{\zeta_t^u} \int_{z_t^f} \int_{z_t^b} z_{t+1}^{u,f}(z_t^b, z_t^f; \zeta_t^u) \varphi_t^u(z_t^b, z_t^f; \zeta_t^u) dz_t^b dz_t^f d\zeta_t^u = 1 \end{aligned}$$

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

B.2 Equilibrium conditions

I now characterize the equilibrium.

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

$$p_t(\theta_t; \zeta_t^u) s_t(z_t; \zeta_t^u) \left(\int_{\zeta_t^e} v_t^e(z_t, \zeta_t^e) \Gamma_t(\zeta_t^e | \zeta_t^u) d\zeta_t^e - v_t^u(z_t; \zeta_t^u) \right) = \psi'(s_t(z_t; \zeta_t^u)). \quad (\text{A.15})$$

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

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

$$+ \delta_t(\zeta_t^e) \int_{\zeta_{t+1}^u} \tilde{v}_{t+1,z}^u(z_{t+1}^e; \zeta_{t+1}^u) \Gamma_t(\zeta_{t+1}^u | \zeta_t^e) d\zeta_{t+1}^u \Big], \quad (\text{A.16})$$

$$u'(c_t^u(z_t; \zeta_t^u)) \geq \beta_t(1+r_t) \int_{\zeta_{t+1}^u} \tilde{v}_{t+1,z}^u(z_{t+1}^u; \zeta_{t+1}^u) \Gamma_t(\zeta_{t+1}^u | \zeta_t^u) d\zeta_{t+1}^u, \quad (\text{A.17})$$

given

$$\begin{aligned} \tilde{v}_{t+1,z}^u(z_{t+1}; \zeta_{t+1}^u) = & p_t(\theta_{t+1}; \zeta_{t+1}^u) s_t(z_{t+1}; \zeta_{t+1}^u) \int_{\zeta_{t+1}^e} u'(c_{t+1}^e(z_{t+1}; \zeta_{t+1}^e)) \Gamma_{t+1}(\zeta_{t+1}^e | \zeta_{t+1}^u) d\zeta_{t+1}^e \\ & + (1 - p_t(\theta_{t+1}; \zeta_{t+1}^u) s_t(z_{t+1}; \zeta_{t+1}^u)) u'(c_{t+1}^u(z_{t+1}; \zeta_{t+1}^u)), \end{aligned} \quad (\text{A.18})$$

where these hold with equality if $z_{t+1}^i(z_t; \zeta_t^i) > \underline{z}_t$, and I have defined the real interest rate

$$1 + r_t \equiv (1 + i_t) \frac{P}{P_{t+1}}.$$

Firms Retailer j facing (13) optimally sets

$$\begin{aligned} P_{tj} = & \frac{\varepsilon}{\varepsilon - 1} (1 + \tau^R) P_t^I - \\ & \frac{\psi}{\varepsilon - 1} \Pi_{tj}^P (1 + \Pi_{tj}^P) \left(\frac{\int_0^1 P_{tk} y_{tk} dk}{y_{tj}} \right) + (1 + i_t)^{-1} \frac{\psi}{\varepsilon - 1} \Pi_{t+1j}^P (1 + \Pi_{t+1j}^P) \left(\frac{\int_0^1 P_{t+1k} y_{t+1k} dk}{y_{tj}} \right) \end{aligned}$$

where $\Pi_{tj}^P \equiv \frac{P_{tj}}{P_{t-1j}} - 1$ denotes j -specific inflation. Starting from identical prior prices, the symmetry across retailers implies that $P_{tj} = P_t$ and thus $y_{tj} = y_t$ across varieties. Dividing the above condition by P_t implies the nonlinear Phillips curve

$$1 = \frac{\varepsilon}{\varepsilon - 1} (1 + \tau^R) \mu_t^{-1} - \frac{\psi}{\varepsilon - 1} \Pi_t^P (1 + \Pi_t^P) + (1 + r_t)^{-1} \frac{\psi}{\varepsilon - 1} \Pi_{t+1}^P (1 + \Pi_{t+1}^P) \frac{y_{t+1}}{y_t} \quad (\text{A.19})$$

where $\mu_t \equiv \frac{P_t}{P_t^I}$ is the gross mark-up.

Finally, it is helpful to write producers' problem (12) so that the firm only has one state variable, the composite $\tilde{\phi}_t^e(\zeta_t^e) \equiv \tilde{p}_t^e \int_{z_t} \tilde{\varphi}_t^e(z_t; \zeta_t^e) dz_t$ giving the measure of workers of type ζ_t^e employed by the firm. Then the constraint summarizing the evolution of $\tilde{\phi}_t^e(\zeta_t^e)$ is

$$\tilde{\phi}_{t+1}^e(\zeta_{t+1}^e) = \int_{\zeta_t^e} \Gamma_t(\zeta_{t+1}^e | \zeta_t^e) (1 - \delta_t(\zeta_t^e)) \left(\tilde{\phi}_t^e(\zeta_t^e) + q_t(\theta_t) \nu_t \int_{\zeta_t^u} \Gamma_t(\zeta_t^e | \zeta_t^u) \int_{z_t} \tilde{\varphi}_t^u(z_t; \zeta_t^u) dz_t d\zeta_t^u \right) d\zeta_t^e,$$

with associated Lagrange multiplier $\lambda_t^\phi(\zeta_{t+1}^e)$. Employing the calculus of variations, producer

optimality is characterized by

$$\int_{\zeta_t^e} s_t^f(\zeta_t^e) \left(\int_{\zeta_t^u} \Gamma_t(\zeta_t^e | \zeta_t^u) \int_{z_t} \frac{m_t(\zeta_t^u) s_t(z_t; \zeta_t^u)}{\bar{s}_t} \tilde{\varphi}_t^u(z_t; \zeta_t^u) dz_t d\zeta_t^u \right) d\zeta_t^e - \mu_t^{-1} \bar{a}_t \frac{k}{q_t(\theta_t)} = 0, \quad (\text{A.20})$$

$$\lambda_t^\phi(\zeta_{t+1}^e) = (1 + r_t)^{-1} s_{t+1}^f(\zeta_{t+1}^e), \quad (\text{A.21})$$

given the real firm surplus from employing a marginal worker of type ζ_t^e in period t

$$s_t^f(\zeta_t^e) \equiv \mu_t^{-1} a_t(\zeta_t^e) - w_t(\zeta_t^e) + (1 - \delta_t(\zeta_t^e)) \int_{\zeta_{t+1}^e} \lambda_t^\phi(\zeta_{t+1}^e) \Gamma_t(\zeta_{t+1}^e | \zeta_t^e) d\zeta_{t+1}^e, \quad (\text{A.22})$$

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

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

$$s_t^f(\zeta_t^e; \hat{W}_t) = \mu_t^{-1} a_t(\zeta_t^e) - \frac{\hat{W}_t}{P_t} + (1 - \delta_t(\zeta_t^e)) \int_{\zeta_{t+1}^e} \lambda_t^\phi(\zeta_{t+1}^e) \Gamma_t(\zeta_{t+1}^e | \zeta_t^e) d\zeta_{t+1}^e, \quad (\text{A.23})$$

where $\lambda_t^\phi(\zeta_{t+1}^e)$ is characterized by (A.20) and (A.21) and $s_t^f(\zeta_t^e)$ is characterized by (A.22).

The surplus for an unemployed worker with wealth z_t and of type ζ_t^u who matches with a firm, becomes type ζ_t^e , and receives wage \hat{W}_t in period t and the equilibrium wage $P_\tau w_\tau(\cdot)$ thereafter is

$$s_t^w(z_t; \zeta_t^u; \zeta_t^e; \hat{W}_t) = \hat{v}_t^e(z_t; \zeta_t^e; \hat{W}_t) - v_t^u(z_t; \zeta_t^u). \quad (\text{A.24})$$

The surplus of union ζ_t^e (which aggregates over its members using a utilitarian social welfare function) is thus

$$s_t^w(\zeta_t^e; \hat{W}_t) = \int_{\zeta_t^u} \Gamma_t(\zeta_t^e | \zeta_t^u) \int_{z_t} s_t^w(z_t; \zeta_t^u; \zeta_t^e; \hat{W}_t) \frac{m_t(\zeta_t^u) s_t(z_t; \zeta_t^u)}{\bar{s}_t} \tilde{\varphi}_t^u(z_t; \zeta_t^u) dz_t d\zeta_t^u.$$

The Nash bargained wage with worker bargaining share ϕ solves

$$W_t^{nb}(\zeta_t^e) = \arg \max_{\hat{W}_t} s_t^w(\zeta_t^e; \hat{W}_t)^\phi s_t^f(\zeta_t^e; \hat{W}_t)^{1-\phi},$$

which yields the first order condition

$$\frac{1-\phi}{\phi} \frac{1}{\frac{\partial s_t^w(\zeta_t^e; \hat{W}_t^{nb})}{\partial \hat{W}_t}} s_t^w(\zeta_t^e; \hat{W}_t^{nb}) = -\frac{1}{\frac{\partial s_t^f(\zeta_t^e; \hat{W}_t^{nb})}{\partial \hat{W}_t}} s_t^f(\zeta_t^e; \hat{W}_t^{nb}).$$

We have that

$$\begin{aligned} \frac{\partial s_t^f(\zeta_t^e; \hat{W}_t^{nb})}{\partial \hat{W}_t} &= -\frac{1}{P_t}, \\ \frac{\partial s_t^w(\zeta_t^e; \hat{W}_t^{nb})}{\partial \hat{W}_t} &= \int_{\zeta_t^u} \Gamma_t(\zeta_t^e | \zeta_t^u) \int_{z_t} \frac{\partial s_t^w(z_t; \zeta_t^u; \zeta_t^e; \hat{W}_t^{nb})}{\partial \hat{W}_t} \frac{m_t(\zeta_t^u) s_t(z_t; \zeta_t^u)}{\bar{s}_t} \tilde{\varphi}_t^u(z_t; \zeta_t^u) dz_t d\zeta_t^u, \\ \frac{\partial s_t^w(z_t; \zeta_t^u; \zeta_t^e; \hat{W}_t^{nb})}{\partial \hat{W}_t} &= \frac{1}{P_t} u'(c_t^e(z_t; \zeta_t^e; \hat{W}_t^{nb})). \end{aligned}$$

It follows that the Nash bargained wage satisfies

$$\begin{aligned} \frac{1-\phi}{\phi} \frac{1}{\int_{\zeta_t^u} \Gamma_t(\zeta_t^e | \zeta_t^u) \int_{z_t} u'(c_t^e(z_t; \zeta_t^e)) \frac{m_t(\zeta_t^u) s_t(z_t; \zeta_t^u)}{\bar{s}_t} \tilde{\varphi}_t^u(z_t; \zeta_t^u) dz_t d\zeta_t^u} \times \\ \int_{\zeta_t^u} \Gamma_t(\zeta_t^e | \zeta_t^u) \int_{z_t} (v_t^e(z_t; \zeta_t^e) - v_t^u(z_t; \zeta_t^u)) \frac{\bar{m}_t(\zeta_t^u) s_t(z_t; \zeta_t^u)}{\bar{s}_t} \tilde{\varphi}_t^u(z_t; \zeta_t^u) dz_t d\zeta_t^u = \\ \mu_t^{-1} a_t(\zeta_t^e) - \frac{W_t^{nb}(\zeta_t^e)}{P_t} + (1 - \delta_t(\zeta_t^e)) \int_{\zeta_{t+1}^e} \lambda_t^\phi(\zeta_{t+1}^e) \Gamma_t(\zeta_{t+1}^e | \zeta_t^e) d\zeta_{t+1}^e. \quad (\text{A.25}) \end{aligned}$$

In steady-state, this characterizes the equilibrium real wage ($w(\zeta_t^e) = \frac{W_t^{nb}(\zeta_t^e)}{P(\zeta_t^e)}$). In transitional dynamics following a macroeconomic shock, by (14) the equilibrium real wage satisfies

$$w_t(\zeta_t^e) = \iota w(\zeta_t^e) + (1 - \iota) \frac{W_t^{nb}(\zeta_t^e)}{P_t}.$$

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

In particular, workers' resource constraints imply

$$c_t^e + (1 + r_t)^{-1} z_{t+1}^e = y_t^e(\zeta_t^e) + z_t, \quad (\text{A.26})$$

$$c_t^u + (1 + r_t)^{-1} z_{t+1}^u = y_t^u(\zeta_t^u) + z_t, \quad (\text{A.27})$$

at each t , where

$$y_t^e(\zeta_t^e) \equiv w_t(\zeta_t^e) - t_t, \quad (\text{A.28})$$

$$y_t^u(\zeta_t^u) \equiv b_t(\zeta_t^u). \quad (\text{A.29})$$

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

$$y_t = p_t^e \int_{\zeta_t^e} \int_{z_t} a_t(\zeta_t^e) \varphi_t^e(z_t; \zeta_t^e) dz_t d\zeta_t^e - \bar{a}_t k \theta_t (1 - \tilde{p}_t^e) \bar{s}_t, \quad (\text{A.30})$$

while final goods market clearing implies

$$p_t^e \int_{\zeta_t^e} \int_{z_t} c_t^e(z_t; \zeta_t^e) \varphi_t^e(z_t; \zeta_t^e) dz_t d\zeta_t^e + (1 - p_t^e) \int_{\zeta_t^u} \int_{z_t} c_t^u(z_t; \zeta_t^u) \varphi_t^u(z_t; \zeta_t^u) dz_t d\zeta_t^u = y_t. \quad (\text{A.31})$$

Asset market clearing implies

$$\begin{aligned} p_t^e \int_{\zeta_t^e} \int_{z_t} z_{t+1}^e(z_t; \zeta_t^e) \varphi_t^e(z_t; \zeta_t^e) dz_t d\zeta_t^e + (1 - p_t^e) \int_{\zeta_t^u} \int_{z_t} z_{t+1}^u(z_t; \zeta_t^u) \varphi_t^u(z_t; \zeta_t^u) dz_t d\zeta_t^u \\ = -z_{t+1}^g + \pi_{t+1} + q_{t+1}, \end{aligned} \quad (\text{A.32})$$

where the real price of the equity claim is

$$q_t = (1 + r_t)^{-1} [\pi_{t+1} + q_{t+1}] \quad (\text{A.33})$$

and real dividends are

$$\pi_{t+1} = y_{t+1} - p_{t+1}^e \int_{\zeta_{t+1}^e} w_{t+1}(\zeta_{t+1}^e) \int_{z_{t+1}} \varphi_{t+1}^e(z_{t+1}; \zeta_{t+1}^e) dz_{t+1} d\zeta_{t+1}^e. \quad (\text{A.34})$$

Finally, budget balance for the government implies

$$p_t^e t_t + z_t^g = (1 - p_t^e) \int_{\zeta_t^u} \int_{z_t} b_t(\zeta_t^u) \varphi_t(z_t; \zeta_t^u) dz_t d\zeta_t^u + (1 + r_t)^{-1} z_{t+1}^g. \quad (\text{A.35})$$

B.3 Bilateral efficiency of wages

Recall the firm and worker surpluses $s_t^f(\zeta_t^e; \hat{W}_t)$ and $s_t^w(z_t; \zeta_t^u; \zeta_t^e; \hat{W}_t)$ characterized in (A.23) and (A.24), respectively. The real wages $\{w_t(\zeta_t^e)\}$ are bilaterally efficient for all agents in

the economy (absent commitment to long-term contracts) if and only if

$$s_t^f(\zeta_t^e; P_t w_t(\zeta_t^e)) \geq 0, \quad (\text{A.36})$$

$$s_t^w(z_t; \zeta_t^u; \zeta_t^e; P_t w_t(\zeta_t^e)) \geq 0, \quad (\text{A.37})$$

for all ζ_t^e employed by the firm and all (ζ_t^u, ζ_t^e) consistent with worker transitions, respectively. As wages are Nash bargained in steady-state, (A.36) is naturally satisfied in a neighborhood of steady-state. The assumed absence of disutility from labor and replacement rates less than 100% make it easy to satisfy (A.37). I verify that these conditions are satisfied for all workers in the stationary RCE and in all transitional dynamics described in the main text.

