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

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

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

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

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

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

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

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

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.

[1] This 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

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

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

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

$$Y_0^u = P_0 b_0. \tag{A.7}$$

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

$$\theta_0 = \frac{\nu_0}{s_0} \tag{A.8}$$

and the job-finding and vacancy-filling probabilities by

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

Goods market clearing at each date requires

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

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

Finally, budget balance for the government is characterized by

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

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 $\mu_0 \equiv \frac{P_0}{P_0^I}$ 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:

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

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

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

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

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

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

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 $k \to 0$ while $\frac{k}{1-\phi}$ remains fixed,*

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

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

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

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

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

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, $k\theta_0 s_0 \to 0$ and thus output y_0, employment $p(\theta_0)s_0$, and the income of the employed y_0^e are defined by

$$p(\theta_0)s_0c_0^e(y_0^e, r_0) + (1 - p(\theta_0)s_0)c_0^u(b_0, r_0) = y_0,$$
$$p(\theta_0)s_0y_0^e + (1 - p(\theta_0)s_0)b_0 = y_0,$$
$$y_0 = p(\theta_0)s_0,$$

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

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

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

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

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

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

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

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

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

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. □

A.5.3 Lemma A.1

Proof. Log-linearizing the Euler equation yields

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

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 $k \to 0$ limit. Recall further that in the $k \to 0$ 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. □

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

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

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

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

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. □

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

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

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

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

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

$$p(\theta_t)(u(y_t^e)-u(b_t))=\psi'(s_t),$$
$$y_t=p(\theta_t)s_t-k\theta_t s_t$$

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

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

where

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

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 $\chi_y > 0$. □

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

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

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. □

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

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

and an unemployed agent of type ζ_t^u faces

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

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

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

subject to the constraint

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

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

We can further aggregate asset market clearing in bonds

$$p^e_t \int_{\zeta^e_t} \int_{z^f_t} \int_{z^b_t} z^{e,b}_{t+1}(z^b_t, z^f_t; \zeta^e_t) \varphi^e_t(z^b_t, z^f_t; \zeta^e_t) dz^b_t dz^f_t d\zeta^e_t$$
$$+ (1 - p^e_t) \int_{\zeta^u_t} \int_{z^f_t} \int_{z^b_t} z^{u,b}_{t+1}(z^b_t, z^f_t; \zeta^u_t) \varphi^u_t(z^b_t, z^f_t; \zeta^u_t) dz^b_t dz^f_t d\zeta^u_t + z^g_{t+1} = 0,$$

and asset market clearing in firm equity

$$p^e_t \int_{\zeta^e_t} \int_{z^f_t} \int_{z^b_t} z^{e,f}_{t+1}(z^b_t, z^f_t; \zeta^e_t) \varphi^e_t(z^b_t, z^f_t; \zeta^e_t) dz^b_t dz^f_t d\zeta^e_t$$
$$+ (1 - p^e_t) \int_{\zeta^u_t} \int_{z^f_t} \int_{z^b_t} z^{u,f}_{t+1}(z^b_t, z^f_t; \zeta^u_t) \varphi^u_t(z^b_t, z^f_t; \zeta^u_t) dz^b_t dz^f_t d\zeta^u_t = 1$$

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

B.2 Equilibrium conditions

I now characterize the equilibrium.

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

$$p_t(\theta_t; \zeta^u_t) s_t(z_t; \zeta^u_t) \left(\int_{\zeta^e_t} v^e_t(z_t, \zeta^e_t) \Gamma_t(\zeta^e_t | \zeta^u_t) d\zeta^e_t - v^u_t(z_t; \zeta^u_t) \right) = \psi'(s_t(z_t; \zeta^u_t)). \tag{A.15}$$

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

$$u'(c^e_t(z_t; \zeta^e_t)) \geq \beta_t(1 + r_t) \Bigg[(1 - \delta_t(\zeta^e_t)) \int_{\zeta^e_{t+1}} u'(c^e_{t+1}(z^e_{t+1}; \zeta^e_{t+1})) \Gamma_t(\zeta^e_{t+1} | \zeta^e_t) d\zeta^e_{t+1}$$

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

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

given

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

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

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

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

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

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

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

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

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

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

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

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

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

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

In steady-state, this characterizes the equilibrium real wage ($w(\zeta_t^e) = \frac{W^{nb}(\zeta_t^e)}{P(\zeta_t^e)}$). 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

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

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

at each t, where

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

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

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

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

while final goods market clearing implies

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

Asset market clearing implies

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

where the real price of the equity claim is

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

and real dividends are

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

Finally, budget balance for the government implies

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

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

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

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

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

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

[2] A 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 Employed	Median Unemployed	Mean Employed	Mean 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 CPS** $1\{u\}_{i,t+12}$	**2004 SIPP Panel** $1\{u\}_{i,t+12}$	$1\{u\}_{i,t+12}$
$logpay_{it}$	-0.012		
	(0.0006)		
$wealth_{it}$		-0.0002	-0.0001
		(0.00005)	(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** Total	Own	UI	Other HH	SNAP +welf.	Soc. Sec.	**Spending**
Mean prior to job loss	1.00	0.67	0.02	0.21	0.03	0.04	1.00
	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.00)	
Mean during UI recipt	0.76	0.02	0.31	0.29	0.05	0.06	0.91
	(0.02)	(0.00)	(0.01)	(0.02)	(0.01)	(0.01)	
Mean after UI exhaustion	0.55	0.08	0	0.29	0.06	0.07	0.80
	(0.02)	(0.01)	(n/a)	(0.02)	(0.01)	(0.01)	
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

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

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'

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

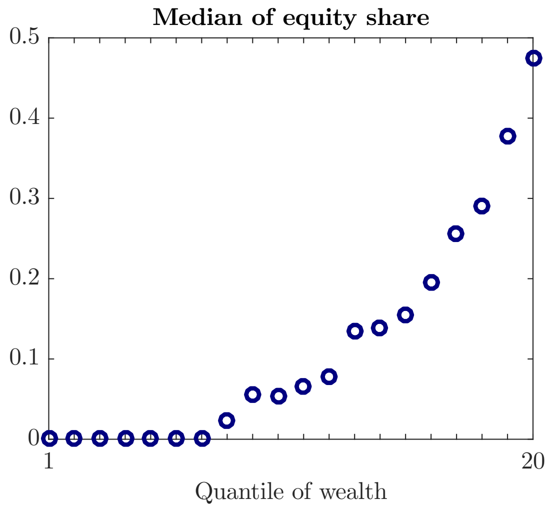

Figure A.1: exposure to corporate profits by wealth quantile in 2004 SCF

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

[4]The 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 *corpexposure* 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-

[5] Computationally, I also assume that agents at the highest 1% of gridpoints in wealth have zero equity to avoid revaluations in wealth far outside the original range. I further check that the 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

