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Abstract

We study the stabilizing role of unemployment benefit extensions. We develop a tractable quantitative model with heterogeneous agents, search frictions, and nominal rigidities. The model allows for both a stabilizing aggregate demand channel and a destabilizing labor market channel of unemployment insurance. We characterize analytically the workings of each channel. Stabilizing aggregate demand effects marginally prevail in the U.S. economy and the unprecedented benefit extensions introduced during the Great Recession played a limited role for unemployment dynamics. Instead, unemployment from the model tracks actual unemployment with a combination of labor market shocks and a shock to the consumers' borrowing capacity.

Keywords: Unemployment insurance; cyclical benefit extensions; heterogeneous agents; redistribution; precautionary motives; opportunity cost of employment; nominal rigidities; search frictions.

JEL codes: E24, E32, E52, J63, J64, J65

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1 Introduction

Due to both automatic and discretionary extensions, the duration of benefits in the U.S. unemployment insurance system is strongly countercyclical. In most states, unemployed individuals can collect unemployment benefits for up to 26 weeks in normal times, but this maximum duration can be extended at times of high unemployment. During the Great Recession, it reached a record of 99 weeks. Countercyclical benefit duration results into a share of unemployed workers receiving unemployment insurance that is also countercyclical, typically fluctuating between 30 percent in booms and 50 percent in recessions. Nearly 7 in 10 (68 percent) unemployed workers were receiving jobless benefits in 2010.[1]

Whether benefit extensions provide a stabilization mechanism that can smooth economic fluctuations and reduce unemployment in recessions is largely debated in academic and policy circles, but still unsettled. One reason for this is that empirical studies of the stabilizing effect of unemployment insurance often come to contradicting conclusions.[2] Existing empirical studies use different methodologies to identify the effects of changes in unemployment insurance policy and may or may not account for all the transmission mechanisms of benefit extensions. Further, they rely on different assumptions when extrapolating the results of micro or regional-level analyses to aggregate implications of the policy changes, making it difficult to interpret the results of such aggregations. A structural macro model is then needed to sort out the various forces and capture general equilibrium effects.

In this paper, we develop a model that includes the most salient transmission mechanisms of benefit extensions. First, a literature has emphasized the discouraging effect of unemployment insurance on either the search effort of unemployed workers or on the job creation of firms through higher outside options of workers when bargaining wages. We label these supply-side effects the "labor market" channel of unemployment insurance. A different literature has highlighted an "aggregate demand" channel of unemployment benefits, working via the heterogeneous responsiveness of individual consumption to unemployment benefits in presence of idiosyncratic risk and liquidity-constrained agents. While countercyclical benefit extensions destabilize the economy through labor market effects, they stabilize it via aggregate demand forces. Moreover, as we discuss, the workings of each channel may be affected by the presence of the other channel. For example, later we show that the strength of the labor market channel is higher with incomplete markets. Intuitively, the lower the consumption in the unemployment state relative to the employment state, the lower the outside option of workers in bargaining; heterogeneous

[1] Instead benefit compensation is typically not a cyclical dimension of U.S. policy. An exception is the policy response to the Covid crisis, the Federal Pandemic Unemployment Compensation (FPUC), which entailed both dimensions. This paper studies both compensation and extensions, with a focus on the latter and an application to the Great Recession.

[2] We extensively review related studies, both empirical and theoretical, at the end of the introduction.

agents and imperfect insurance thus bring in an additional mechanism for unemployment insurance to affect bargained wages by the alleviation of consumption differences. This makes a unified general equilibrium framework necessary to study the net stabilizing effect of unemployment insurance. Existing works, however, have mostly focused on either one or the other transmission mechanism. Further, studies of the aggregate demand channel have mainly framed unemployment insurance policy in terms of a time-invariant benefit level, while historically the most relevant policy dimension has been the cyclicality of benefit extensions.