C Empirical appendix

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

C.1 Moments on consumption, unemployment risk, and wealth

In this subsection I describe moments on consumption, unemployment risk, and wealth used to calibrate and evaluate the quantitative model in 3. I provide further details regarding sample construction and variable definitions at the end of this appendix.

C.1.1 Consumption sensitivities to income

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

The first two rows of Table A.1 imply that self-reported MPCs out of unexpected, transitory income shocks are 25% higher for unemployed versus employed households. I estimate these sample means using the 2010 Survey of Household Income and Wealth (SHIW) administered in Italy, a data source also used by other researchers studying MPCs (e.g., Japelli and Pistaferri [2014]). The advantage of this data source is its rich set of information collected alongside estimates of MPCs, including household heads' contemporaneous employment status used here. A disadvantage is that the reported horizon of spending was not asked in the

Moment	Mean	Obs.	Source
Annual MPC employed	0.47 (0.005)	4,213	2010 SHIW
Annual MPC unemployed	0.72 (0.027)	129	2010 SHIW
Two-month Δ spending at UI exhaustion	-\$263 (\$8)	27,740	Ganong and Noel [2019]
Two-month Δ income at UI exhaustion	-\$1,300 (\$11)	27,740	Ganong and Noel [2019]

Table A.1: consumption sensitivities to income by employment status

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

survey, though as Auclert [2019] notes, the consistency of average MPCs with the annual MPCs elicited in a later 2012 survey suggests that respondents had a one-year time frame in mind here. Another disadvantage is of course that the survey was administered in Italy, while I am interested in evidence for the U.S.²

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

C.1.2 Wealth by employment status

I next document cross-sectional differences in wealth by employment status, summarized in Table A.2. I find that wealth is considerably lower among the unemployed versus the employed. Together with prior research finding higher MPCs among low wealth households

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

Moment	Median		Mean	
	Employed	Unemployed	Employed	Unemployed
[1] Transaction accounts	0.5	0.1	3.2	1.3
[2] Bonds	0	0	1.0	0.2
[3] Other financial assets	1.9	0.0	21.6	8.6
[4] Non-financial assets	21.8	1.8	57.5	17.8
[5] Credit card	(0.0)	0	(0.4)	(0.4)
[6] Other debt	(7.3)	(0.4)	(14.6)	(6.7)
Liquid ([1]+[2]+[5])	0.2	0.0	3.8	1.1
Total ([1]+[2]+[3]+[4]+[5]+[6])	13.1	1.7	68.3	20.8
Number households	3,322	132	3,322	132

Table A.2: wealth scaled by mean monthly household income in 2004 SCF (\$6,761)

Note: sampling weights are used to estimate population-wide statistics.

(e.g., Broda and Parker [2014]), this suggests that MPCs will be higher among this group.

Using the 2004 Survey of Consumer Finances (SCF), Table A.2 summarizes median and mean wealth by employment status. I scale by average monthly income over the past year among households with an employed or unemployed household head (\$6,761 in \$2004) to ease interpretation as well as the eventual mapping between data and model. The median household with an unemployed head holds 11.4 fewer months of income in total wealth than the employed; given the skewness of wealth (especially among households with an employed head), mean unemployed total wealth is 47.5 months of income below that of the employed. The latter forms an important targeted moment in my baseline calibration.

While my baseline calibration is to the distribution of total wealth, in appendix D I present an alternative calibration matching the distribution of liquid wealth: transaction (checking, saving, money market, call, and prepaid) accounts and directly held bonds, less credit card balances, as in Kaplan et al. [2018]. The mean unemployed household holds 2.7 fewer months of income in liquid wealth than the mean employed household.

C.1.3 Wage-EU and wealth-EU relationships

I next document negative relationships between wages and employment-to-unemployment (EU) transition probabilities and between wealth and EU probabilities in Table A.3. This is important in determining the precautionary responses to changes in UI.

The first column of Table A.3 uses 2004-2007 data from the monthly Outgoing Rotation Groups of the Current Population Survey (CPS) to find a tight negative relationship between 1-year-ahead EU probabilities and weekly pay when employed. The CPS interviews households for four months, rotating them out of the panel for eight months before resur-

$1\{e\}_{i,t} \times$	2004-07	2004 SIPP Panel	
	CPS	$1\{u\}_{i,t+12}$	$1\{u\}_{i,t+12}$
\logpay_{it}	-0.012 (0.0006)		
$wealth_{it}$		-0.0002 (0.00005)	-0.0001 (0.00005)
\logearn_{it}			-0.010 (0.002)
Time FE	Yes	Yes	Yes
Observations	158,181	18,874	18,874

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

Note: standard errors reported in parentheses are clustered at the household level in each regression. Observations below the 5th percentile and above the 95th percentile of wealth are dropped in the SIPP regressions to minimize the influence of outliers. Sampling weights in both the CPS and SIPP are used.

veying them. In the fourth month, earnings data is collected for those individuals which report themselves as employed. Consider all individuals i who have their fourth interview in each calendar month t , report being employed with positive pay, and remain in the labor force twelve months later. Letting \logpay_{it} denote log weekly pay and $1\{u\}_{it+12}$ denote an indicator for unemployment in calendar month $t + 12$, I run the specification

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

The fixed effects allow for time-varying average probabilities of an employed individual becoming unemployed over the sample period. The estimated $\hat{\beta} = -0.012$ implies that a 10pp increase in the wage is associated with a 0.12pp decrease in the probability of an individual being unemployed one year in the future. Given an average such probability ranging from 1.6% to 2.8% in each month of 2004 through 2006, this is economically meaningful.

The second column of Table A.3 uses the 2004 panel of the Survey of Income and Program Participation (SIPP) to estimate a similarly tight negative relationship between 1-year-ahead EU probabilities and wealth when employed. In the 2004 panel, household balance sheet data was collected in the third and sixth waves of the survey. Consider all household heads i whose interview in one of these waves is in calendar month t and report being employed, provide non-missing wealth and income (the latter described further below), and remain in the labor force twelve months later. Letting $wealth_{it}$ denote total wealth scaled by mean monthly income corresponding to the SCF definition in Table A.2 and $1\{u\}_{it+12}$ denote an

Moment	Income						Spending
	Total	Own	UI	Other HH	SNAP +welf.	Soc. Sec.	
Mean prior to job loss	1.00 (0.00)	0.67 (0.01)	0.02 (0.00)	0.21 (0.01)	0.03 (0.00)	0.04 (0.00)	1.00
Mean during UI receipt	0.76 (0.02)	0.02 (0.00)	0.31 (0.01)	0.29 (0.02)	0.05 (0.01)	0.06 (0.01)	0.91
Mean after UI exhaustion	0.55 (0.02)	0.08 (0.01)	0 (n/a)	0.29 (0.02)	0.06 (0.01)	0.07 (0.01)	0.80
Observations	869	869	869	869	869	869	27,740
Source	Rothstein and Valletta [2017] extract from 2001 and 2008 SIPP panels						Ganong and Noel [2019]

Table A.4: income and consumption through unemployment spell

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

indicator for unemployment in calendar month $t + 12$, I run the specification

$$1\{u\}_{it+12} = \alpha_{1t} + \beta_1 \text{wealth}_{it} + \epsilon_{1it}.$$

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

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

C.1.4 Income and consumption through unemployment spell

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

The first and last columns in Table A.4 quantify the average declines in household income and spending among UI recipients during receipt and after exhaustion relative to the period prior to job loss. The decline in income is estimated using Rothstein and Valletta [2017]’s extract of unemployment spells in the 2001 and 2008 SIPP panels. Among household heads who lose their jobs and ultimately exhaust UI, household income falls by an average of 24% during UI receipt and a further 21% after UI exhaustion. The associated decline in spending has been estimated by a large literature beginning with Gruber [1997]. In their recent work using the JPMorgan Chase panel, Ganong and Noel [2019] estimate that the spending of UI exhaustees falls by 9% during UI receipt and a further 11% after UI exhaustion.

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

C.2 Portfolio shares

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

$$\tilde{q}_t \equiv \pi_t + q_t. \tag{A.38}$$

In response to an unexpected shock in period t studied in sections 5 and 6 of the main text, this equity value will change. This will revalue household balance sheets according to their positions in equity. Since the absence of aggregate risk renders the composition of agents’

³For the average household, the sum of the reported components of total income explain almost all of reported total income, though a few percentage points remains unexplained.

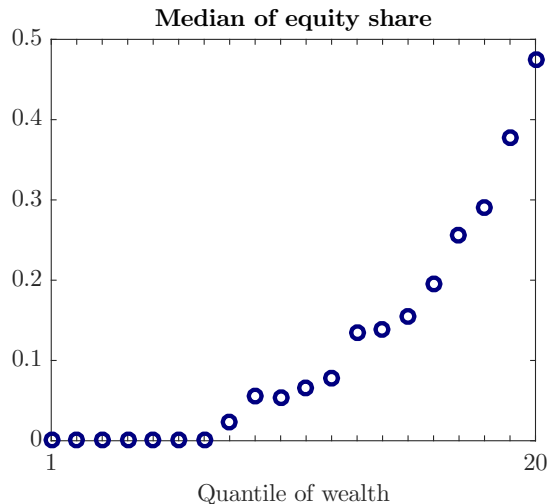


Figure A.1: exposure to corporate profits by wealth quantile in 2004 SCF

Note: sample is identical to that in Table A.2 and sampling weights are used.

portfolios indeterminate, I use empirical patterns in household portfolios to map household wealth z into positions in bonds and equity which add up to z at the initial (pre-shock) \tilde{q}_t :

$$z_t^b(z), z_t^f(z) := z_t^b + \tilde{q}_t z_t^f = z.$$

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

$$dz = d\tilde{q}_t z_t^f(z)$$

on impact of the shock. In this subsection I describe empirical patterns in household portfolios using the 2004 SCF and how I use them to define the mappings $z_t^b(z)$ and $z_t^f(z)$.

The 2004 SCF implies that households have very little exposure to corporate profits at low levels of wealth, but have positive and rising exposure to corporate profits at moderate/high levels of wealth. I construct a measure of such exposure using the asset holdings of labor force participants described in Table A.2. I compute the ratio of household i 's total position in public and private equity relative to total wealth. I then compute the median of this measure by the 5% quantile of wealth.⁴ Figure A.1 demonstrates that the equity share is nonlinear, with positive and rising exposure only at moderate/high levels of wealth.

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

⁴The median appears more informative than the mean since we are dividing here by measures of wealth, which can be small.

log-linear specification. For an agent with wealth z , I assume that

$$z_t^f(z) = \begin{cases} 0 & \text{if } z \leq z_t^*, \\ \frac{1}{\tilde{q}_t} z \gamma_t (\log z - \log z_t^*) & \text{if } z > z_t^* \end{cases}$$

is held in firm equity, where \tilde{q}_t refers to the pre-shock price of equity and $z_t^*, \gamma_t > 0$. The remainder $z_t^b(z) = z - \tilde{q}_t z_t^f(z)$ is held in the riskless bond. I set z_t^* to be the 35th percentile of the pre-shock wealth distribution, consistent with median *corpeexposure* only rising meaningfully after the 35th quantile in Figure A.1. γ_t is then set such that the implied aggregate wealth invested in firm equity is consistent with that in the pre-shock equilibrium.⁵

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

C.3 Data sources, sample construction, and variable definitions

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

C.3.1 2010 SHIW

The 2010 SHIW microdata covers survey responses of 19,836 individuals from 7,951 households. The responses to two questions are used in the analysis described in the main text.

The first question of interest asks about households' employment status for most of 2010 (B01 on the questionnaire). I define as employed those who respond with code 1–5 (indicating different forms of paid employment such as being a production worker or manager), 6–10 (indicating different forms of self-employment such as being an entrepreneur), or 20 (“other self-employed”). I define as unemployed those who respond with code 12 (“unemployed”). Other codes indicate non-employment such as that of students, homemakers, or retirees.

The second question of interest asks about households' MPC out of unexpected, transitory income shocks (E14 on the questionnaire), also studied in Japelli and Pistaferri [2014]. It asks: “Imagine you unexpectedly receive a reimbursement equal to the amount your house-

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

hold earns in a month. How much of it would you save and how much would you spend? Please give the percentage you would save and the percentage you would spend.” I define the MPC as respondents’ stated percentage of how much they would spend.

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

C.3.2 2004 SCF

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

Balance sheet information is available in the summary extract public data. Six line items are used to construct each household’s balance sheet: transaction accounts (checking, saving, money market, call, and prepaid accounts); bonds (not including bond funds or saving bonds); total financial wealth (which includes the last two categories); total non-financial wealth; credit card debt; and total net worth. Two line items are used to construct each household’s total exposure to firm equity in particular: publicly traded equities (both held directly and held indirectly, such as via mutual funds or IRAs) and private business equity.

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

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

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

C.3.3 2004 SIPP Panel

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

Wealth data at the household level is available in the topical module focused on assets and liabilities asked of respondents in the 3rd and 6th wave of the survey. I use total net worth and treat this as comparable to total net worth in the SCF.

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

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

I start my sample with 69,256 observations of reference persons (which I treat as household heads) with complete interview and asset information surveyed in waves 3 and 6. Only 44,958 are employed as of the wealth survey date, and of these only 20,970 provide complete interview information and are in the labor force 1 year from their wealth survey date, forming the sample for the analysis of wealth-EU relationships in Table A.3.⁶

C.3.4 2004–2007 CPS

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

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

I start my sample with 479,210 individuals whose fourth interview takes place between January 2004 through December 2006 (and thus whose eighth interview should be between

⁶I further trim the 5% lowest and 5% highest observations of wealth to minimize the role of outliers in the regression analysis in Table A.3.