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

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

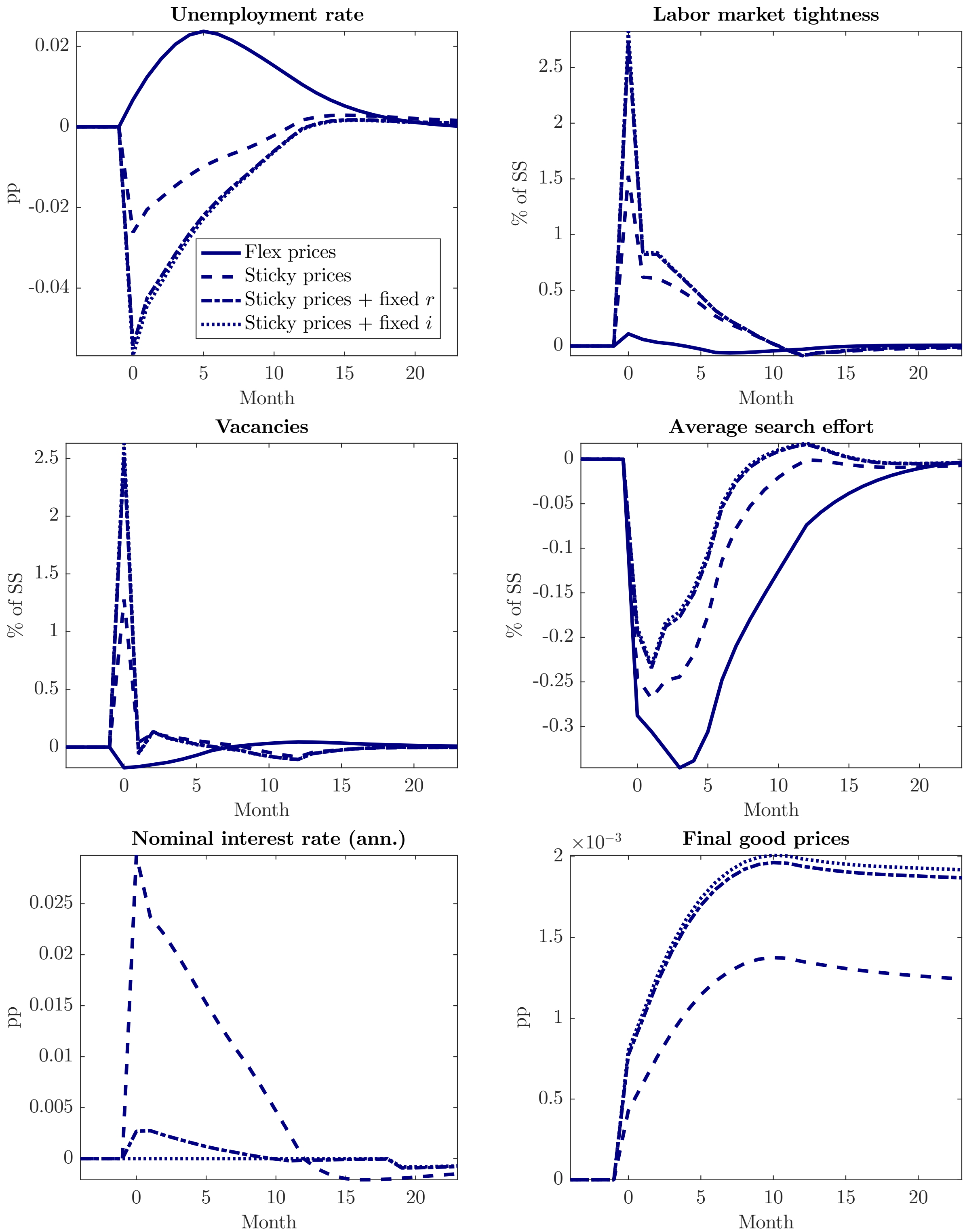

Figure A.2: additional effects of UI starting from steady-state

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
Real rate, wealth, and average MPC				
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
Income during unemployment				
Share unemployed receiving UI	0.39	0.43	ζ	0.5
Max UI / mean wage UI recipients	0.6	0.59	$\overline{ui}$	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
Incidence of unemployment				
Unemployment rate	5%	5.0%	ϕ	0.955
Fraction w/ duration > 6 mos	0.17	0.17	λ	-0.14
Search and the labor market				
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 $\epsilon^{\delta}_{\beta} = \epsilon^{\delta}_{a} = 0$

Note: relative to the baseline, I assume $\epsilon^{\delta}_{\beta} = \epsilon^{\delta}_{a} = 0$ and drop the associated targeted moments. The other targets are unchanged from the baseline.
* Among households earning ≤ \$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

[7] I expect this effect would be reversed in an alternative model of matching where search falls with tightness, as in Mukoyama et al. [2018]. Nonetheless, I 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
Real rate, wealth, and average MPC				
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^δ_β	-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
Income during unemployment				
Share unemployed receiving UI	0.39	0.44	ζ	0.5
Max UI / mean wage UI recipients	0.6	0.58	$\overline{ui}$	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
Incidence of unemployment				
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^δ_a	-0.011
Search and the labor market				
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 $\epsilon^\delta_a = \delta^\delta_\beta = 0$ and re-calibrate the other parameters of the model to match the same other targets. This yields the parameter choices in Table A.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
Real rate, wealth, and average MPC				
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	$\epsilon^{\delta}_{\beta}$	-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
Income during unemployment				
Share unemployed receiving UI	0.39	0.42	ζ	0.5
Max UI / mean wage UI recipients	0.6	0.58	$\overline{ui}$	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
Incidence of unemployment				
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^{δ}_{a}	-0.011
Search and the labor market				
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 ≤ $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.

[8] In 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.

[9] To 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

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

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

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

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

[10]As 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

[11] It is also revealing to ask what would happen if the slope of match efficiencies by duration of unemployment changed, holding fixed the match efficiency of initially unemployed workers — i.e., a shock to 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.

[12] For 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.