We fill this gap in the literature by studying theoretically and quantitatively the effects of cyclical benefit duration on labor market dynamics within a model that includes both a labor market and an aggregate demand channel. We characterize analytically both transmission mechanisms of unemployment insurance and identify the determinants of their strength. We demonstrate quantitatively that benefit extensions on balance stabilize unemployment fluctuations, i.e. the aggregate demand channel prevails. Benefit extensions raise consumption of liquidity-constrained unemployed workers and reduce motives for precautionary saving for employed workers. With nominal price frictions, the increase in aggregate demand raises labor demand and job creation, which in turn results in a reduction in idiosyncratic unemployment risk, which further decreases precautionary motives via a feedback loop between endogenous unemployment risk and aggregate demand effects. Under our calibration these mechanisms overpower the amplifying pressure exerted by benefit extensions via labor market effects. Even so, we later show that the net contribution of benefit extensions to U.S. cyclical fluctuations has not been large relative to other driving forces. During the Great Recession, benefit extensions had a modest net stabilizing effect. We also quantify the separate contribution of the automatic extensions embedded in the U.S. system and the discretionary extensions implemented in 2008. The tractability of the model finally permits to quantify the separate contribution of the two transmission channels by closing each in turn. We show that the model's predictions are consistent with the relevant estimates from the empirical literature.

To capture both channels, we first model a labor market with search frictions. Within this framework, the decision of firms to create jobs is the key driver of labor market outcomes. The wage in each match is determined through Nash bargaining and is subject to wage rigidity. Bargaining brings in a role for unemployment benefits, via the opportunity cost of employment, to affect equilibrium wages and hiring, referred to as the macro effect of unemployment insurance on labor markets; real wage rigidity contributes to determining the power of this effect.[3] Second, we introduce an aggregate demand channel via

[3] We abstract from the micro effect of benefit extensions, by fixing the search effort of unemployed workers. Rothstein (2011) and Farber and Valletta (2015), among others, estimate these effects to be small. While our framework can accommodate variable search intensity, abstracting from it also simplifies the analysis.

heterogeneous agents and incomplete markets, as well as nominal rigidities. Specifically, workers face liquidity constraints during a single period but pool their assets at the end of the period. Workers can be employed, unemployed receiving benefits, or unemployed not receiving benefits. The labor market status of each worker is *iid* and determined each period by the evolution of aggregate rates of employment and benefit recipiency. Employed workers have enough income to optimize their consumption, while unemployed workers are borrowing-constrained. This structure enables both a redistribution channel of unemployment insurance and a motive for precautionary savings, but keeps the model tractable while at the same time preserving its suitability for quantitative analysis, as we extensively discuss.[4]

We capture benefit extensions via the share of unemployed workers receiving the benefits. There are two reasons for this. First, benefit extensions naturally increase the recipiency rate and drive its cyclicality. Second, what matters to the transmission channels of unemployment insurance policy, via aggregate consumption and average wages, is the share of workers receiving the benefits, not the maximum benefit duration of individual workers. We thus directly model policy in terms of the recipiency rate.[5] Then, to account for the two key features of the U.S. unemployment insurance system, we model automatic extensions as a policy rule where the share of recipients depends on the unemployment rate (to proxy for extensions automatically activated at certain unemployment thresholds) and model discretionary extensions as an exogenous shock to the recipiency rule (and later estimate it from the data).

To study the workings and the quantitative implications of our model, we proceed in three steps. We first assess whether countercyclical unemployment insurance policy, both in terms of benefit compensation and duration, stabilizes or destabilizes the unemployment rate when fluctuations are driven by a variety of alternative driving forces that can be accommodated by our framework. Within a calibrated version of the model, we show that with both channels active, countercyclical unemployment insurance stabilizes unemployment in response to all shocks considered. We show that the same policy has a destabilizing effect if we switch off the aggregate demand channel by either relaxing liquidity constraints (as in a representative agent model) or abstracting from nominal rigidities (as in a flexible price model).[6]

As a second step, we inspect analytically the mechanisms of each channel of bene-

[4]See the calibration section and the dedicated Section 5.3.

[5]Recipiency is also determined by eligibility and take-up rates, which are also cyclical and push recipiency up in downturns. Maximum duration is however the key determinant of cyclicality, as demonstrated by the fact that recipiency for regular programs, which have a fixed duration, is only mildly cyclical. At the same time, by using recipiency we capture the contribution of these factors to benefit policy transmission, despite not explicitly modelling them.