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

D Supplementary impulse responses from steady-state

In this section I supplement the impulse responses starting from the model's stationary RCE in section 5. I first describe, for my baseline extension of UI, the dynamics of other macroeconomic aggregates excluded from the main text for brevity. I provide the calibration of alternative steady-states studied in the main text, and then characterize the effects of UI in an alternative calibration of the wealth distribution. I provide additional experiments investigating eligibility/take-up, deficit finance, and the effect of raising the replacement rate rather than UI duration. I finally characterize the model's fiscal multiplier in response to a conventional government spending shock, demonstrating that it is consistent with available estimates and lending credibility to my analysis of UI.

D.1 Other macroeconomic aggregates in baseline experiment

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

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

Under sticky prices, the unemployment rate instead falls during the period of extended UI. In partial equilibrium, consumption demand rises and search effort falls during the period of extended UI. To clear the goods market, vacancies would have to rise. Given the rise in vacancies and decline in search, retailers' marginal costs would rise and this would generate inflation. The monetary authority responds by raising the nominal interest rate and thus real interest rate, but the rise in the real rate is not as large as under flexible prices. Hence, equilibrium vacancies rise and unemployment falls.

With sticky prices and a constant real interest rate for 18 months, the effect on unemployment, vacancies, tightness, and inflation are all amplified because there is no crowd out of aggregate demand. Given the tighter labor market, workers raise their search relative to

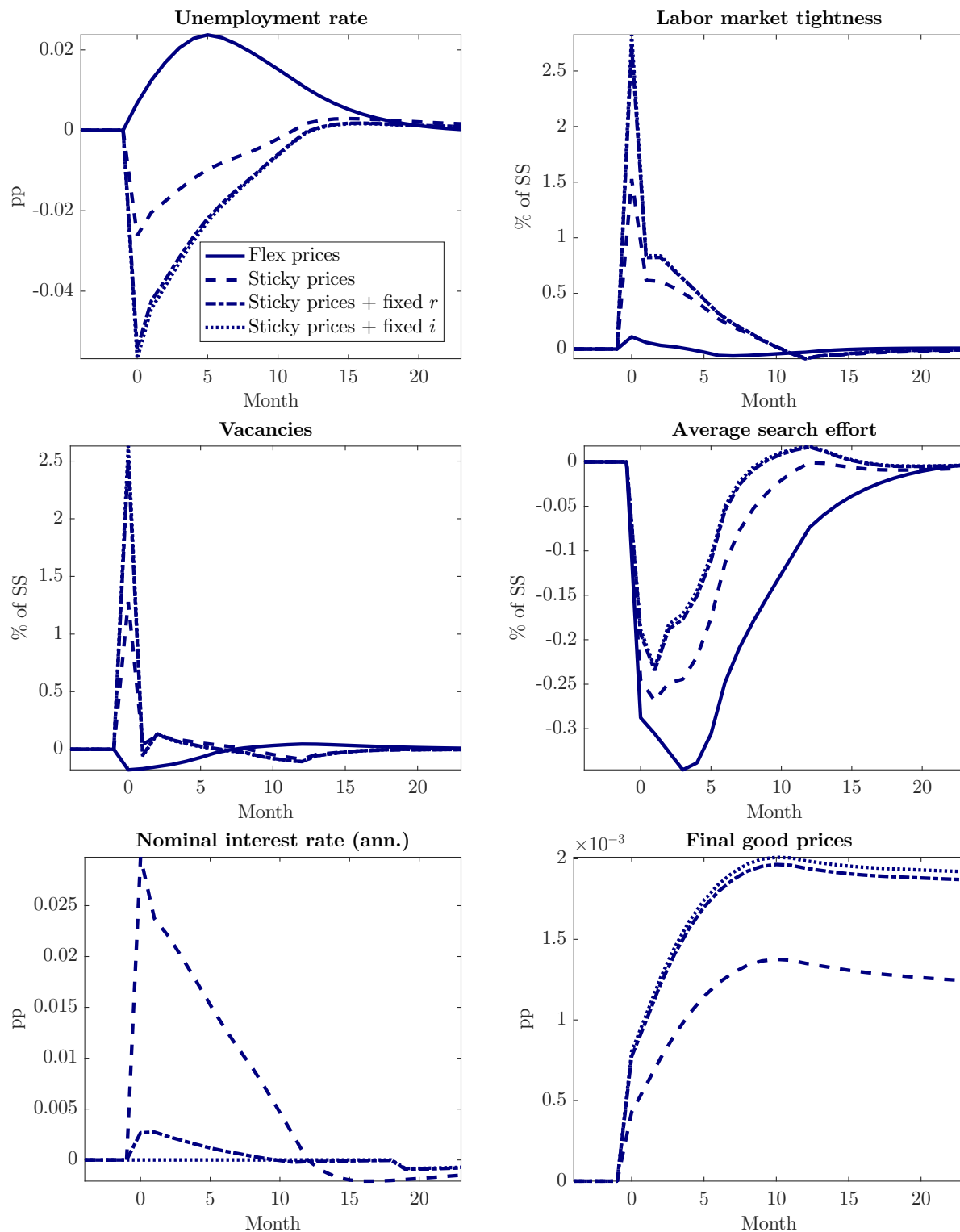


Figure A.2: additional effects of UI starting from steady-state

Note: the panels describe additional effects of a one-year extension of UI duration by three months starting from the stationary RCE with no other macroeconomic shocks.

Moment	Target	Achieved	Parameter	Value
<i>Real rate, wealth, and average MPC</i>				
Real interest rate (ann.)	2%	2.0%	z^g/\bar{a}	-8.98
Mean wealth / monthly HH income	66.0	66.0	$\bar{\beta}$	0.99337
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	0.43	ζ	0.5
Max UI / mean wage UI recipients	0.6	0.59	$\frac{\zeta}{\bar{w}i}$	0.51
Mean HH income w. UI / pre job loss	0.76	0.73	ω_1	0.37
Mean HH income w.o UI / pre job loss	0.55	0.56	ω_2	0.50
<i>Incidence of unemployment</i>				
Unemployment rate	5%	5.0%	ϕ	0.955
Fraction w/ duration > 6 mos	0.17	0.17	λ	-0.14
<i>Search and the labor market</i>				
Duration elasticity to benefit duration	0.1	0.14	ξ	15
Vacancies per unemployed worker	0.634	0.634	\bar{m}	0.20
Fraction of monthly wage to hire worker	0.108	0.108	k/\bar{a}	0.045

Table A.5: calibration results assuming $\epsilon_\beta^\delta = \epsilon_a^\delta = 0$

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

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

the case with an active Taylor rule.⁷ Note that the constant real interest rate requires that the central bank still raise the nominal rate somewhat, because there is inflation.

With sticky prices and a constant nominal interest rate for 18 months, the positive inflation lowers the ex-ante real interest rate, further stimulating demand. Thus, all of the responses are slightly amplified relative to the previous case.

D.2 Alternative calibrations from main text

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

Identical δ Workers' separation rates in the model vary by their persistent level of productivity and discount factor. These allow the model to match the sensitivity in employment-to-unemployment flows by wage and the mean difference in wealth between the unemployed

⁷I expect this effect would be reversed in an alternative model of matching where search falls with tightness, as in Mukoyama et al. [2018]. Nonetheless, I expect that the effect on unemployment and output would be little changed: as demonstrated by my analytical results as well as quantitative sensitivities, vacancy creation and thus tightness should adjust to the new search response so that the overall change in employment still ultimately reflects the change in demand through redistribution and precautionary saving.

Moment	Target	Achieved	Parameter	Value
<i>Real rate, wealth, and average MPC</i>				
Real interest rate (ann.)	2%	2.0%	z^g/\bar{a}	-8.48
Mean wealth / monthly HH income	66.0	65.7	$\bar{\beta}$	0.99335
Mean (U-E) wealth / monthly HH income	-47.5	-42.0	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	0.44	$\underline{\zeta}$	0.5
Max UI / mean wage UI recipients	0.6	0.58	$\frac{\zeta}{wi}$	0.4
Mean HH income w. UI / pre job loss	0.76	0.74	ω_1	0.37
Mean HH income w.o UI / pre job loss	0.55	0.55	ω_2	0.50
<i>Incidence of unemployment</i>				
Unemployment rate	5%	5.0%	ϕ	0.969
Fraction w/ duration > 6 mos	0.17	0.19	λ	-0.14
EU probability on log wage	-0.012	-0.007	ϵ_a^δ	-0.011
<i>Search and the labor market</i>				
Duration elasticity to benefit duration	0.4	0.36	ξ	2.5
Vacancies per unemployed worker	0.634	0.634	\bar{m}	0.23
Fraction of monthly wage to hire worker	0.108	0.108	k/\bar{a}	0.044

Table A.6: calibration results targeting higher disincentive effect

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

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

and employed, respectively. They also contribute importantly to the heterogeneity in MPCs by duration of unemployment implied by the model.

To understand how the quantitative results change with an identical δ across workers and thus shallower profile of MPCs by duration of unemployment, I set $\epsilon_a^\delta = \delta_\beta^\delta = 0$ and re-calibrate the other parameters of the model to match the same other targets. This yields the parameter choices in Table A.5.

Higher target for micro disincentive effect Turning to the supply-side, in the baseline calibration the elasticity of disutility from search $\xi = 15$ is used to target a micro elasticity of 0.1, within the range of estimates for the U.S. provided in the survey of Schmieder and von Wachter [2016]. However, as these authors note, a wide range of estimates for this elasticity have been obtained in the literature, reaching as high as roughly 0.4.

To understand how the quantitative results change under a higher disincentive effect of UI, I instead use ξ to target an elasticity of unemployment duration with respect to benefit duration of 0.4, and re-calibrate the other parameters of the model to match the same targets.

Moment	Target	Achieved	Parameter	Value
<i>Real rate, wealth, and average MPC</i>				
Real interest rate (ann.)	2%	2.0%	z^g/\bar{a}	-5.10
Mean wealth / monthly HH income	3.7	4.1	$\bar{\beta}$	0.99425
Mean (U-E) wealth / monthly HH income	-2.7	-2.9	ϵ_β^δ	-14
Fraction HH with negative wealth	0.26	0.29	\underline{z}/\bar{a}	-0.5
Mean quarterly MPC to \$500 rebate*	0.21	0.22	Δ^β	0.00125
<i>Income during unemployment</i>				
Share unemployed receiving UI	0.39	0.42	ζ	0.5
Max UI / mean wage UI recipients	0.6	0.58	$\frac{\zeta}{\bar{w}}$	0.44
Mean HH income w. UI / pre job loss	0.76	0.74	ω_1	0.37
Mean HH income w.o UI / pre job loss	0.55	0.55	ω_2	0.50
<i>Incidence of unemployment</i>				
Unemployment rate	5%	5.0%	ϕ	0.952
Fraction w/ duration > 6 mos	0.17	0.17	λ	-0.14
EU probability on log wage	-0.012	-0.011	ϵ_a^δ	-0.011
<i>Search and the labor market</i>				
Duration elasticity to benefit duration	0.1	0.09	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 A.7: calibration results targeting liquid wealth distribution

Note: sources for targets are provided in the main text. The table provides the main parameter used to target each moment.

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

This yields the parameter choices in Table A.6. Note that while the supply-side of the model has changed, agents' consumption behavior is little changed relative to the baseline: the comparable MPCs to those in Table 3 are 16% for the employed, 34% for the short-term unemployed, 45% for the medium-term unemployed, and 57% for the long-term unemployed.

D.3 Sensitivity to wealth distribution

I now explore the sensitivity of the effects of UI to the definition of wealth used to calibrate the model. In the main text I parameterized the model to match the distribution of total net worth. I now assess the sensitivity of the model's results using a calibration to liquid wealth: transaction accounts plus directly held bonds less credit card balances, as in Kaplan et al. [2018].

Table A.7 summarizes the calibration results. Consistent with Table A.2 presented earlier in this appendix, the new targets are that mean wealth is only 3.7 times average monthly income; the unemployed have on average 2.7 times fewer months of average income than the

	Baseline	Liquid wealth
Quarterly MPC, employed	0.16	0.16
Quarterly MPC, ST unemployed	0.36	0.33
Quarterly MPC, MT unemployed	0.47	0.48
Quarterly MPC, LT unemployed	0.59	0.69
Output multiplier	1.1	1.3
Avg change in unemp. rate	-0.02pp	-0.03pp

Table A.8: sensitivity of effects of UI under sticky prices and fixed i

Note: the baseline calibration matches the distribution of total net worth in the U.S., whereas the counterfactual matches the distribution of liquid wealth (transaction accounts plus directly held bonds less credit card balances).

employed; and 26% of the agents have negative wealth. Notably, $\bar{\beta}$ must be lower than in the baseline calibration to target lower average wealth.⁸

Focusing on the case with sticky prices and a constant nominal interest rate for 18 months, Table A.8 demonstrates that a three-month extension of UI for one year generates slightly higher stimulus than in the baseline calibration.⁹ This is because this calibration features a steeper gradient of MPCs by employment status, even though the average MPC in the economy is the same as the baseline.

D.4 Other features of UI policy

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

Higher eligibility/take-up of UI amplifies the stimulus by expanding the scale of transfers. This is relevant because the fraction of the unemployed who are eligible for and take up UI is countercyclical (Chodorow-Reich and Karabarbounis [2016]). The second column of Table A.9 indicates that if the eligibility/take-up probability ζ_t increases to 1 during months 0 through 5, the output multiplier and reduction in unemployment are larger.

⁸In this calibration, I further set $\tau^R = -\frac{1}{\epsilon}$ so that retailers earn zero profits in equilibrium. This minimizes the size of firm equity (so that it is only proportional to hiring costs), which seems appropriate in a calibration targeting liquid wealth.

⁹To simulate a UI shock (or any other aggregate shock), I must also specify agents' portfolio composition between bonds and firm equity. Similar to the approach in appendix C.2, I assume a piecewise log-linear equity share by level of wealth, and in particular that only households above the 75th percentile of wealth have firm equity. This is motivated by the mean ratio of directly held bonds to total liquid wealth rising above zero only at this percentile (after partitioning households in the SCF by 5% quantile of wealth). Directly held bonds may be the only component of liquid wealth capturing a claim to firm profits since they can include corporate bonds.