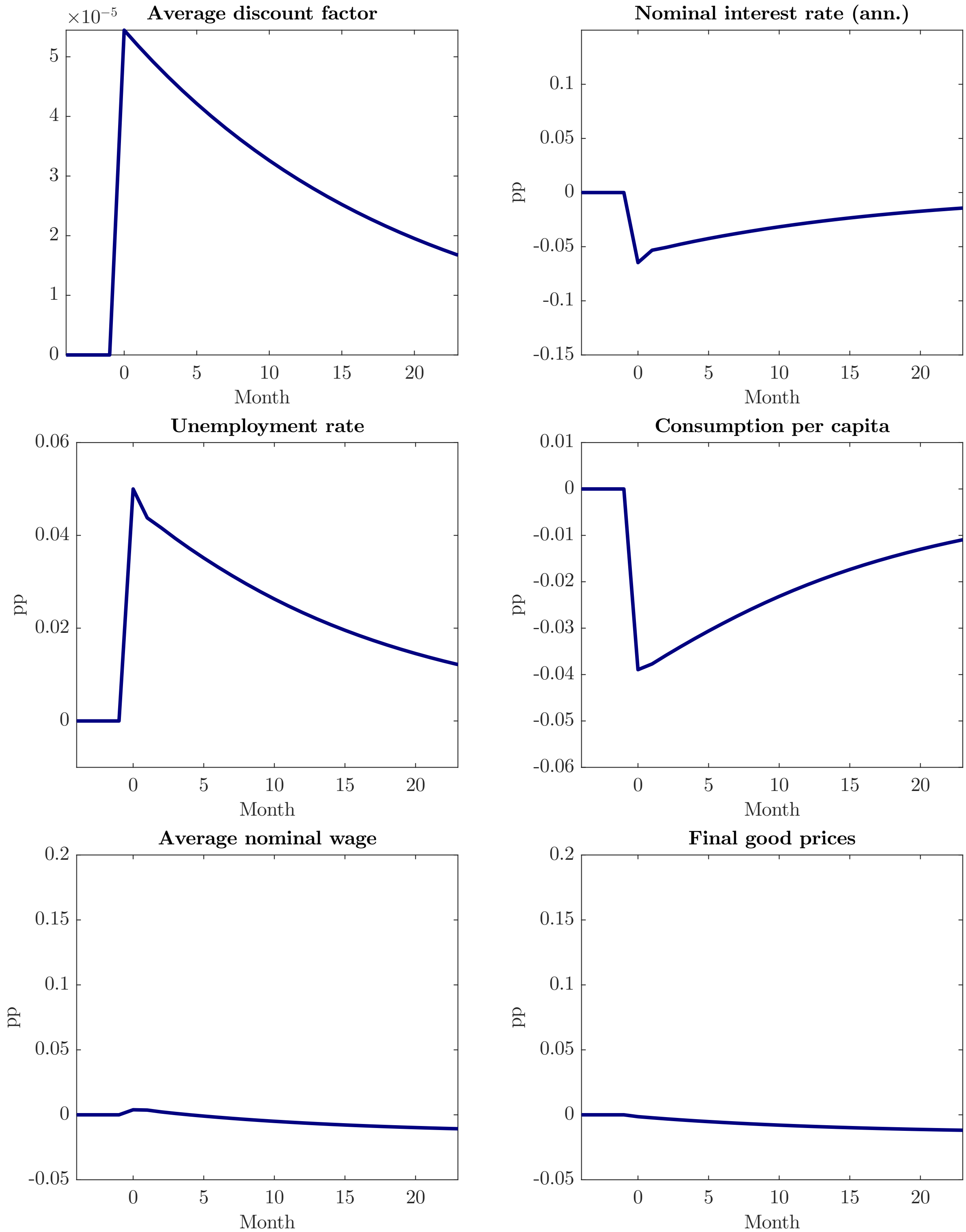

Figure A.3: discount factor shock

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

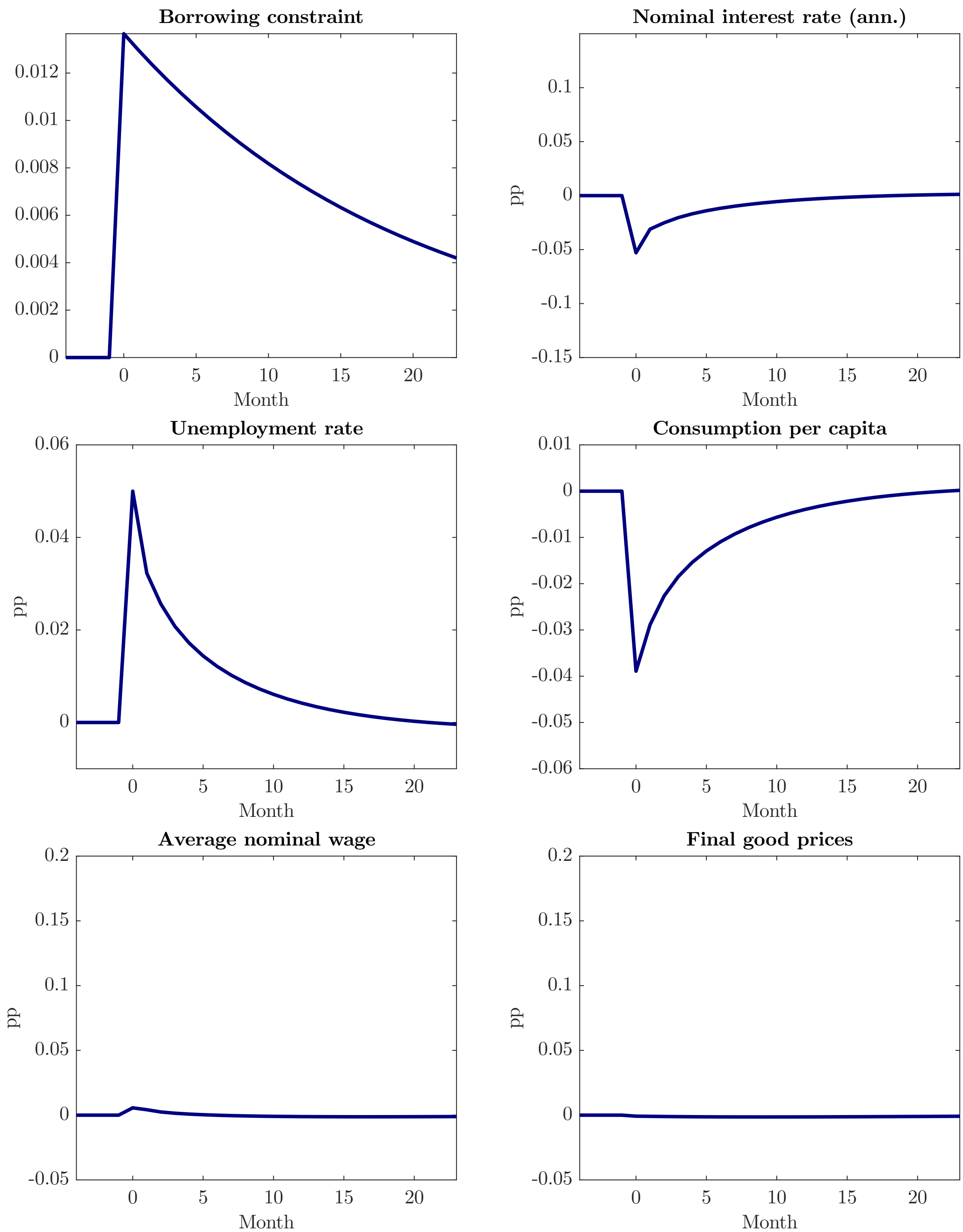

Figure A.4: borrowing constraint shock

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

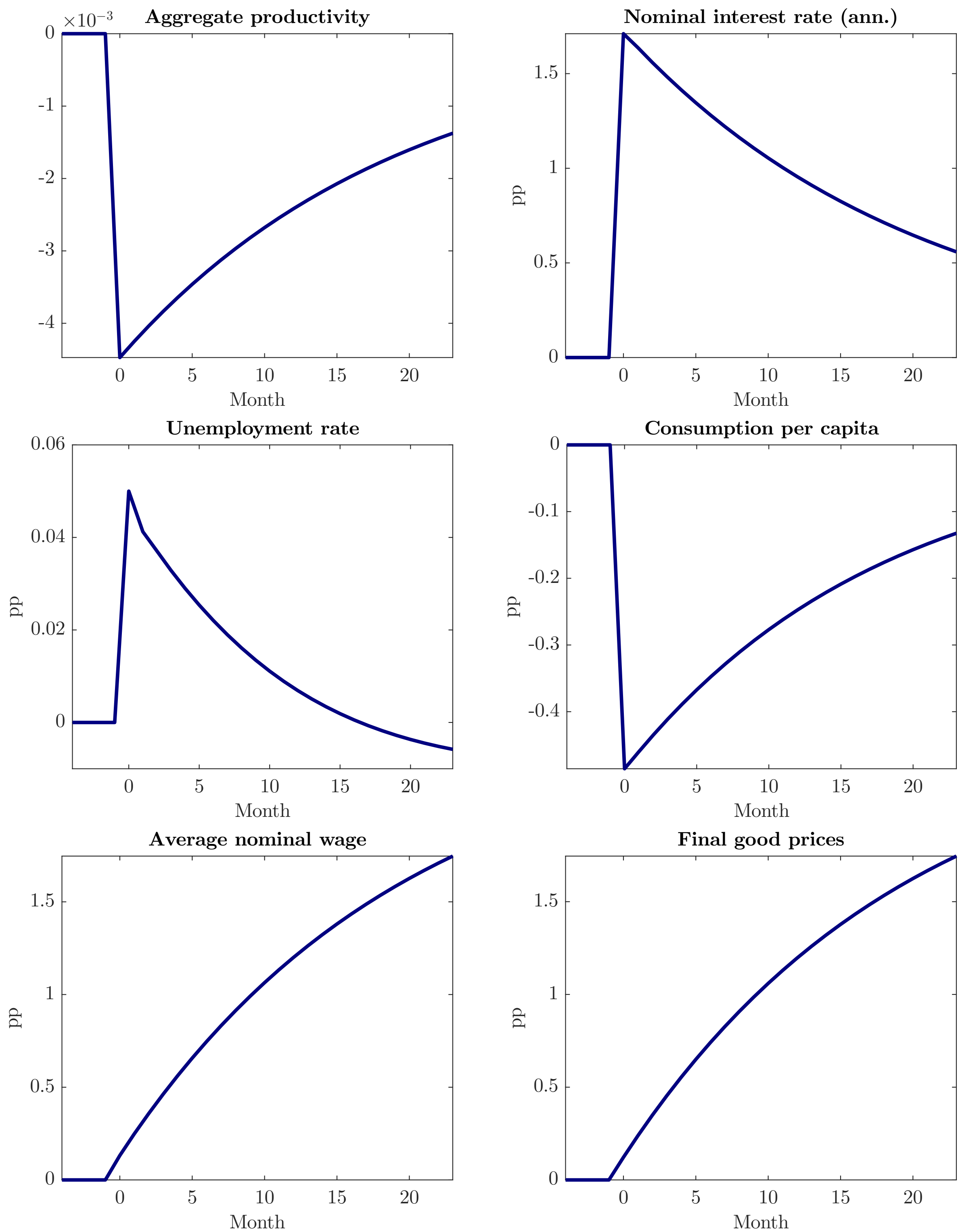

Figure A.5: productivity shock

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