[6]For example, with an elasticity of benefit duration to unemployment of 0.633 that we estimate in US data, the standard deviation of unemployment decreases by 16.72 percent if fluctuations are driven by separation shocks. Under the same policy, absent aggregate demand effects, the relative volatility now increases by 6.64 percent.

fit extensions. We derive equations that characterize the direct impact of unemployment insurance on firms' hiring via both the labor market and the aggregate demand channel. Benefit duration directly impacts the opportunity cost of employment of the worker, which in turn affects the outcome of wage bargaining and the incentives to post vacancies. As we said, the aggregate demand channel works via a redistribution effect toward liquidity-constrained unemployed and a precautionary motive effect on employed, which in presence of nominal price frictions affect labor demand and job creation. We show analytically that the difference in consumption of benefit recipients and non-recipients is a key determinant of both channels of benefit extensions. We also characterize the direct impact of benefit compensation, for which a key driver is the difference in consumption of employed and benefit recipients.

Finally, we turn to the ability of the model to account for actual unemployment dynamics. We estimate automatic and discretionary extensions and processes for four aggregate shocks, and feed them into the model. After showing that the model does a reasonable job in matching the behavior of unemployment starting the 1970s, with fluctuations driven by productivity shocks, we focus on the Great Recession. In line with both the economic literature and the narrative of the 2007-09 downturn, we estimate two labor market shocks (separations to unemployment and transitions to long-term unemployment) and a shock to the household borrowing capacity. We show that with these shocks, the (untargeted) unemployment rate from the model closely tracks the actual rate during the Great Recession. We also show that benefit extensions had a mild stabilizing effect during the Great Recession and quantify the contribution of each channel. We find that without discretionary extensions, the unemployment rate would have been 0.17 percentage points higher in 2010, with the labor market channel contributing to a peak increase of 0.25 percentage points and the aggregate demand channel to a peak decrease of 0.27 percentage points.[7]

We now turn to reviewing the related empirical and theoretical literature.

Relation to the literature. We first review theoretical work studying either supply-side or aggregate demand effects of unemployment insurance on aggregate outcomes. The closest theoretical study to ours that focuses on labor market effects is Mitman and Rabinovich (2020). These authors extend a standard search and matching model to incorporate unemployment benefit extensions and find that they played, along with exogenous productivity shocks, a major role in driving the dynamics of unemployment over the last 50 years. In their model, benefit extensions drive wages up and reduce firms' surplus, dis-

[7] That the model can track actual unemployment with shocks directly estimated from the data, rather than with arbitrary shocks estimated to target unemployment dynamics, is important for two reasons. First, it externally validates our model as a suitable framework to study unemployment. Second, given that the effects of extensions differ depending on the driving force of fluctuations, it gives us confidence on the quantification of the impact of extensions.

couraging job creation.[8] The main difference with our work is that we also allow for an aggregate demand channel of benefit extensions.

Focusing instead on aggregate demand effects are McKay and Reis (2016), who study the role of unemployment insurance, and more generally of the social safety net, as an automatic stabilizer. They do this within a model with heterogeneous agents, uninsurable exogenous idiosyncratic risk and nominal rigidities. In their framework, higher levels of unemployment insurance stabilize individual income and consumption; more stable individual consumption translates into more stable aggregate demand and output. While the key distinction with our paper is that we also allow for labor market effects, a further distinction is that they concentrate their analysis on the impact of a time-invariant level of benefits, while we consider a policy where both compensation and duration respond to the state of the economy.[9]

Closer to our paper, Kekre (2021) also emphasizes the role of aggregate demand within a model with incomplete markets, nominal rigidities and search frictions. He shows that unemployment benefit extensions had a contemporaneous output multiplier around 1 or higher during the Great Recession. Relative to our paper, he considers richer heterogeneity of the demand side that allows for a distribution of assets. We instead propose a more tractable modelling of the demand side, but preserve the suitability of the model for quantitative analysis. We characterize analytically and transparently the determinants of both transmission channels and their interconnections. To do that, we derive expressions for the direct effect of unemployment insurance on aggregate consumption, as well as on the opportunity cost of employment. We further use those expressions to quantify the separate contribution of the two channels by computing counterfactuals where we close each channel in turn. Likewise our paper, Kekre (2021) also studies the effects of cyclical benefit extensions, but his analytical derivations are confined to the impact of compensation, while we derive analytical results for both compensation and extensions. We finally differ as we show that with shocks directly estimated from the data, unemployment from the model closely tracks (untargeted) actual unemployment during the Great Recession. In doing that, we also quantify the distinct impact and timing of automatic and discretionary extensions. We can do this as we separately estimate the two components of extensions, using data on recipiency rates.