	Baseline	Higher eligibility/ take-up	Deficit financing	rr shock
Output multiplier	1.1	1.2	1.3	0.7
Avg change in unemp. rate	-0.02pp	-0.03pp	-0.03pp	-0.04pp

Table A.9: policy sensitivities under sticky prices and fixed i

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

Deficit finance of UI amplifies the stimulus through redistribution because the borrowing constraint breaks Ricardian equivalence in this environment. This is also relevant in practice because extended UI benefits, as with other discretionary fiscal measures, are typically deficit-financed. The third column of Table A.9 summarizes the effects of a year of extended UI holding taxes on the employed fixed for the first 24 months, with the government asset position z_t^g adjusting to balance the budget each period. After $t = 24$, taxes again balance each period's budget with assets returning to steady-state according to

$$z_{t+1}^g = z_t^g + \rho^z(z_t^g - z_t^g)$$

given $\rho^z = 0.95$. The output multiplier and reduction in unemployment are now larger.

Comparing duration to level, we can see the effectiveness of the long-term unemployed as a “tag” in stabilization. The fourth column of Table A.9 keeps UI duration at 6 months but raises the replacement rate among all UI recipients by 10pp for one year. The output multiplier falls relative to duration extensions, consistent with the long-term unemployed having especially high MPCs and long-term unemployment being a particularly costly state of the world against which agents precautionary save. Nonetheless, the aggregate stimulus is higher in the case of the replacement rate increase owing to the larger magnitude of transfers under this policy.

D.5 Fiscal multiplier and comparison to estimates

I finally characterize the model-implied fiscal multiplier in response to a conventional government spending shock, demonstrating that it is consistent with available estimates and lending credibility to my analysis of UI.

I augment the model with government spending as follows. I assume the government purchases a CES bundle of final goods g_t analogous to that consumed by households. Government purchases enter separably into household utility such that their only effect on the

	Sticky prices	Sticky prices + fixed i
Budget-balanced	0.6	1.3
Deficit-financed	0.9	1.4

Table A.10: model-generated fiscal multipliers

Note: each cell reports the output multiplier of a one-year increase in government spending relative to steady-state GDP of 1%, starting from the stationary RCE. The output multiplier is defined analogously to (30) except with government spending in the denominator. Deficit financing in the last row assumes unchanged taxes for first 24 months before adjusting to retire the accumulated debt, as in the second column of Table A.9.

equilibrium conditions are in goods market clearing (21), where g_t appears on the left-hand side, and the government’s budget constraint (22), where g_t appears on the right-hand side. This augmented model nests that in main text.

Starting from the model’s steady-state (in which $g = 0$), I then characterize the fiscal multiplier associated with a shock to government spending. I simulate a one-year increase in g_t relative to steady-state GDP of 1%, and I compute the fiscal multiplier as in (30) except with the change in g_t in the denominator. I consider four scenarios summarized in Table A.10. Along the row dimension, I vary the form of financing: either contemporaneous taxes on the employed, or deficits (with eventually future taxes on the employed) as described in appendix D.4. Along the column dimension, I vary the monetary policy response: either an active Taylor rule, or a constant nominal interest rate for 18 months (as at the zero lower bound) after which policy follows an active Taylor rule. In all cases, prices are sticky and $\iota = 0.94$, the degree of real wage rigidity which I calibrate to match macro data in section 6 of the main text.

The model-implied fiscal multipliers are consistent with available evidence, lending credibility to my analysis of UI. I obtain a budget-balanced fiscal multiplier with an active Taylor rule of 0.6, and a deficit-financed fiscal multiplier under the same monetary regime of 0.9. This is consistent with the time-series evidence summarized by Ramey [2011] that the “aggregate multiplier for a temporary, deficit-financed increase in government purchases (that enter separately in the utility function and have no direct effect on private sector production functions) is probably between 0.8 and 1.5” (p.673). When spending is deficit-financed and the nominal interest rate is held fixed, the fiscal multiplier rises to 1.4 in my model. This is slightly lower than the evidence summarized by Chodorow-Reich [2019] finding a “no monetary policy response deficit-financed national multiplier of about 1.7 or above” (p.3), drawing on evidence from cross-region multipliers. A more persistent government spending shock while monetary policy maintains a constant nominal interest rate would generate a

larger multiplier closer to the data, consistent with Figure 4 for UI in the main text.

E Supplementary results for Great Recession

In this section I supplement the Great Recession analysis in section 6 of the main text. I first contrast the effect of discount factor, borrowing constraint, productivity, separation rate, and match efficiency shocks. I then present an alternative calibration featuring both discount rate shocks and separation rate shocks, where the latter are directly disciplined by the data. I finally provide a case study of the expiration of extended benefits in December 2013 under an alternative assumption on agents' expectations regarding how long they would last.

E.1 Impulse responses to fundamental shocks

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

$$\begin{aligned}\bar{\beta}_t &= (1 - \rho^{\bar{\beta}})\bar{\beta} + \rho^{\bar{\beta}}(\bar{\beta}_{t-1} - \bar{\beta}) + \epsilon_t^{\bar{\beta}}, \\ \bar{z}_t &= (1 - \rho^{\bar{z}})\bar{z} + \rho^{\bar{z}}(\bar{z}_{t-1} - \bar{z}) + \epsilon_t^{\bar{z}}, \\ \bar{a}_t &= (1 - \rho^{\bar{a}})\bar{a} + \rho^{\bar{a}}(\bar{a}_{t-1} - \bar{a}) + \epsilon_t^{\bar{a}}, \\ \bar{\delta}_t &= (1 - \rho^{\bar{\delta}})\bar{\delta} + \rho^{\bar{\delta}}(\bar{\delta}_{t-1} - \bar{\delta}) + \epsilon_t^{\bar{\delta}}, \\ \bar{m}_t &= (1 - \rho^{\bar{m}})\bar{m} + \rho^{\bar{m}}(\bar{m}_{t-1} - \bar{m}) + \epsilon_t^{\bar{m}},\end{aligned}$$

in each case. The persistence of each process is set to 0.95 and the size of each shock is chosen to deliver a 0.05pp rise in the unemployment rate on impact. In all cases, the environment features sticky prices, monetary policy following the Taylor rule, and $\iota = 0.94$ as calibrated in section 6.

The impulse responses to a positive discount factor shock are provided in Figure A.3. At unchanged prices and a constant nominal interest rate, the increase in desired saving would generate a decline in production and rise in unemployment. This would generate nominal deflation among retailers which can adjust their prices.¹⁰ The central bank responds to the resulting deflation and decline in output by lowering the nominal interest rate, mitigating but not eliminating the decline in economic activity. In this way, a positive discount factor shock can jointly rationalize the rise in unemployment and decline in the nominal interest

¹⁰As noted in footnote 48 in the main text, the initial rise in nominal wages is due to selection.

rate early in the Great Recession. As described in the main text, I view such a shock as capturing the shock to financial conditions during this period more broadly.

The impulse responses to a positive borrowing constraint shock are provided in Figure A.4. The dynamics are qualitatively similar to those after a positive discount factor shock, as both shocks raise households' desired saving on impact. Quantitatively, however, there is a limit to the magnitude of borrowing constraint shocks which can be considered, since at a certain point the lowest wealth and income households would face negative consumption.

The impulse responses to a negative productivity shock are provided in Figure A.5. Given relatively rigid real wages but first assuming prices were fully flexible, a negative productivity shock would induce a fall in vacancy creation, rise in unemployment, fall in consumption, and rise in the real interest rate. Given an active Taylor rule, the rise in the real interest rate is achieved via nominal inflation which induces a rise in the nominal interest rate. Given sticky prices, the increase in inflation and thus interest rates are muted, but the same qualitative dynamics still obtain. Hence, at least given the (standard) Taylor rule, productivity shocks alone cannot explain why the zero lower bound would be binding.

The impulse responses to a positive separation rate shock and negative match efficiency shock are provided in Figures A.6 and A.7, respectively. These shocks are similarly negative “supply” shocks, simultaneously raising unemployment while raising firms' marginal costs and thus generating inflation. Hence, an inflation targeting central bank will again raise the nominal interest rate, so these shocks alone cannot rationalize the rise in unemployment and decline in the nominal interest rate early in the Great Recession.¹¹

E.2 Calibration with discount factor and separation rate shocks

I now present a calibration to the Great Recession featuring both discount factor and separation rate shocks, where the latter are directly measured in the data. Following the results in the prior subsection, such a calibration thus features both “demand” and “supply” shocks.

I first estimate the aggregate separation rate and its associated innovations during the Great Recession period. I follow the methodology of Shimer [2012] to estimate the aggregate separation rate in each month.¹² In particular, I define the aggregate separation probability in month t as the ratio of short-term unemployed workers in month $t+1$ (that is, unemployed

¹¹It is also revealing to ask what would happen if the slope of match efficiencies by duration of unemployment changed, holding fixed the match efficiency of initially unemployed workers — i.e., a shock to λ in (27), if we made it time-varying. As would be expected, a negative shock (more duration-dependence in job-finding rates) implies a rise in the fraction of long-term unemployed agents. More notably, the change in long-term unemployment for any percentage change in overall unemployment is an order of magnitude larger than for any of the other shocks described here.

¹²For simplicity, as in his baseline analysis, I ignore non-participants and possible worker heterogeneity. The former is consistent with my model environment but the latter is not.

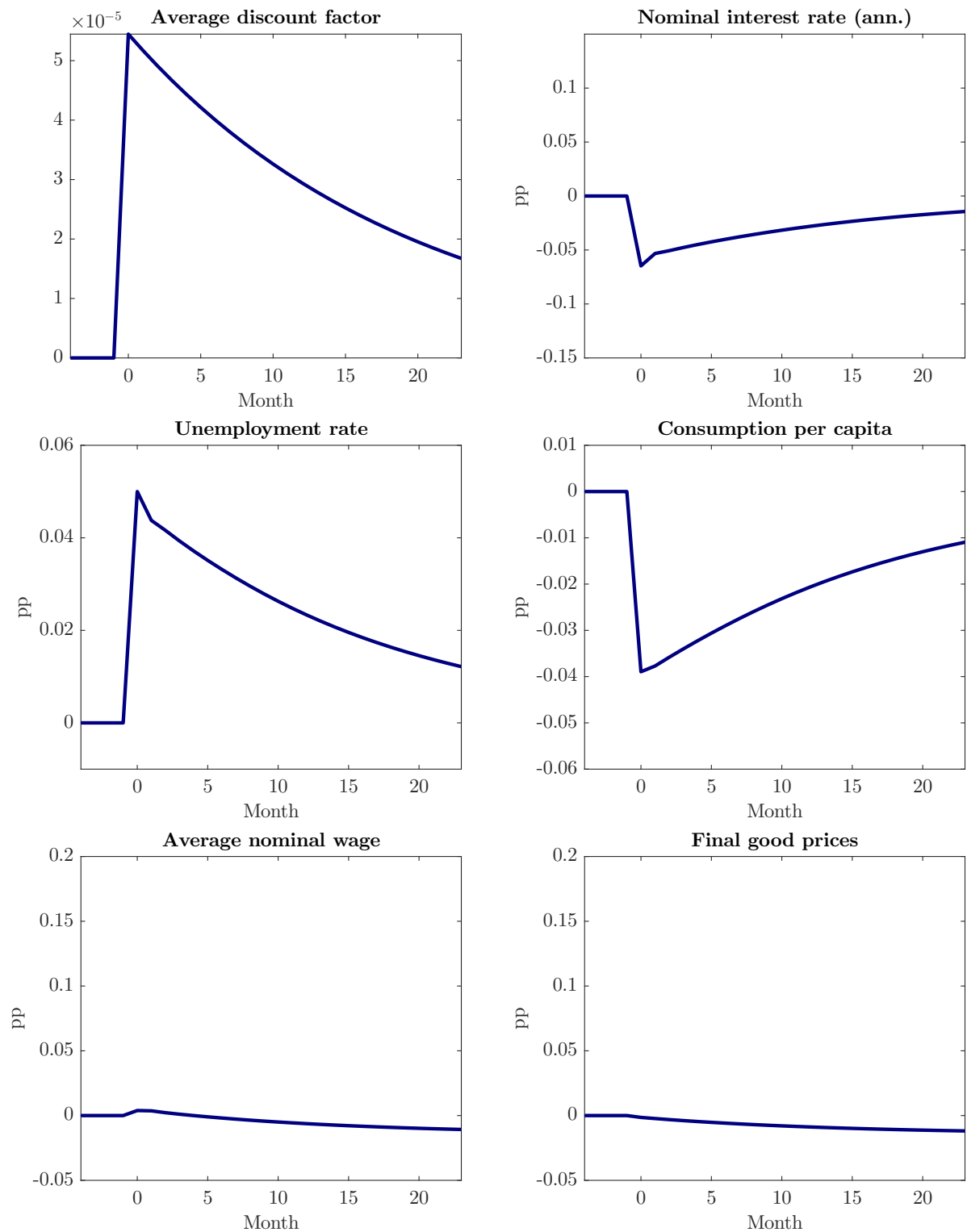


Figure A.3: discount factor shock

Note: average discount factor assumed to follow an AR(1) process with persistence 0.95. Initial shock chosen to imply a $0.05pp$ change in unemployment on impact. Environment features sticky prices and the calibrated degree of real wage rigidity $\iota = 0.94$.