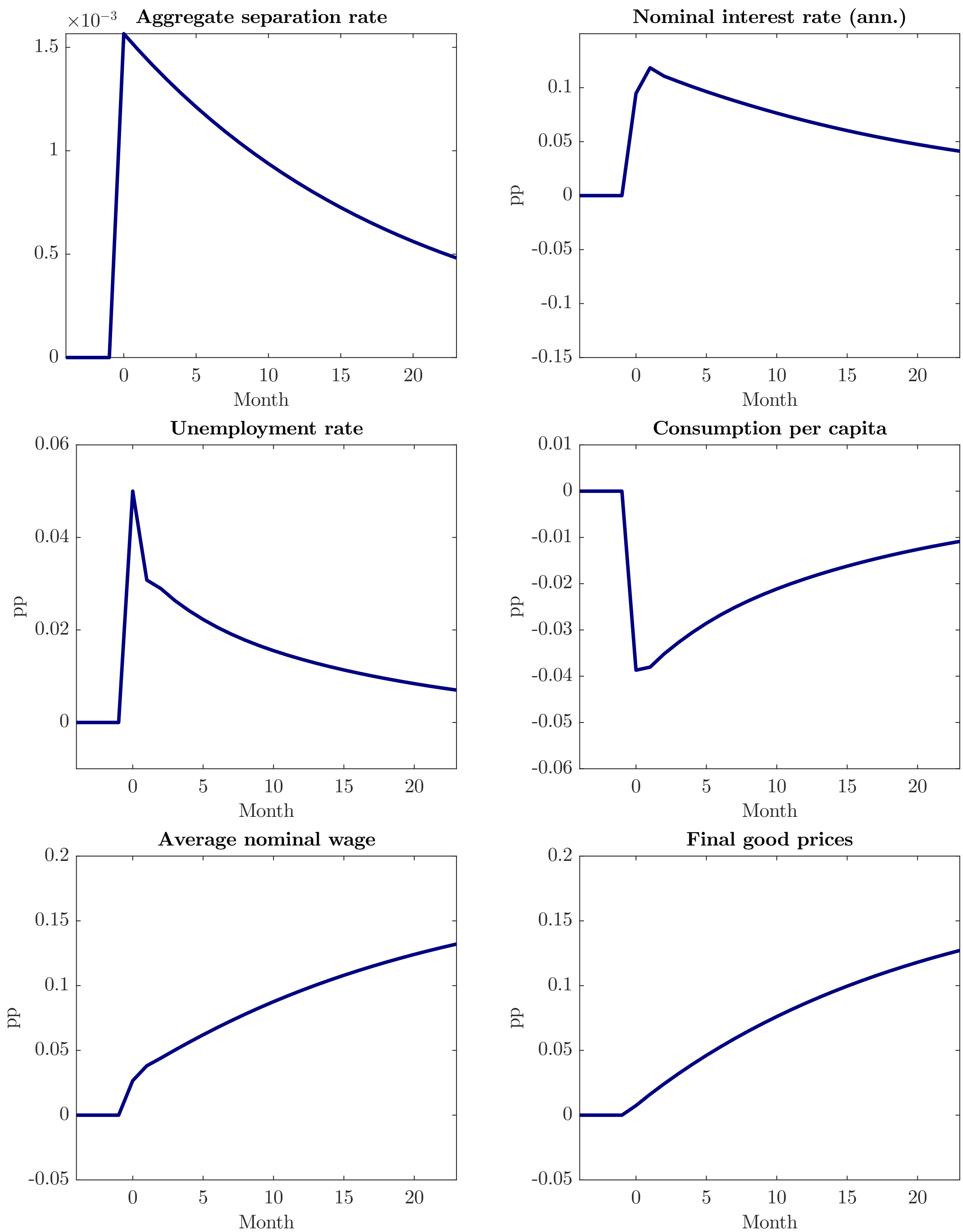

Figure A.6: separation rate shock

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

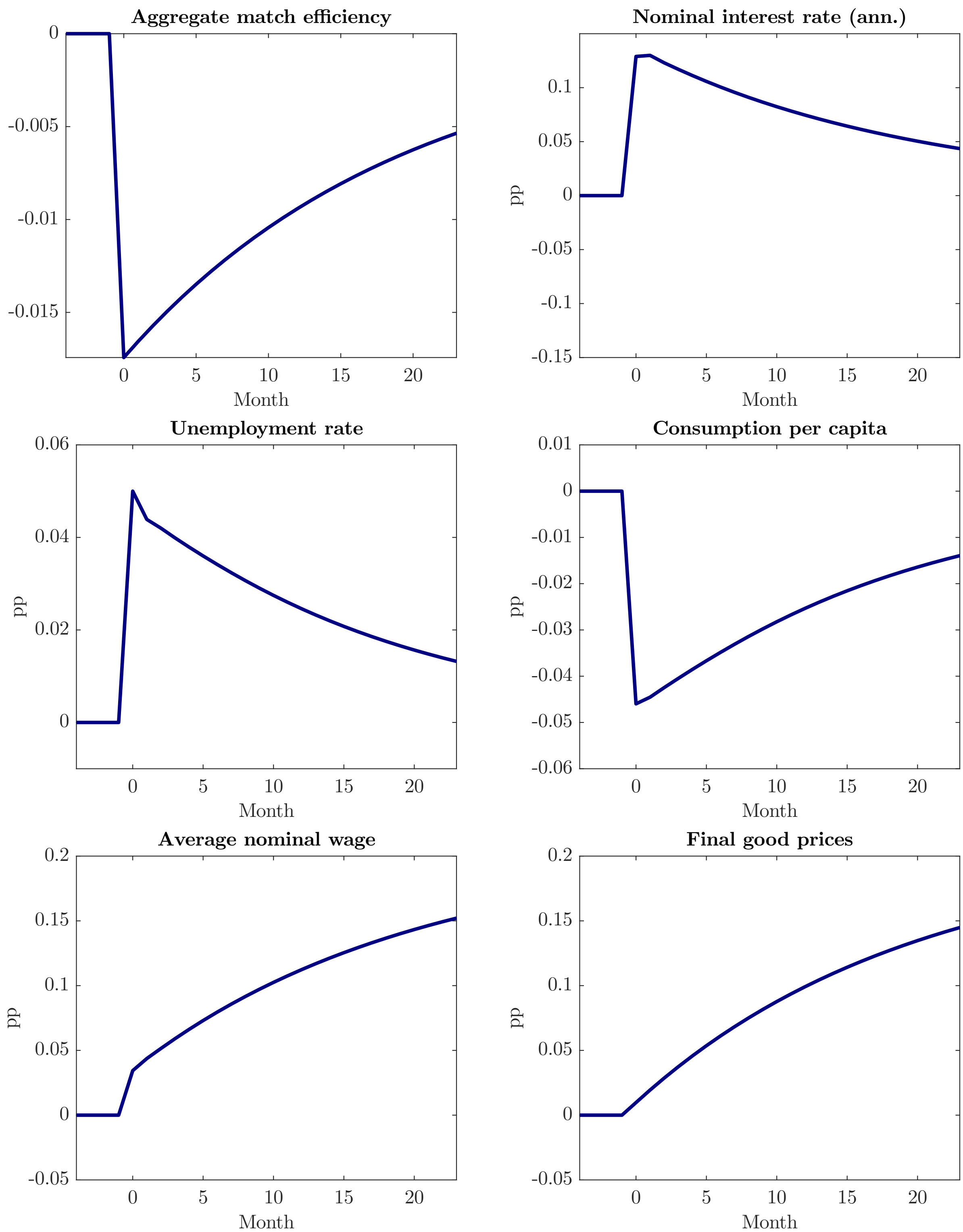

Figure A.7: match efficiency shock

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

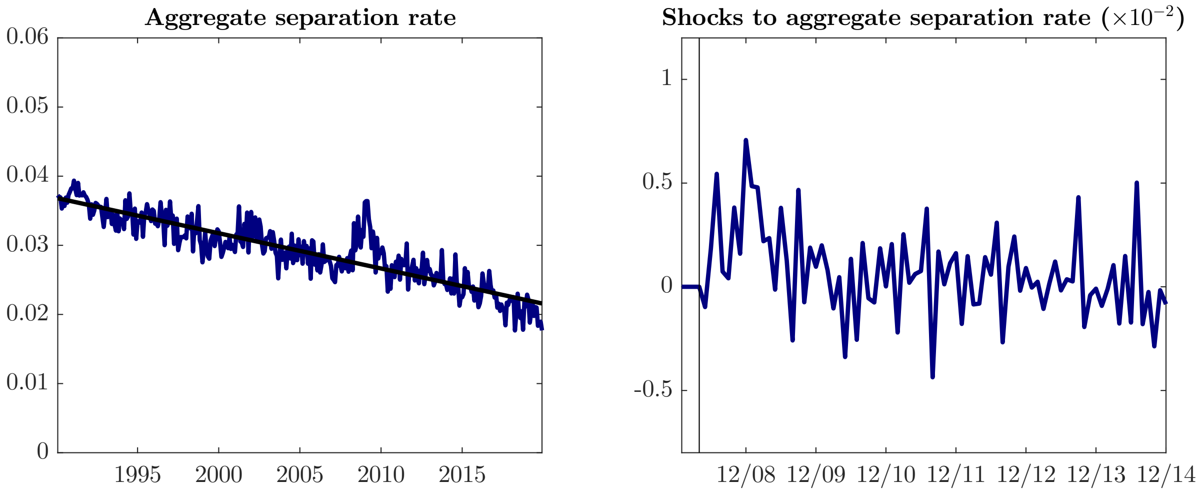

Figure A.8: separation rate and innovations fed into model