On the empirical side, Chodorow-Reich, Coglianese and Karabarbounis (2018) exploit

[8]They find that the model with extensions explains 61 percent of unemployment fluctuations, while the model without extensions explains 30 percent. In an earlier contribution, Faig, Zhang and Zhang (2016) found that benefit extensions contributed to a 37 percent increase in unemployment volatility since 1945 and increased unemployment by 0.5 percentage points during the Great Recession, via a mechanism similar to that in Mitman and Rabinovich (2020).

[9]In separate work, McKay and Reis (2021) study the role of aggregate demand and aggregate fluctuations for the optimal time-invariant benefit level. They show that the stabilizing role of unemployment insurance makes the optimal replacement rate higher. Relative to McKay and Reis (2016), they make idiosyncratic risk endogenous but do not allow for a direct effect of unemployment insurance on wages and hiring, i.e. the labor market channel studied in this paper.

the fact that extensions of unemployment benefit duration during the Great Recession were based on real-time unemployment data, which are subject to measurement error. Using data revisions, they decompose variation in benefit duration into a part coming from variation in economic conditions and a part coming from measurement error. They show that exogenous changes in unemployment benefit duration (computed as the difference between duration based on actual unemployment and duration based on its real-time measure) only had limited effects on macroeconomic outcomes. Importantly, the predictions of our model with both channels active fall into their range of estimates. They estimate that the effect on unemployment of benefit extensions, whether automatic or discretionary, is between -0.5 and 0.3 percentage points at the 90 percent confidence level. We find that automatic and discretionary extensions stabilized unemployment by a peak net effect of -0.31 percentage points.

Hagedorn et al. (2019) develop a different empirical strategy. They estimate the effects of unemployment benefit extensions during the Great Recession exploiting a policy discontinuity at border counties. The key assumption behind their identification strategy is that counties just across a state border share the same economic conditions, but differ in terms of state-level unemployment benefit policies. Relying on border counties differences, the authors find that unemployment benefit extensions raised equilibrium wages, and caused a sharp contraction in vacancy creation and employment and raised unemployment. They interpret these results as evidence of supply-side effects of unemployment insurance, whereby extensions raise the opportunity cost of employment, this way increasing equilibrium wages and reducing job creation.[10] Other studies using a similar identification strategy, but different estimation techniques, find smaller effects of extensions on unemployment. Using a border county identification strategy, but not quasi-forward differences, Boone et al. (2021) estimate that benefit extensions decreased the employment-to-population rate by at most 0.35 percentage points at the 95 percent confidence level. Dieterle, Bartalotti and Brummet (2020) also use a similar identification strategy, but control for distance between counties. They find that during the Great Recession, extensions increased the unemployment rate by 0.2 or 0.5 percentage points, depending on the specification, but their confidence bounds are wide and include negative as well as positive values. Yet, we note that our model predicts that, absent aggregate demand effects, discretionary extensions alone would have increased unemployment by about 0.08 percentage points, a value falling within the range of estimates in Boone et al. (2021) and Dieterle, Bartalotti and Brummet (2020).

While the previous studies focus on estimating the impact of benefit extensions on ag-

[10]Consistently with this interpretation, we note that aggregate demand effects may spillover across counties as individuals working in one county may live or shop in a border county. In this instance, aggregate demand effects would not be reflected in the differences in economic outcomes between two border counties.

gregate outcomes such as unemployment, emphasizing supply-side transmission channels of unemployment insurance, several other studies have looked at the response of individual outcomes. Recent examples include Rothstein (2011), Farber and Valletta (2015), and Johnston and Mas (2018).[11]

Studies that estimate the aggregate demand channel of unemployment insurance are few. One notable exception is Di Maggio and Kermani (2016). They show that a more generous unemployment insurance reduces the responsiveness of aggregate demand to exogenous shocks. They focus, in particular, on durable consumption at the state-level. They do not study the cyclicality of benefits but focus on their average value.