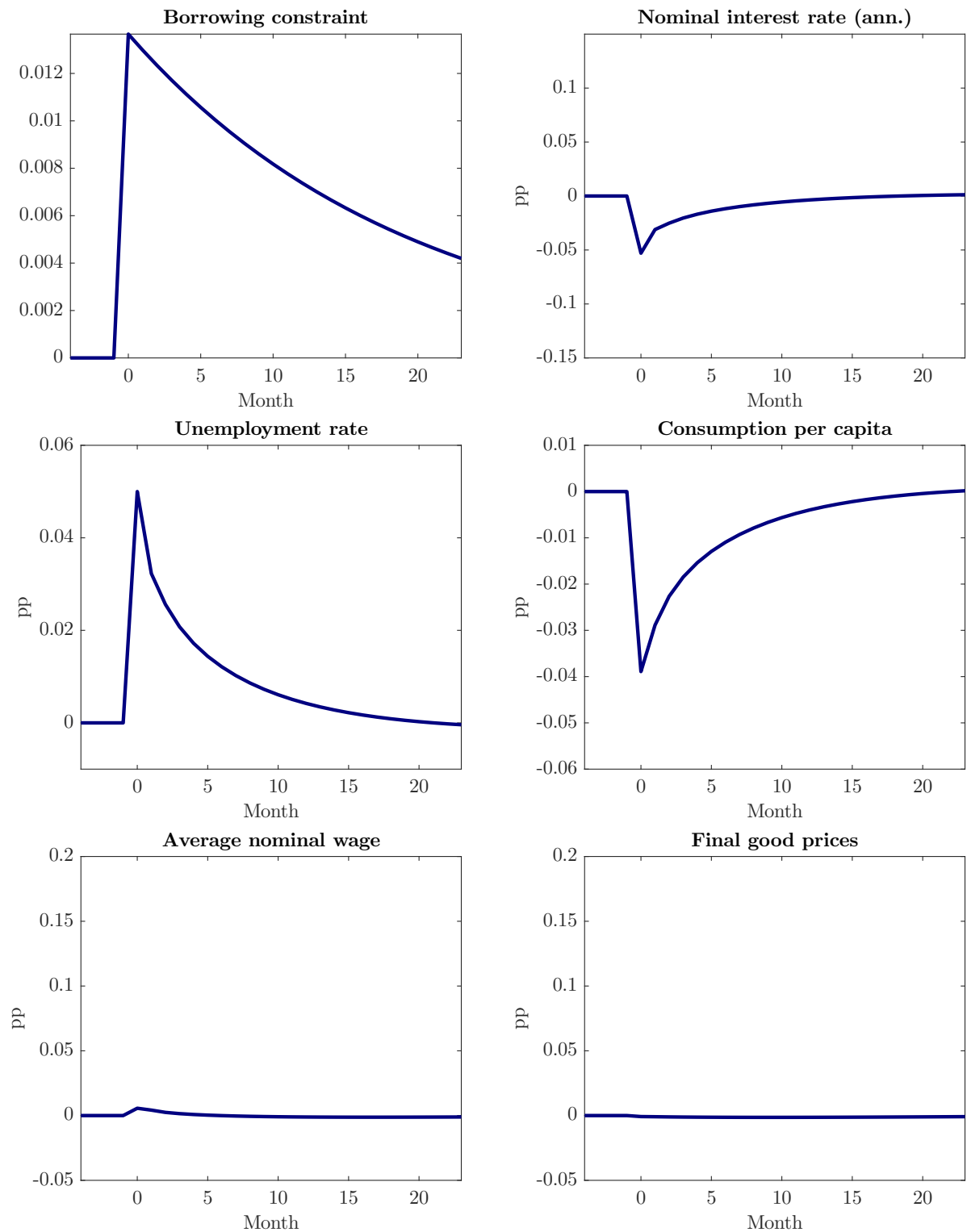


Figure A.4: borrowing constraint shock

Note: borrowing constraint assumed to follow an AR(1) process with persistence 0.95. Initial shock chosen to imply a $0.05pp$ change in unemployment on impact. Environment features sticky prices and the calibrated degree of real wage rigidity $\iota = 0.94$.

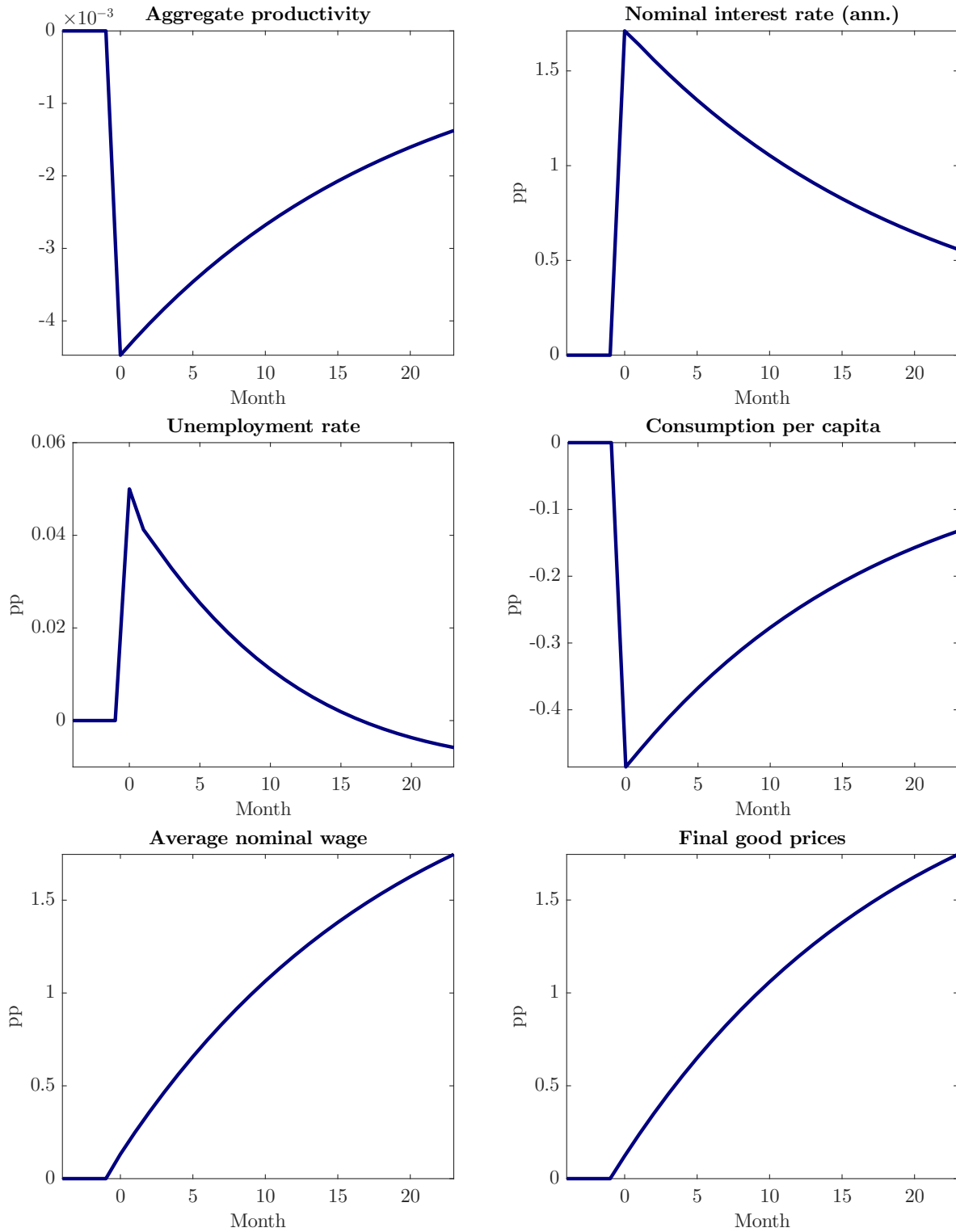


Figure A.5: productivity shock

Note: average productivity assumed to follow an AR(1) process with persistence 0.95. Initial shock chosen to imply a $0.05pp$ change in unemployment on impact. Environment features sticky prices and the calibrated degree of real wage rigidity $\iota = 0.94$.

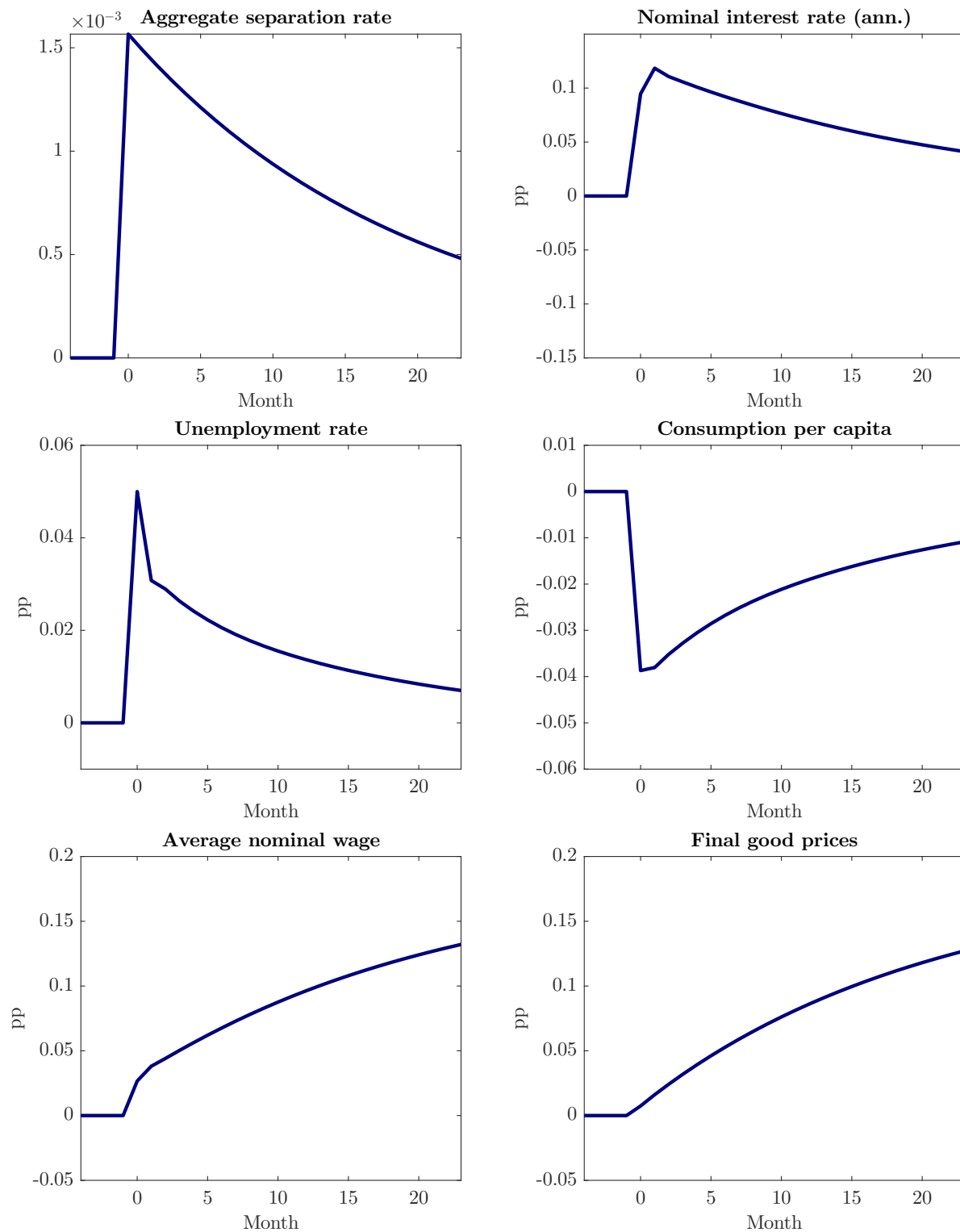


Figure A.6: separation rate shock

Note: separation rate assumed to follow an AR(1) process with persistence 0.95. Initial shock chosen to imply a $0.05pp$ change in unemployment on impact. Environment features sticky prices and the calibrated degree of real wage rigidity $\iota = 0.94$.

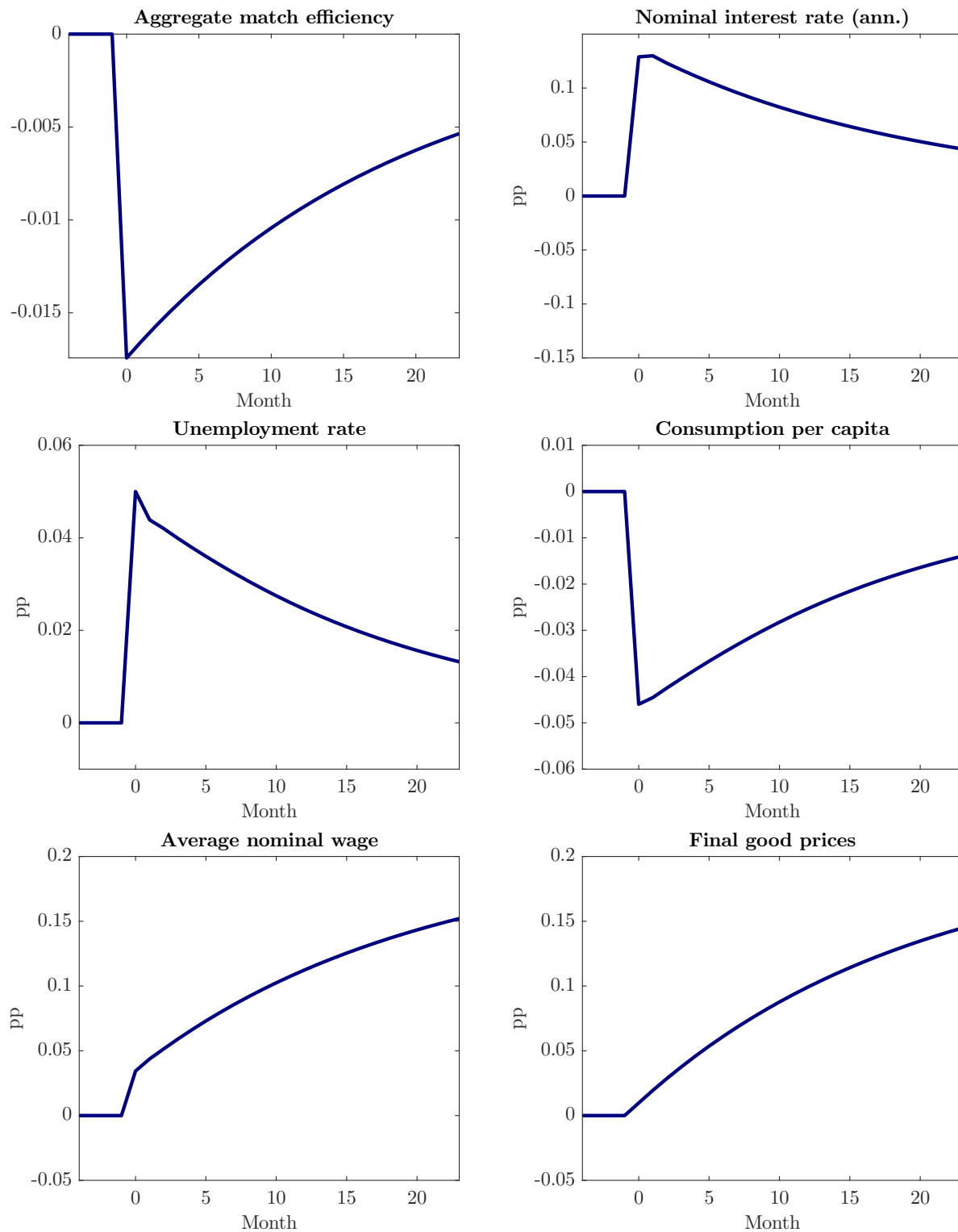


Figure A.7: match efficiency shock

Note: match efficiency assumed to follow an AR(1) process with persistence 0.95. Initial shock chosen to imply a $0.05pp$ change in unemployment on impact. Environment features sticky prices and the calibrated degree of real wage rigidity $\iota = 0.94$.