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

[13]This 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].

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

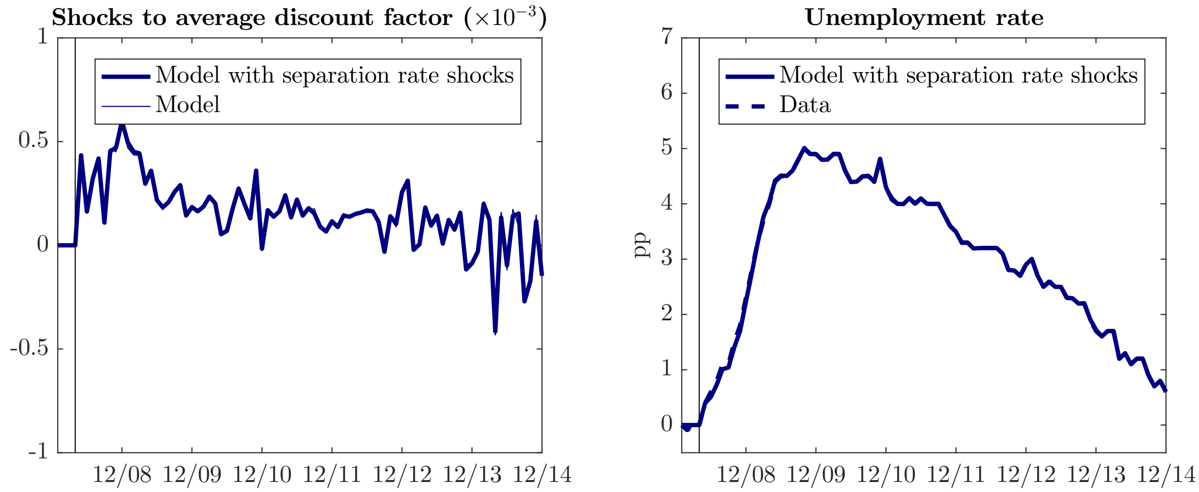

Figure A.9: discount factor shocks and unemployment given separation rate shocks

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.