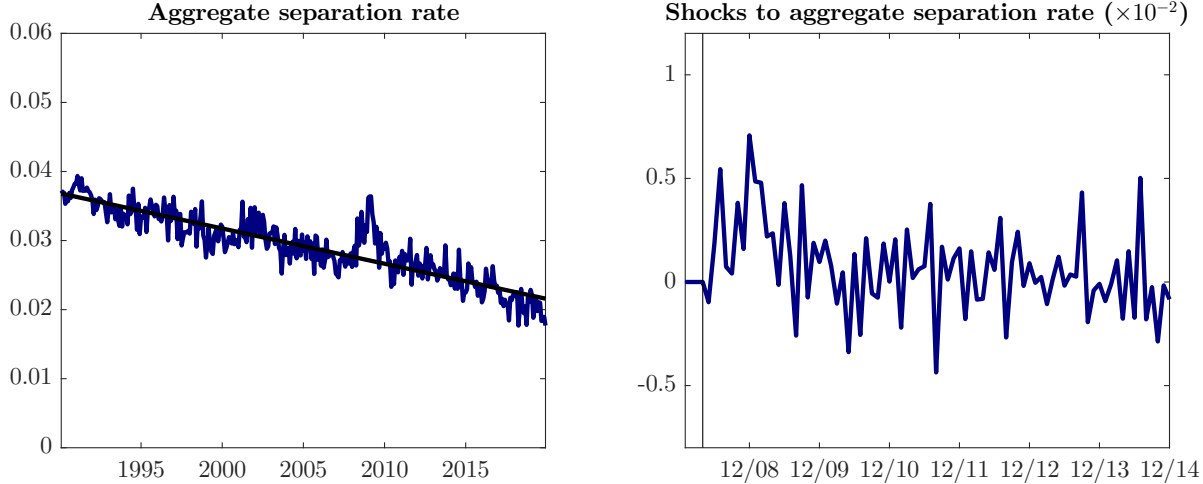


Figure A.8: separation rate and innovations fed into model

Note: aggregate separation rate estimated using the methodology of Shimer [2012]. Solid black line in left panel depicts linear trend over 1990-2019. Right panel depicts innovations of detrended series over 5/2008–12/2014 which are fed into the model.

workers with unemployed duration less than 5 weeks) relative to employed workers in t .¹³ I then solve for the aggregate separation rate, corrected for time aggregation, using equation (5) in Shimer [2012].¹⁴ The resulting separation rate from 1990 through 2019 is plotted in the first panel of Figure A.8. Over the period of overlap with Shimer [2012], my estimates are virtually identical to his.

As is evident, the separation rate has trended down over the last several decades, the causes of which are further discussed in Shimer [2012]. Given this slow-moving trend, I estimate shocks to $\bar{\delta}_t$ over the Great Recession after first detrending the series in Figure A.8 by its linear trend over the 1990-2019 period, and then fitting an AR(1) process on the detrended data. I estimate a persistence coefficient of 0.49 and resulting innovations over the May 2008 - December 2014 period depicted in the right panel of Figure A.8. As is evident, these innovations are almost all positive through 2009, implying a rise in separation rates in the early part of the Great Recession.

Given this sequence of separation rate shocks, I recalibrate the sequence of discount factor shocks and degree of real wage rigidity to match the observed path of unemployment in the data and minimize the sum of squared differences between the final goods price index in model and data. The left panel of Figure A.9 demonstrates that the sequence of discount

¹³This uses seasonally adjusted data from the BLS and, to correct for a structural break in the design of the CPS in January 1994, the CPS Basic Monthly Files for all months thereafter. See appendix A of Shimer [2012].

¹⁴This also uses the job finding rate, which we construct using the job-finding probability computed as in equation (5) in that paper.

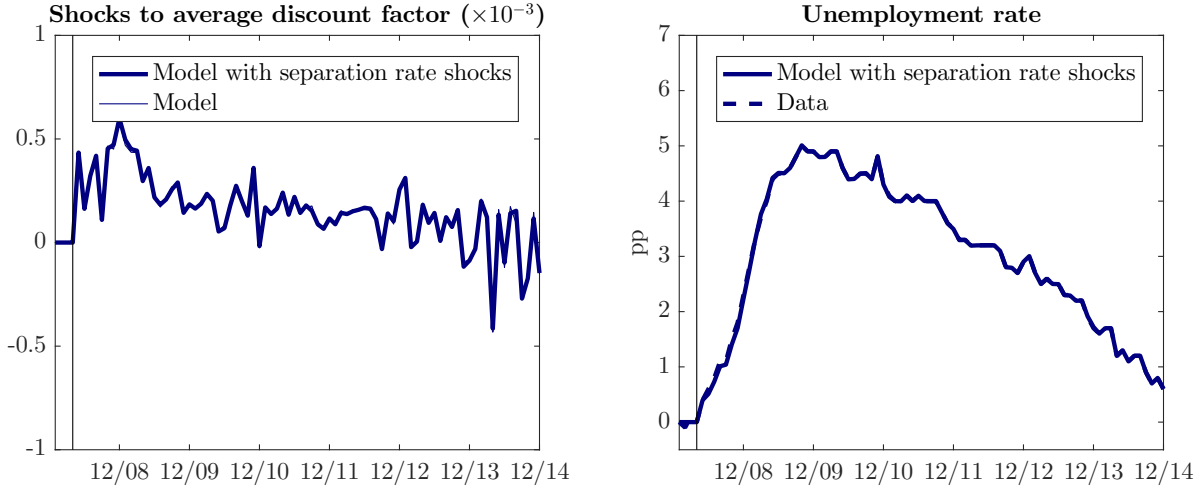


Figure A.9: discount factor shocks and unemployment given separation rate shocks

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 and separation rate shocks in Figure A.8, unemployment in model matches that in data. Unemployment series is displayed in deviations from steady-state (for model) and April 2008 (in data).

factor shocks are very close to those in the baseline calibration. The right panel demonstrates that the unemployment rate is indeed virtually identical to the data.

Figure A.10 compares other model-generated time-series with the data, all of which are untargeted in the calibration except the final goods price index, analogous to Figure 7 in the main text. As with the baseline calibration, the calibration with separation rate shocks generates fluctuations qualitatively and in many respects quantitatively in line with the data.

Importantly, I continue to estimate a high degree of real wage rigidity ($\iota = 0.94$) in this calibration. Consistent with the impulse responses studied in the prior subsection, a positive separation rate shock is inflationary. Figure A.11 compares the dynamics of nominal wages and prices in the calibrated model with separation rate shocks to the model without separation rate shocks from the main text. As is evident, in the absence of separation rate shocks wages and prices would have fallen by more, given the same path of unemployment as observed in the data. Nonetheless, the implied effects on inflation are not large enough to change my estimation of real wage rigidity (to the nearest 0.01) to match the data. Given the comparable degree of real wage rigidity, the calibration with separation rate shocks implies comparable stimulus from UI extensions during the Great Recession. Figure A.12 compares the model dynamics to a counterfactual economy subject to the same discount factor and separation rate shocks but with no UI extensions.

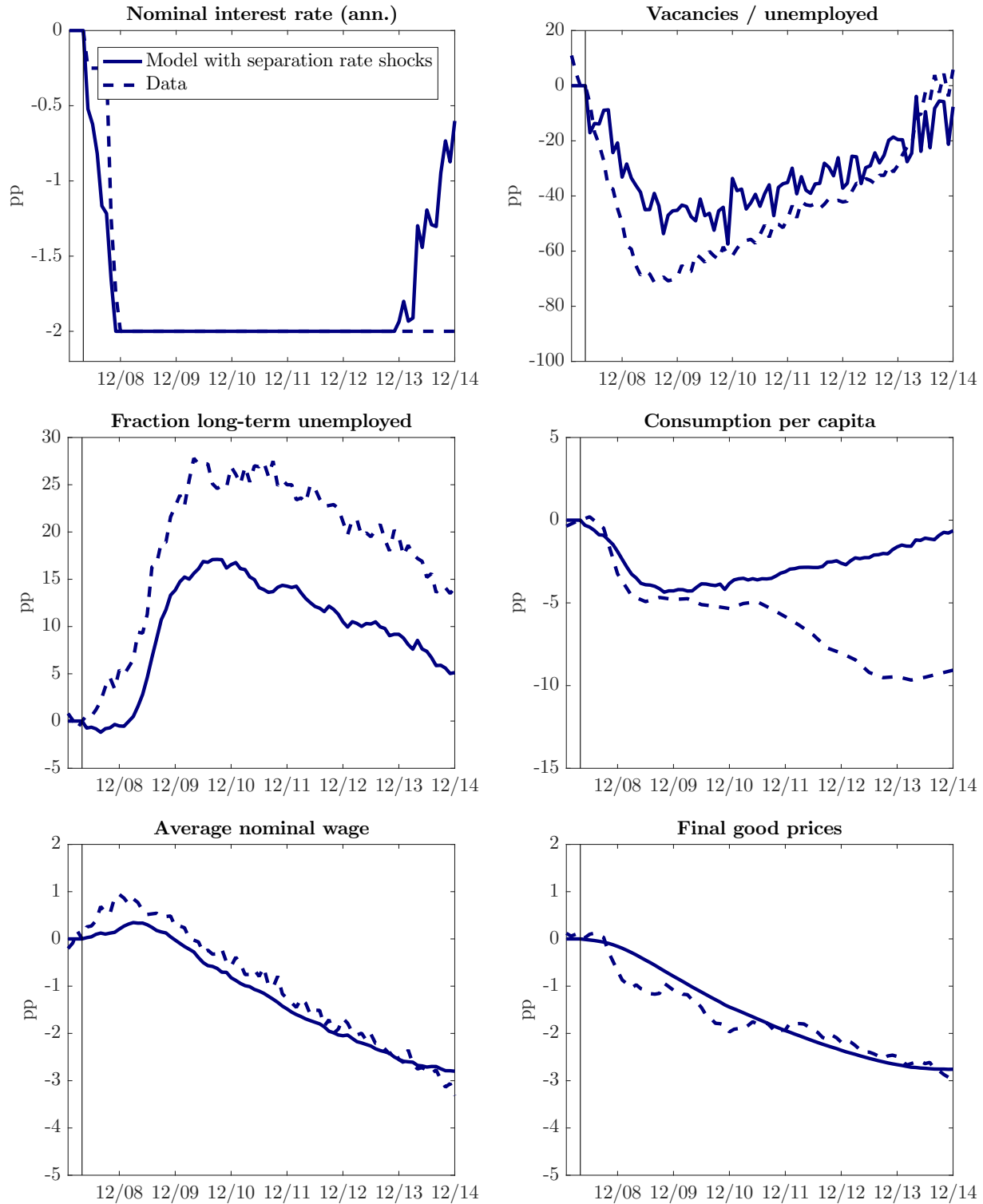


Figure A.10: untargeted macro time-series given separation rate shocks

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).

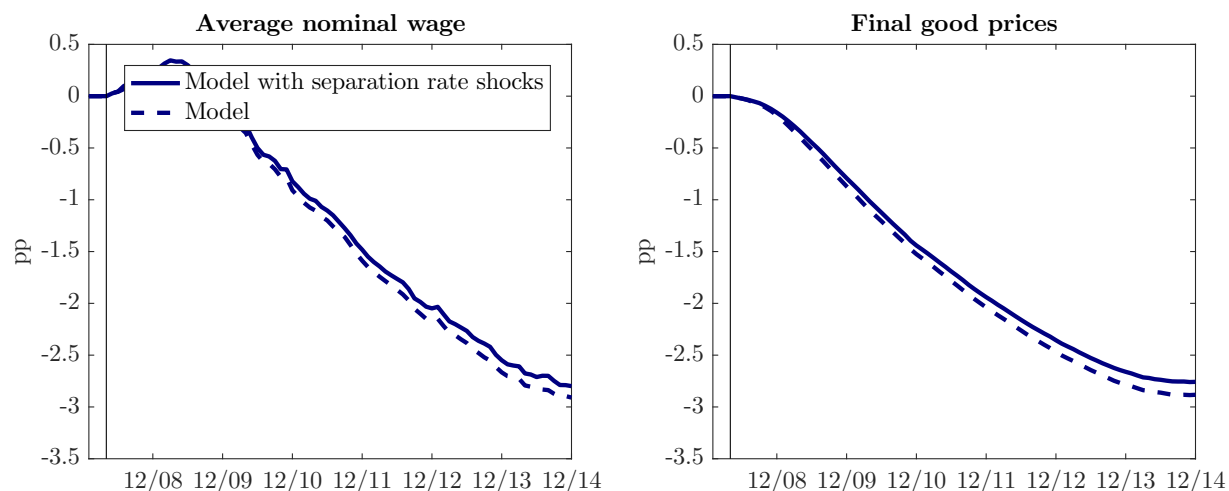


Figure A.11: wages and prices with and without separation rate shocks

Note: series displayed in deviations from steady-state. Both series are generated using alternative sequences of discount factor shocks to match the same unemployment series in Figure 5.

E.3 Case study of extended benefit expiration in December 2013

I finally turn to a case study of the expiration of extended benefits in December 2013. In my baseline analysis, I assume that when extended benefits were reauthorized for the last time in January 2013, agents rationally expected that they would expire at the end of that year. I now consider the model's predictions if agents had expected the benefits to last for longer, only to have them expire unexpectedly in December 2013.

In particular, I study the model's predictions assuming that in January 2013 when 8 months of extended benefits were reauthorized, agents had expected these benefits to last through December 2014 (i.e., for 24 months).

In Figure A.13, I depict the calibrated path of discount factor shocks in the model in which agents had expected extended benefits to last through December 2014, but then they unexpectedly expire in December 2013. Like in the baseline calibration (depicted by the thin line in this same figure), these are calibrated to match the path of unemployment through December 2014, shown in the first panel of Figure A.14. Relative to the baseline calibration, the calibration with unexpected expiration requires a larger positive discount factor shock in January 2013 and a smaller (more negative) discount factor shock in January 2014: expectations of more generous UI in the first case would require a more contractionary offsetting fundamental shock to match the data, while the unexpected expiration in the second case would require an expansionary offsetting fundamental shock to match the data.