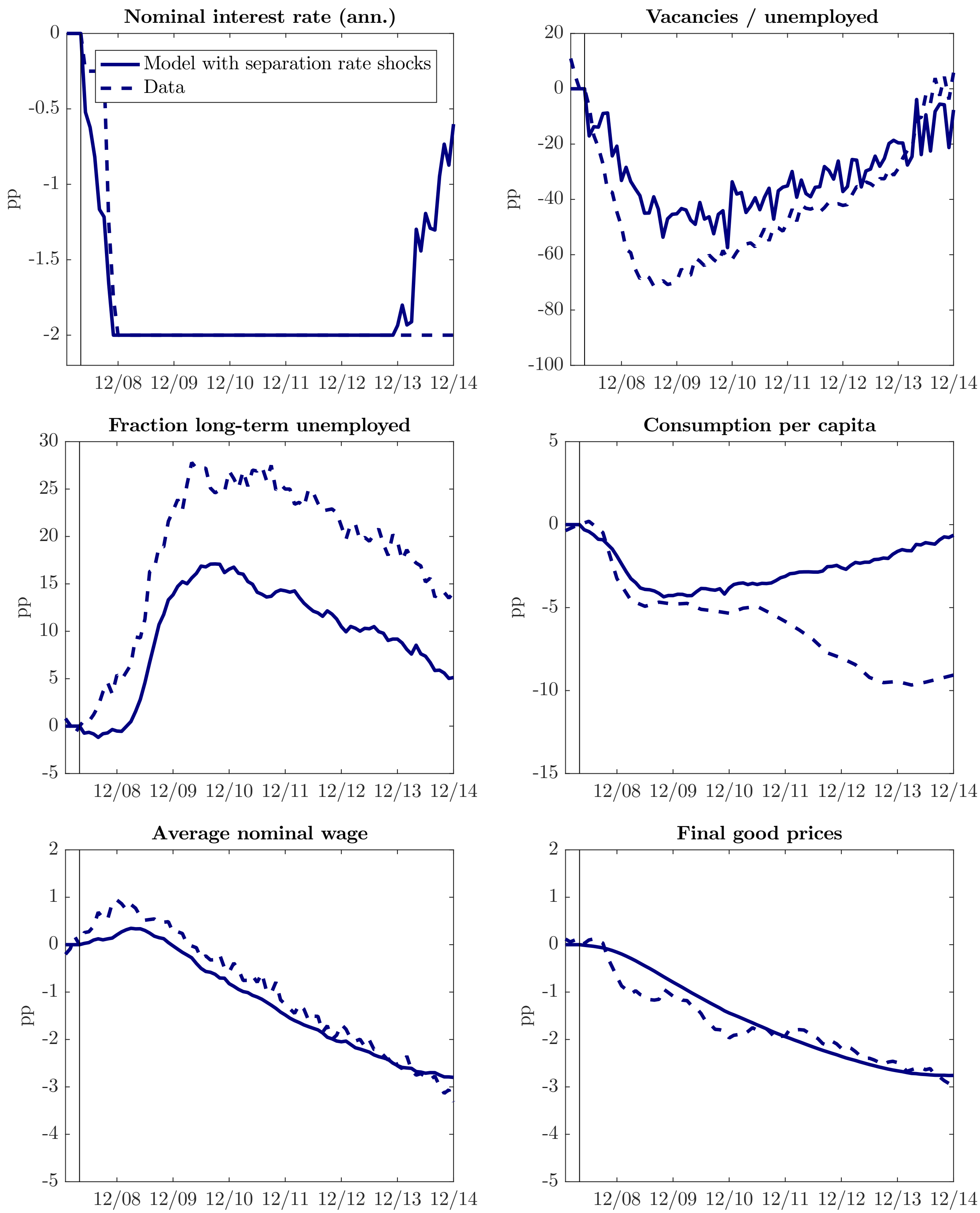

Figure A.10: untargeted macro time-series given separation rate shocks

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).

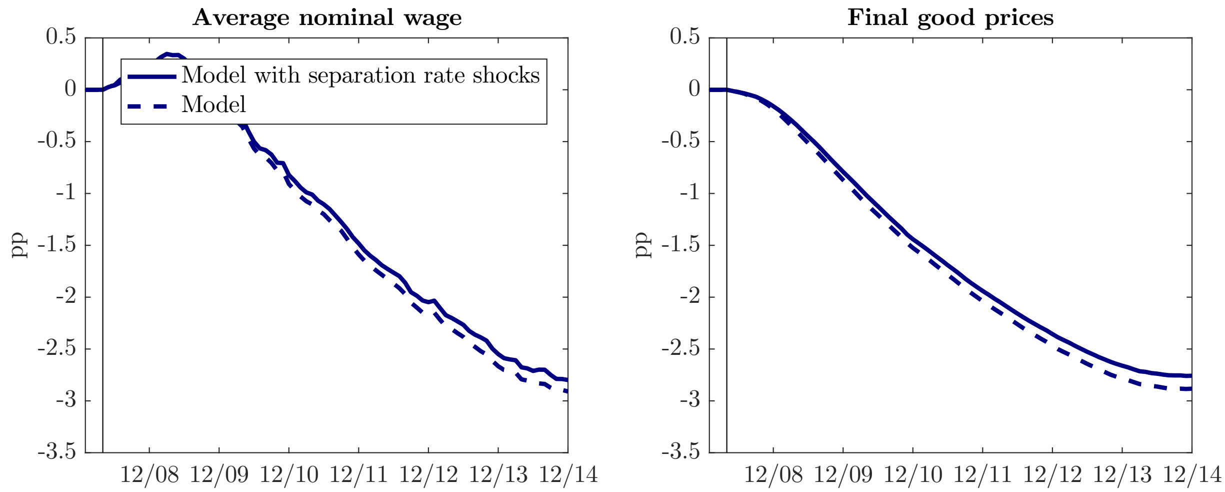

Figure A.11: wages and prices with and without separation rate shocks

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

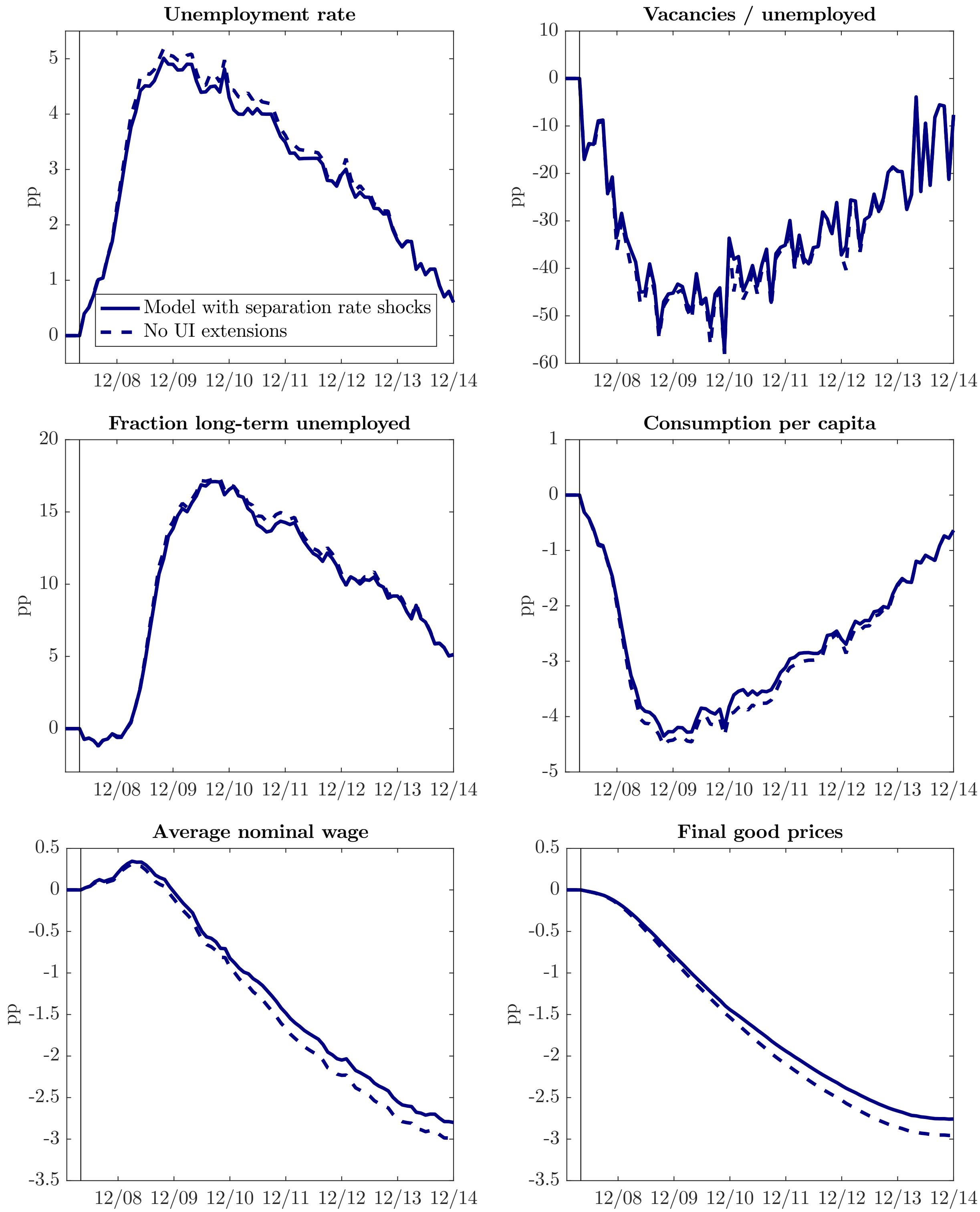

Figure A.12: effects of UI shocks given separation rate shocks

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

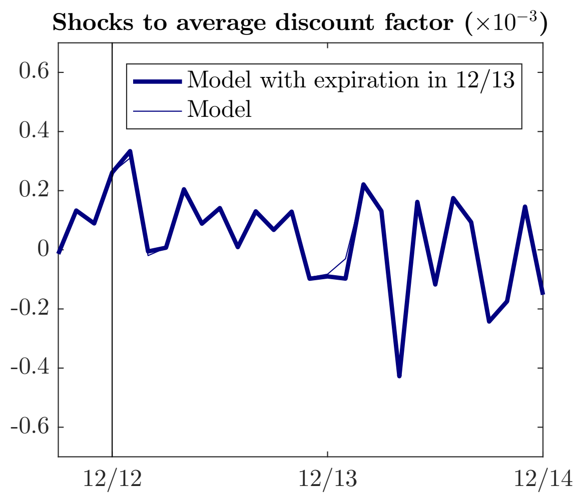

Figure A.13: discount factor shocks given UI expiration in 12/13

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).

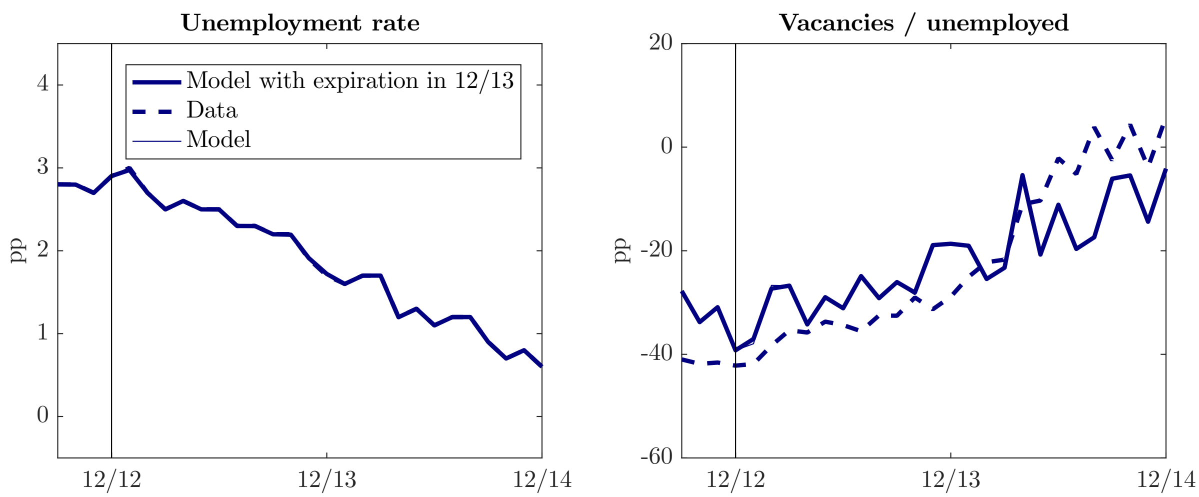

Figure A.14: unemployment and vacancies/unemployment given UI expiration in 12/13

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

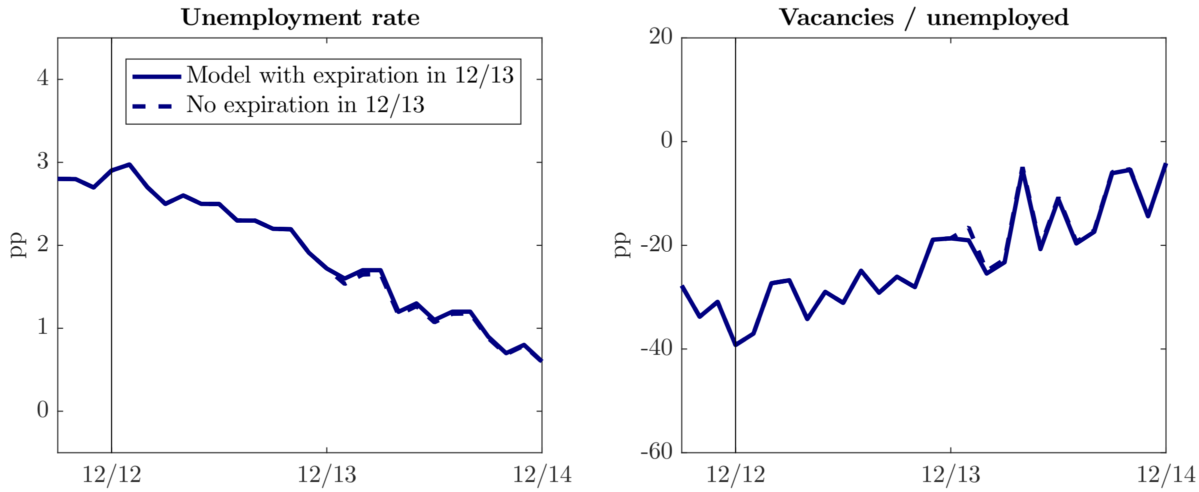

Figure A.15: effects of UI expiration in 12/13

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 $\bar{\bar{d}} \equiv \max\{\bar{d}, 8\}$ after which unemployed agents face identical problems. It follows that the state space along the duration margin can be limited to $\{0, 1, \ldots, \bar{\bar{d}} - 1, \geq \bar{\bar{d}}\}$. 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 $\{\epsilon_{z_{+1}}, \epsilon_t, \epsilon_\theta, \epsilon_{s^f}\}$ and step lengths $\{\Delta_r, \Delta_t, \Delta_\theta, \Delta_{s^f}\}$.