Because the shocks are recalibrated to match the path of unemployment, the paths of other variables are very similar to the baseline model. The second panel of Figure A.14

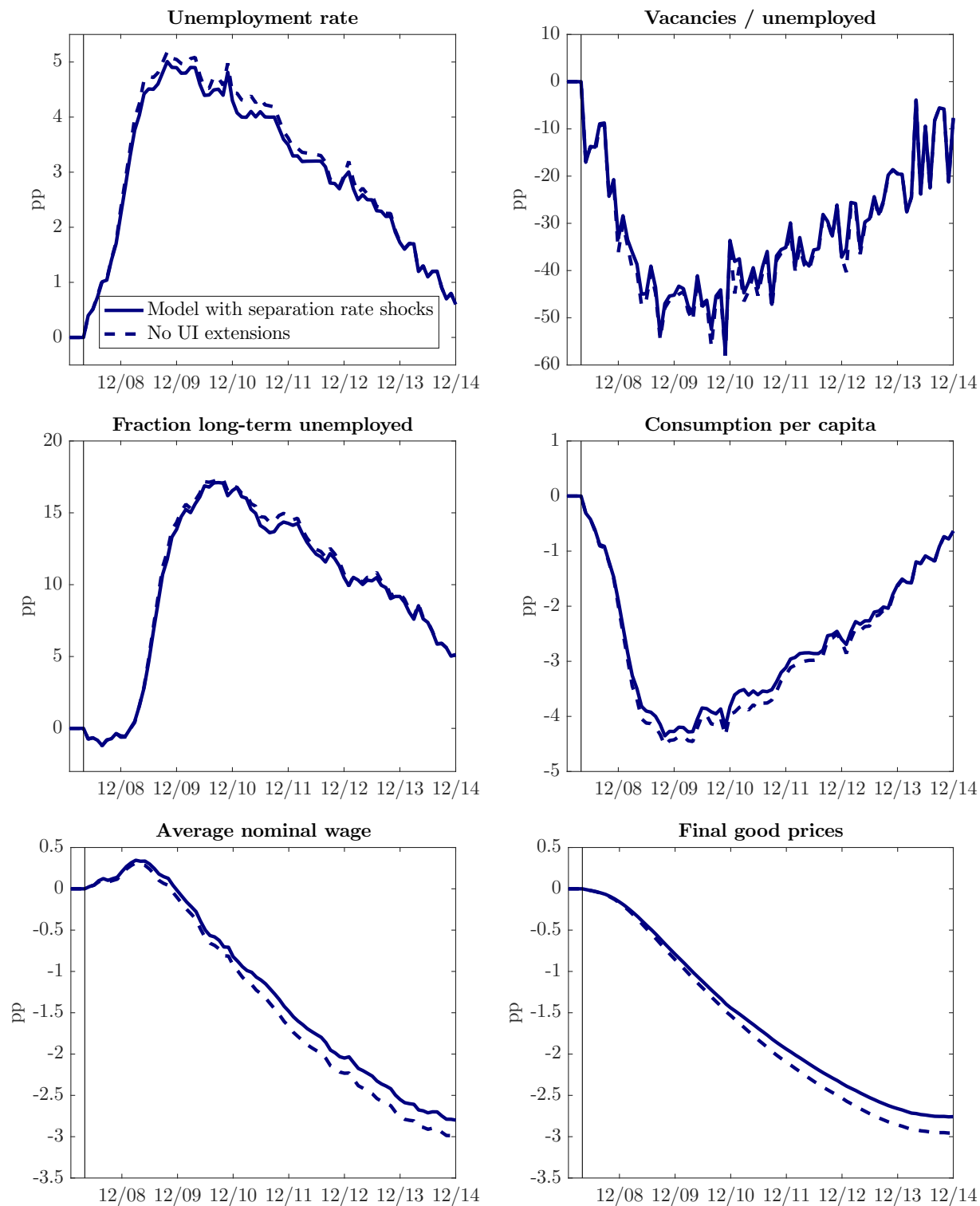


Figure A.12: effects of UI shocks given separation rate shocks

Note: counterfactual environment maintains the same separation rate shocks in Figure A.8 and discount factor shocks in Figure A.9.

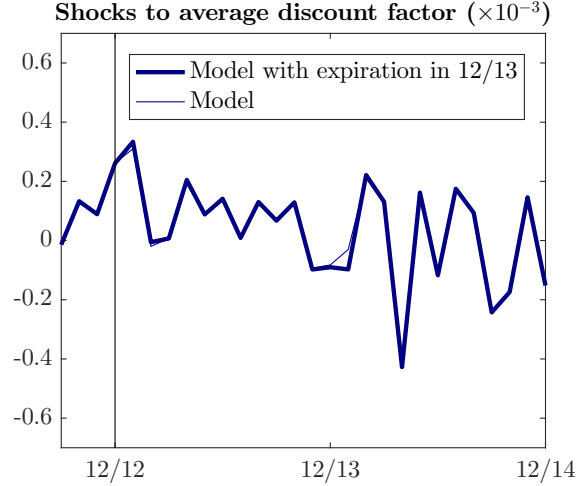


Figure A.13: discount factor shocks given UI expiration in 12/13

Note: average discount factor assumed to follow an AR(1) process with persistence 0.95. Shocks to UI are as described in Table 7, except in 1/13 agents expect UI extensions to last through 12/14, but then in 1/14 they unexpectedly are eliminated. Unemployment series is displayed in deviations from steady-state (for model) and April 2008 (in data).

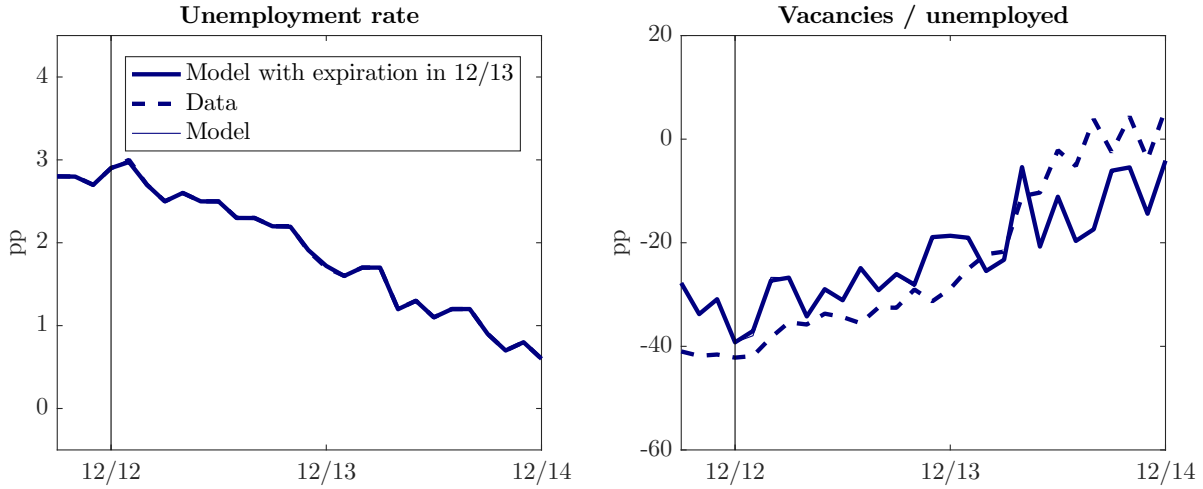


Figure A.14: unemployment and vacancies/unemployment given UI expiration in 12/13

Note: series displayed in deviations from steady-state (for model) and April 2008 (in data).

illustrates this in the context of vacancy data. The dynamics of the model with unexpected expiration and the baseline model are visually identical, and both track the data. Notably, in the model with unexpected expiration, there is no sharp drop in vacancies relative to the unemployed in January 2014 when agents learn that benefits have ended.

Of course, this does not mean that the unexpected expiration of benefits is neutral, because shocks are recalibrated to match the data. Figure A.15 compares the model with

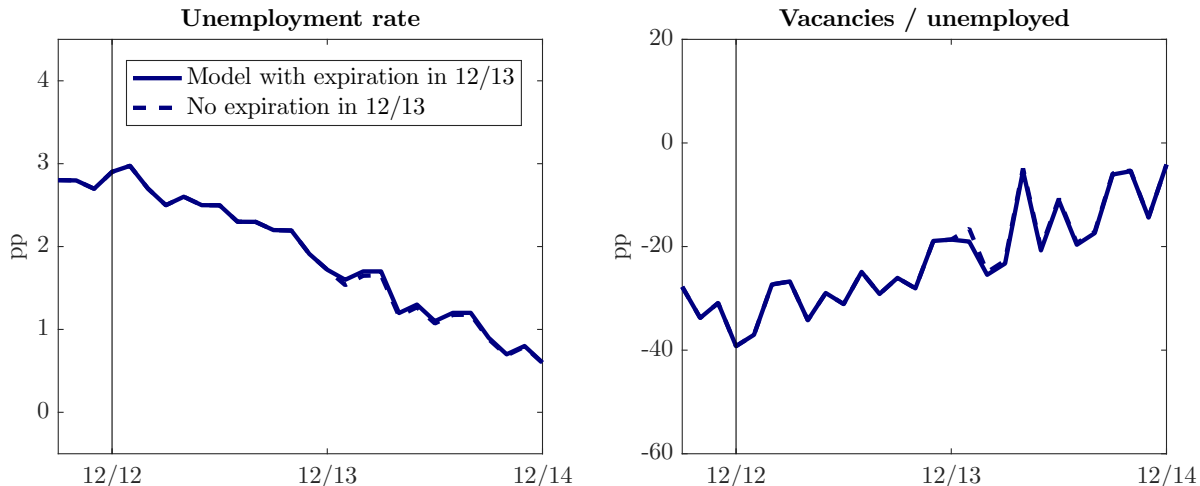


Figure A.15: effects of UI expiration in 12/13

Note: counterfactual environment maintains the same discount factor shocks in Figure A.13.

expiration to a counterfactual in which extended benefits had not expired, and instead had continued as expected through December 2014. As is evident, in the counterfactual the real economy would have recovered slightly faster towards trend.

F Computational algorithm

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

F.1 Algorithm to solve for the stationary RCE

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

$$\{r, t, \theta, s^f(\zeta^e)\}.$$

This generalizes the algorithm of simpler heterogeneous agent models where only a fixed point in r needs to be obtained. In the present setting with labor market frictions and government intervention via UI, a conjecture of t is needed to calculate agents' real income when

employed; a conjecture of θ is needed to calculate agents' search decisions when unemployed; and a conjecture of $s^f(\zeta^e)$ is needed to calculate equilibrium wages.

The idiosyncratic state space is simplified and approximated as follows. The functional forms of UI (28) and duration dependence in matching (27) together define a duration $\bar{d} \equiv \max\{\bar{d}, 8\}$ after which unemployed agents face identical problems. It follows that the state space along the duration margin can be limited to $\{0, 1, \dots, \bar{d} - 1, \geq \bar{d}\}$. I use the Rouwenhorst procedure as described in Kopecky and Suen [2010] to discretize the persistent component of worker productivity into three values, and I use the Gauss-Hermite procedure to discretize the transitory component of worker productivity into three values. Following (25), the discount factors take on three values $\{\bar{\beta} - \Delta^\beta, \bar{\beta}, \bar{\beta} + \Delta^\beta\}$. Finally, I discretize assets using a grid of 151 points, denser near the lower bound \underline{z}^b .

I then solve for the stationary RCE as follows:

1. Initialize small, positive tolerance levels $\{\epsilon_{z+1}, \epsilon_t, \epsilon_\theta, \epsilon_{sf}\}$ and step lengths $\{\Delta_r, \Delta_t, \Delta_\theta, \Delta_{sf}\}$.
2. Conjecture $\{r, t, \theta, s^f(\zeta^e)\}$.
3. Use (A.21) and (A.22) to compute $w(\zeta^e)$.
4. Use (A.28) and (A.29) to compute real incomes $\{y^e(\zeta^e), y^u(\zeta^u)\}$.
5. Iterate workers' value functions backward using optimality conditions (A.15)-(A.18) and resource constraints (A.26)-(A.27), obtaining approximations of the value functions $\{\hat{v}^e, \hat{v}^u\}$ and policy functions $\{\hat{s}, \hat{c}^e, \hat{c}^u\}$. Here Carroll [2006]'s endogenous gridpoint method substantially speeds up convergence.
6. Iterate the resulting policy functions forward, obtaining approximations of the beginning-of-period distribution $\{\hat{p}^e, \hat{\varphi}^e, \hat{\varphi}^u\}$ and middle-of-period distribution $\{\hat{p}^e, \hat{\varphi}^e, \hat{\varphi}^u\}$.
7. Using the approximated policy functions and ergodic distribution, assess market clearing and consistency conditions and update $\{r', t', \theta', s^{f'}(\zeta^e)\}$ accordingly:
 - (a) Compute the end-of-period market value of firm equity q using (A.30), (A.33), (A.34) and stationarity.
 - (b) Compute steady-state net asset demand \hat{z}_{+1} , given by the left-hand side less the right-hand side of (A.32).
 - (c) Compute steady-state taxes \hat{t} solving (A.35).
 - (d) Compute the firm's marginal profit from posting a vacancy $\widehat{dvacpost}$, given by the left-hand side of (A.22).

- (e) Compute workers' surplus net of firms' surplus $\widehat{dbargain}$, given by the left-hand side less the right-hand side of (A.25).
- (f) Set $\{r', t', \theta', s^{f'}(\zeta^e)\}$ based on the deviations in $\{\hat{z}_{+1}, \hat{t}, \widehat{dvacpost}, \widehat{dbargain}\}$ from $\{0, t, 0, 0\}$:

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

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

F.2 Algorithm to solve for transitional dynamics

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

$$\{\tilde{q}_0, \{r_0, t_0, \theta_0, w_0(\zeta^e)\}, \dots, \{r_T, t_T, \theta_T, w_T(\zeta^e)\}\}$$

for T very large, at which point it is assumed that the initial stationary RCE is again reached. The rationale for iterating over $\{r_t, t_t, \theta_t, w_t(\zeta^e)\}$ was explained in the prior subsection.¹⁵ We also need to iterate over the beginning-of-period-0 market value of equity \tilde{q}_0 , given by

$$\tilde{q}_0 = \pi_0 + q_0, \tag{A.39}$$

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

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

$$\{\tilde{q}_0, \{r_0, t_0, \theta_0, \mu_0, w_0(\zeta^e)\}, \dots, \{r_T, t_T, \theta_T, \mu_T, w_T(\zeta^e)\}\},$$

¹⁵While in the prior subsection we iterated over firm surplus $s^f(\zeta^e)$ rather than real wages $w(\zeta^e)$, this was only because in steady-state it is much easier to use (A.21) and (A.22) to solve for $w(\zeta^e)$ given $s^f(\zeta^e)$ rather than vice-versa.

where $\mu_t \equiv \frac{P_t}{P_t^e}$ is the gross mark-up of retailers, no longer constant with nominal rigidity.

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

I then solve for the equilibrium as follows:

1. Initialize a small, positive tolerance level ϵ .
2. Conjecture $\{\tilde{q}_0, \{r_t, t_t, \theta_t, w_t(\zeta^e)\}_{t=0}^T\}$ in the flexible price case or $\{\tilde{q}_0, \{m_t, t_t, \theta_t, \mu_t, w_t(\zeta^e)\}_{t=0}^T\}$ in the sticky price case.
3. Under flexible prices, solve for the constant mark-up μ consistent with (A.19).
4. Use (A.28)-(A.29) to compute real incomes $\{y_t^e(\zeta^e), y_t^u(\zeta^u)\}$.
5. Iterate workers' value functions backward using optimality conditions (A.15)-(A.18) and resource constraints (A.26)-(A.27), obtaining approximations of the value functions $\{\hat{v}_t^e, \hat{v}_t^u\}_{t=0}^T$ and policy functions $\{\hat{s}_t, \hat{c}_t^e, \hat{c}_t^u\}_{t=0}^T$. Carroll [2006]'s endogenous gridpoint method again speeds up convergence.
6. Re-value agents' initial wealth given the conjectured \tilde{q}_0 and assumed equity shares in asset portfolios across the idiosyncratic state space, described further in section C.2.
7. Using the policy functions from step 5 with the re-valued wealth distribution from step 6, iterate forward to obtain approximations of the beginning-of-period distributions $\{\hat{p}_t^e, \hat{\varphi}_t^e, \hat{\varphi}_t^u\}_{t=0}^T$ and middle-of-period distributions $\{\hat{p}_t^e, \hat{\varphi}_t^e, \hat{\varphi}_t^u\}_{t=0}^T$.
8. Using the approximated policy functions and distributions, assess market clearing and consistency conditions and update $\{\tilde{q}_0, \{m_t, t_t, \theta_t, w_t(\zeta^e)\}_{t=0}^T\}$ (under flexible prices) or $\{\tilde{q}_0, \{m_t, t_t, \theta_t, \mu_t, w_t(\zeta^e)\}_{t=0}^T\}$ (under sticky prices) accordingly:
 - (a) Compute the end-of-period market value of firm equity by iterating backward on (A.30), (A.33), and (A.34) given $q_{T+1} = q^{ss}$.
 - (b) Compute the beginning-of-period-0 market value of firm equity \hat{q}_0 using (A.39) and \hat{q}_0 from the previous step.
 - (c) Compute net asset demand \hat{z}_{t+1} , given by the left-hand side less the right-hand side of (A.32).
 - (d) Compute taxes \hat{t}_t solving (A.35).
 - (e) Iterate backwards on (A.21) and (A.22) given $s_{T+1}^f(\zeta^e) = s^f(\zeta^e)$ to compute $s_t^f(\zeta^e)$. Then compute the firm's marginal profit from posting a vacancy $\widehat{dvacpost}_t$, given by the left-hand side of (A.22).

- (f) Compute real wages $\hat{w}_t(\zeta^e)$ implied by (14).
- (g) Under sticky prices, iterate backwards on price-setting (A.19) to compute $\{\Pi_t^P\}$ given $\Pi_{T+1}^P = 0$, evaluate the monetary policy rule (29) to compute $\{i_t\}$, and then construct $\{\hat{r}_t = i_t(1 + \Pi_{t+1}^P)^{-1}\}$.
- (h) Under flexible prices:
- If $\|(\hat{\tilde{q}}_0 - \tilde{q}_0, \{\hat{\tilde{z}}_{t+1}, \hat{t}_t - t_t, \widehat{dvacpost}_t, \hat{w}_t(\zeta^e) - w_t(\zeta^e)\}_{t=0}^T)\| < \epsilon$, stop.
 - Otherwise, let

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

where the Jacobian H_{flex} is constructed as described in the next subsection.

- (i) Under sticky prices:
- If $\|(\hat{\tilde{q}}_0 - \tilde{q}_0, \{\hat{\tilde{z}}_{t+1}, \hat{t}_t - t_t, \widehat{dvacpost}_t, \hat{r}_t - r_t, \hat{w}_t(\zeta^e) - w_t(\zeta^e)\}_{t=0}^T)\| < \epsilon$, stop.
 - Otherwise, let

$$(\tilde{q}'_0, \{m'_t, t'_t, \theta'_t, \mu'_t, w'_t(\zeta^e)\}_{t=0}^T)' = (\tilde{q}_0, \{m_t, t_t, \theta_t, \mu_t, w_t(\zeta^e)\}_{t=0}^T)' - H_{sticky}^{-1}(\hat{\tilde{q}}_0 - \tilde{q}_0, \{\hat{\tilde{z}}_{t+1}, \hat{t}_t - t_t, \widehat{dvacpost}_t, \hat{r}_t - r_t, \hat{w}_t(\zeta^e) - w_t(\zeta^e)\}_{t=0}^T)',$$

where the Jacobian H_{sticky} is constructed as described in the next subsection.

I use the quasi-Newton algorithm to solve for the fixed point in macroeconomic aggregates in the last two steps above. As recommended by Auclert et al. [2021], the use of the quasi-Newton algorithm substantially speeds up convergence versus, for instance, slowly updating the sequence of macroeconomic aggregates using ad-hoc updating rules. A key ingredient in this algorithm is an estimate of the Jacobian H associated with the system of market clearing and consistency conditions which characterize an equilibrium, which I describe in the next subsection.

F.3 Jacobians used to solve for transitional dynamics

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

$$\begin{aligned} \hat{\tilde{q}}_0(\tilde{q}_0, \{r_t, t_t, \theta_t, w_t(\zeta^e)\}_{t=0}^T) - \tilde{q}_0 &= 0, \\ \hat{\tilde{z}}_{t+1}(\tilde{q}_0, \{r_t, t_t, \theta_t, w_t(\zeta^e)\}_{t=0}^T) &= 0, \quad \forall t \in \{0, \dots, T\}, \end{aligned}$$

$$\begin{aligned}
\hat{t}_t(\tilde{q}_0, \{r_t, t_t, \theta_t, w_t(\zeta^e)\}_{t=0}^T) - t_t &= 0, \quad \forall t \in \{0, \dots, T\}, \\
\widehat{dvacpost}_t(\tilde{q}_0, \{r_t, t_t, \theta_t, w_t(\zeta^e)\}_{t=0}^T) &= 0, \quad \forall t \in \{0, \dots, T\}, \\
\hat{w}_t(\zeta^e; \tilde{q}_0, \{r_t, t_t, \theta_t, w_t(\zeta^e)\}_{t=0}^T) - w_t(\zeta^e) &= 0, \quad \forall t \in \{0, \dots, T\},
\end{aligned}$$

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

$$\begin{aligned}
\hat{q}_0(\tilde{q}_0, \{r_t, t_t, \theta_t, \mu_t, w_t(\zeta^e)\}_{t=0}^T) - \tilde{q}_0 &= 0, \\
\hat{z}_{t+1}(\tilde{q}_0, \{r_t, t_t, \theta_t, \mu_t, w_t(\zeta^e)\}_{t=0}^T) &= 0, \quad \forall t \in \{0, \dots, T\}, \\
\hat{t}_t(\tilde{q}_0, \{r_t, t_t, \theta_t, \mu_t, w_t(\zeta^e)\}_{t=0}^T) - t_t &= 0, \quad \forall t \in \{0, \dots, T\}, \\
\widehat{dvacpost}_t(\tilde{q}_0, \{r_t, t_t, \theta_t, \mu_t, w_t(\zeta^e)\}_{t=0}^T) &= 0, \quad \forall t \in \{0, \dots, T\}, \\
\hat{r}_t(\tilde{q}_0, \{r_t, t_t, \theta_t, \mu_t, w_t(\zeta^e)\}_{t=0}^T) - r_t &= 0, \quad \forall t \in \{0, \dots, T\}, \\
\hat{w}_t(\zeta^e; \tilde{q}_0, \{r_t, t_t, \theta_t, \mu_t, w_t(\zeta^e)\}_{t=0}^T) - w_t(\zeta^e) &= 0, \quad \forall t \in \{0, \dots, T\}.
\end{aligned}$$

Let the associated Jacobian evaluated at the stationary RCE be denoted H_{sticky} . Note that locally around the stationary RCE, the zero lower bound will not be binding. To adjust H_{sticky} to account for a constant nominal interest rate rather than active Taylor rule, we thus also compute the Jacobian of

$$\hat{i}_t(\tilde{q}_0, \{r_t, t_t, \theta_t, \mu_t, w_t(\zeta^e)\}_{t=0}^T), \quad \forall t \in \{0, \dots, T\},$$

which I denote H_i at the stationary RCE.

I estimate these Jacobians numerically by simply perturbing each of the inputs and parallelizing the computation. These are the Jacobians I use when characterizing all of the impulse responses starting from the stationary RCE in section 5 of the main text and section E.1 of this appendix.

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

1. Assume the economy is in the deterministic steady-state as of period -1 .
2. In period 0, an aggregate shock is realized. Characterize the transitional dynamics using the algorithm in the prior subsection, given the steady-state Jacobian H_{sticky} .
3. Given the equilibrium from *period 1* onwards (with no more shocks), denote the unemployment rate in the first period of this simulation $1 - p_1^e$. Further characterize the Jacobian associated with the market clearing and consistency conditions through period T :

$$\begin{aligned}
\hat{q}_1(\tilde{q}_1, \{r_{1+t}, t_{1+t}, \theta_{1+t}, \mu_{1+t}, w_{1+t}(\zeta^e)\}_{t=0}^{T-1}) - \tilde{q}_1 &= 0, \\
\hat{z}_2(\tilde{q}_1, \{r_{1+t}, t_{1+t}, \theta_{1+t}, \mu_{1+t}, w_{1+t}(\zeta^e)\}_{t=0}^{T-1}) &= 0, \quad \forall t \in \{0, \dots, T-1\}, \\
\hat{t}_{1+t}(\tilde{q}_1, \{r_{1+t}, t_{1+t}, \theta_{1+t}, \mu_{1+t}, w_{1+t}(\zeta^e)\}_{t=0}^{T-1}) - t_{1+t} &= 0, \quad \forall t \in \{0, \dots, T-1\}, \\
\widehat{dvacpost}_{1+t}(\tilde{q}_1, \{r_{1+t}, t_{1+t}, \theta_{1+t}, \mu_{1+t}, w_{1+t}(\zeta^e)\}_{t=0}^{T-1}) &= 0, \quad \forall t \in \{0, \dots, T-1\}, \\
\hat{r}_{1+t}(\tilde{q}_1, \{r_{1+t}, t_{1+t}, \theta_{1+t}, \mu_{1+t}, w_{1+t}(\zeta^e)\}_{t=0}^{T-1}) - r_{1+t} &= 0, \quad \forall t \in \{0, \dots, T-1\}, \\
\hat{w}_{1+t}(\tilde{q}_1, \{r_{1+t}, t_{1+t}, \theta_{1+t}, \mu_{1+t}, w_{1+t}(\zeta^e)\}_{t=0}^{T-1}) - w_{1+t}(\zeta^e) &= 0, \quad \forall t \in \{0, \dots, T-1\}.
\end{aligned}$$

This is again done numerically by simply perturbing each of the inputs and parallelizing the computation. Denote this Jacobian $H_{sticky,1}$. Similarly, characterize the Jacobian associated with the active Taylor rule through period T

$$i_{1+t}(\tilde{q}_1, \{r_{1+t}, t_{1+t}, \theta_{1+t}, \mu_{1+t}, w_{1+t}(\zeta^e)\}_{t=0}^{T-1}), \quad \forall t \in \{0, \dots, T-1\}.$$

Denote this Jacobian $H_{i,1}$.

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

$$dH_{sticky} \equiv \frac{H_{sticky,1} - (\mathcal{T}_1^{(1)})' H_{sticky} \mathcal{T}_1^{(1)}}{(1 - p_1^e) - (1 - p^e)},$$

where $\mathcal{T}_1^{(1)}$ is a selection matrix which eliminates from H_{sticky} all rows pertaining to equilibrium conditions in the last period and all columns pertaining to equilibrium variables in the last period. Thus $(\mathcal{T}_1^{(1)})' H_{sticky} \mathcal{T}_1^{(1)}$ is effectively the Jacobian of an economy with one less period in the finite sequence-space representation, and is what we compare to $H_{sticky,1}$. Analogously, compute

$$dH_i \equiv \frac{H_{i,1} - (\mathcal{T}_{i,1}^{(1)})' H_i \mathcal{T}_{i,1}^{(1)}}{(1 - p_1^e) - (1 - p^e)},$$

where $\mathcal{T}_{i,1}^{(1)}$ is a selection matrix which eliminates from H_i the last row and all columns pertaining to equilibrium variables in the last period.

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

(a) In period s , an aggregate shock is realized. Compute the approximated Jacobian

$$H_{sticky,s} = \begin{cases} (\mathcal{T}_s^{(1)})' H_{sticky} \mathcal{T}_s^{(1)} + ((1 - p_s^e) - (1 - p^e)) dH_{sticky} & \text{if } s = 1, \\ (\mathcal{T}_s^{(1)})' H_{sticky} \mathcal{T}_s^{(1)} + ((1 - p_s^e) - (1 - p^e)) (\mathcal{T}_s^{(2)})' dH_{sticky} (\mathcal{T}_s^{(2)}) & \text{if } s > 1, \end{cases}$$

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

$$H_{i,s} = \begin{cases} (\mathcal{T}_{i,s}^{(1)})' H_i \mathcal{T}_{i,s}^{(1)} + ((1 - p_s^e) - (1 - p^e)) dH_i & \text{if } s = 1, \\ (\mathcal{T}_{i,s}^{(1)})' H_i \mathcal{T}_{i,s}^{(1)} + ((1 - p_s^e) - (1 - p^e)) (\mathcal{T}_{i,s}^{(2)})' dH_i (\mathcal{T}_{i,s}^{(2)}) & \text{if } s > 1, \end{cases}$$

(b) Construct the approximated Jacobian accounting for the zero lower bound, which is identical to $H_{sticky,s}$ at all rows except $3(T + 1 - s) + 2$ through $4(T + 1 - s) + 1$, and at each row $3(T + 1 - s) + 1 + j$ for $j \in \{1, \dots, T + 1 - s\}$ is given by

$$H_{sticky+zlb,s}[3(T + 1 - s) + 1 + j, :] = \begin{cases} H_{sticky,s}[3(T + 1 - s) + 1 + j, :] - H_{i,s}[j, :] & \text{if zero lower bound binds in} \\ \text{period } j \text{ of simulation from } s \text{ onwards,} \\ H_{sticky,s}[3(T + 1 - s) + 1 + j, :] & \text{otherwise.} \end{cases}$$

Intuitively, in the periods when the zero lower bound is binding, $H_{sticky+zlb,s}$ “undoes” the response of the active Taylor rule on the real interest rate in $H_{sticky,s}$.

- (c) Using $H_{sticky+zlb,s}$, characterize the transitional dynamics starting from period s onwards using the algorithm in the prior subsection.
- (d) Increment s by 1 and return to step (a).

By dynamically updating the Jacobian used in the simulation, I can still solve for the model’s transitional dynamics even though the economy moves far away from the stationary RCE, and the expected horizon at the zero lower bound changes as the simulation proceeds.

To my knowledge, this algorithm is novel to the literature. I use the unemployment rate as the key variable to update the Jacobian in steps 4 and 5(a) because I find that it works well for my purposes; in future work, it would be useful to study whether economic theory can more systematically guide the dynamic updating of the Jacobian.

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