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

$$r' = \begin{cases} r - \Delta_r \hat{z}_{+1} \text{ if } |\hat{z}_{+1}| > \epsilon_{z_{+1}}, \\ r \text{ otherwise} \end{cases},$$

$$t' = \begin{cases} t + \Delta_t (\hat{t} - t) \text{ if } |\hat{t} - t| > \epsilon_t, \\ t \text{ otherwise} \end{cases},$$

$$\theta' = \begin{cases} \theta + \Delta_\theta \widehat{dvacpost} \text{ if } |\widehat{dvacpost}| > \epsilon_\theta, \\ \theta \text{ otherwise} \end{cases},$$

$$s^{f\prime}(\zeta^e) = \begin{cases} s^f(\zeta^e) + \Delta_{s^f} \widehat{dbargain} \text{ if } |\widehat{dbargain}| > \epsilon_{s^f}, \\ s^f(\zeta^e) \text{ otherwise} \end{cases}.$$

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

F.2 Algorithm to solve for transitional dynamics

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

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

for T very large, at which point it is assumed that the initial stationary RCE is again reached. The rationale for iterating over $\{r_t, t_t, \theta_t, w_t(\zeta^e)\}$ was explained in the prior subsection.[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

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

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

where $\mu_t \equiv \frac{P_t}{P_t^I}$ 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 $\bar{\bar{d}}$ 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 $\{\hat{\tilde{p}}_t^e, \hat{\tilde{\varphi}}_t^e, \hat{\tilde{\varphi}}_t^u\}_{t=0}^T$ 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 $\hat{\tilde{q}}_0$ 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 $||(\hat{\tilde{q}}_0 - \tilde{q}_0, \{\hat{z}_{t+1}, \hat{t}_t - t_t, \widehat{dvacpost}_t, \hat{w}_t(\zeta^e) - w_t(\zeta^e)\}_{t=0}^T)|| < \epsilon$, stop.
- Otherwise, let

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

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

(i) Under sticky prices:

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

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

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

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

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

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

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

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

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

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 $1 - p^e_1$. Further characterize the Jacobian associated with the market clearing and consistency conditions through period T:

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

   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

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

   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:

$$dH_{sticky} \equiv \frac{H_{sticky,1} - (\mathcal{T}_1^{(1)})' H_{sticky} \mathcal{T}_1^{(1)}}{(1 - p^e_1) - (1 - p^e)},$$

   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

$$dH_i \equiv \frac{H_{i,1} - (\mathcal{T}_{i,1}^{(1)})' H_i \mathcal{T}_{i,1}^{(1)}}{(1 - p^e_1) - (1 - p^e)},$$

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

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

   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.

References

Adrien Auclert. Monetary policy and the redistribution channel. *American Economic Review*, 109(6):2333–2367, 2019.

Adrien Auclert, Bence Bardoczy, Matthew Rognlie, and Ludwig Straub. Using the sequence-space Jacobian to solve and estimate heterogeneous-agent models. *Econometrica*, 89(5): 2375–2408, 2021.

Christian Broda and Jonathan A. Parker. The economic stimulus payments of 2008 and the aggregate demand for consumption. *Journal of Monetary Economics*, 68:S20–36, 2014.

Christopher D. Carroll. The method of endogenous gridpoints for solving dynamic stochastic optimization problems. *Economic Letters*, 91(3):312–320, 2006.

Gabriel Chodorow-Reich. Geographic cross-sectional fiscal spending multipliers: what have we learned? *American Economic Journal: Economic Policy*, 11(2):1–34, 2019.

Gabriel Chodorow-Reich and Loukas Karabarbounis. The cyclicality of the opportunity cost of employment. *Journal of Political Economy*, 124(6):1563–1618, 2016.

Peter Ganong and Pascal Noel. Consumer spending during unemployment: positive and normative implications. *American Economic Review*, 109(7):2383–2424, 2019.

Jonathan Gruber. The consumption smoothing benefits of unemployment insurance. *American Economic Review*, 87(1):192–205, 1997.

Robert E. Hall. High discounts and high unemployment. *American Economic Review*, 107 (2):305–330, 2017.

Tullio Japelli and Luigi Pistaferri. Fiscal policy and MPC heterogeneity. *American Economic Journal: Macroeconomics*, 6(4):107–136, 2014.

David S. Johnson, Jonathan A. Parker, and Nicholas S. Souleles. Household expenditure and the income tax rebates of 2001. *American Economic Review*, 96(5):1589–1610, 2006.

Greg Kaplan, Benjamin Moll, and Giovanni L. Violante. Monetary policy according to hank. *American Economic Review*, 108(3):697–743, 2018.

Karen A. Kopecky and Richard M.H. Suen. Finite state markov-chain approximations to highly persistent processes. *Review of Economic Dynamics*, 13:701–714, 2010.

Alisdair McKay and Ricardo Reis. Optimal automatic stabilizers. *Review of Economic Studies*, 88(5):2375–2406, 2021.

Alisdair McKay, Emi Nakamura, and Jon Steinsson. The power of forward guidance revisited. *American Economic Review*, 106(10):3133–3158, 2016.

Toshihiko Mukoyama, Christina Patterson, and Aysegul Sahin. Job search behavior over the business cycle. *American Economic Journal: Macroeconomics*, 10(1):190–215, 2018.

Jonathan A. Parker, Nicholas S. Souleles, David S. Johnson, and Robert McClelland. Consumer spending and the economic stimulus payments of 2008. *American Economic Review*, 103(6):2530–2553, 2013.

Valerie A. Ramey. Can government purchases stimulate the economy? *Journal of Economic Literature*, 49(3):673–685, 2011.

Morten O. Ravn and Vincent Sterk. Job uncertainty and deep recessions. *Journal of Monetary Economics*, 90:125–141, 2017.

Julio J. Rotemberg. Sticky prices in the United States. *Journal of Political Economy*, 90(6): 1187–1211, 1982.

Jesse Rothstein and Robert G. Valletta. Scraping by: income and program participation after the loss of extended unemployment benefits. *Journal of Policy Analysis and Management*, 36(4):880–908, 2017.

Johannes F. Schmieder and Till von Wachter. The effects of unemployment insurance benefits: new evidence and interpretation. *Annual Review of Economics*, 8:547–581, 2016.

Robert Shimer. Reassessing the ins and outs of unemployment. *Review of Economic Dynamics*, 15(2):127–148, 2012.

Ivan Werning. Incomplete markets and aggregate demand. *Working paper*, 2015.