The remainder of the paper is organized as follows. Section 2 describes the model. Section 3 describes the calibration of the model. Section 4 quantitatively evaluates the net stabilizing effects of countercyclical unemployment insurance. Section 5 inspects the mechanisms analytically and discusses the intuition. Section 6 evaluates the ability of the model to account for unemployment dynamics starting early 1970s and during the Great Recession. It also quantifies the contribution of benefit extensions, via both transmission channels. Section 7 concludes.

2 The Model

There is a continuum of identical households/families, each with a continuum of members of measure one. Household members face idiosyncratic unemployment risk. Unemployment risk is endogenous, resulting from the job creation decision of firms. Unemployment risk is uninsurable. The family has assets and can borrow up to a certain limit. At the start of each period, after borrowing, the family allocates a share of the assets to each member in the form of cash. After the cash is allocated, a lottery among family members determines who is employed and receives a wage, and who is unemployed; the lottery also determines who among the unemployed can receive unemployment insurance. Firms are of three types: final goods, retailers and wholesale firms. A competitive final good sector combines varieties of intermediate goods into final goods. A measure one of monopolistically competitive retailers facing nominal price rigidities differentiate a wholesale good into varieties and sell them to the final good firms. A continuum of wholesale firms hire workers in a frictional labor market to produce wholesale goods and sell them to the retailers in competitive markets. The government sets the nominal inter-

[11] Rothstein (2011) finds small negative effects of benefit extensions on the transition rate from unemployment to employment, but concentrated among long-term unemployed. Farber and Valletta (2015), instead, find no negative effect on the transition rate from unemployment to employment, but a small positive effect on the transition rate from unemployment to inactivity. Johnston and Mas (2018) find a small negative effect of a cut in benefit duration on nonemployment duration.

est rate according to a Taylor rule. It also collects taxes on labor and profit income and pays unemployment insurance and safety net transfers. The level and the duration of unemployment insurance respond to the economy's aggregate state according to a policy rule.

Summing up, the model includes search frictions, price rigidity, and incomplete markets. Labor market frictions allow for the labor market channel of unemployment benefit extensions, while market incompleteness together with price rigidities for the aggregate demand channel. Despite the complexity of the channels, the i.i.d. nature of idiosyncratic unemployment risk makes the model analytically tractable.

2.1 Timing

The intra-period timing is the following: i) aggregate shocks are realized; ii) the family borrows and allocates cash to its members; iii) firms post vacancies, matches are formed, wages are bargained and separations realize; iv) i.i.d. employment shocks and benefit recipiency shocks are realized; v) family members consume and firms produce.

2.2 Unemployed, Vacancies and Matching

Firms with open vacancies and unemployed workers searching for jobs meet randomly. The aggregate number of matches, m_t, is a function of the (efficiency-weighted) number of searchers, s_t, and the number of vacancies, v_t, according to a standard Cobb-Douglas matching function,

$$m_t = \alpha_m s_t^{\alpha} v_t^{1-\alpha}, \tag{1}$$

where α is the elasticity of matches to searching unemployed and α_m is matching efficiency.

Unemployed workers can either be short-term unemployed or long-term unemployed, with the latter searching with lower search efficiency than the former. We derive total efficiency units of search at time t as the sum of searchers weighted by their specific search efficiency:

$$s_t = (1 - n_{t-1}) \left[\omega_{t-1} + \overline{\sigma} \left(1 - \omega_{t-1}\right)\right], \tag{2}$$

where, at the start of period t, there are $(1 - n_{t-1})$ unemployed workers and, of these, a share ω_{t-1} is short-term unemployed and searches with search efficiency normalized to 1, while a complementary share $(1 - \omega_{t-1})$ is long-term unemployed and searches with search efficiency $0 < \overline{\sigma} < 1$.

Given the matching function (1), the probability ρ_t^s that a unit of search activity leads to a match is given by $\rho_t^s = \alpha_m \left(v_t / s_t\right)^{1-\alpha}$ and the probability ρ_t^v a firm fills a vacancy is given by $\rho^v_t = \alpha_m \left(v_t/s_t\right)^{-\alpha}$.

Employment evolves according to the law of motion

$$n_t = \rho_t n_{t-1} + m_t, \tag{3}$$

where ρ_t is the exogenous time-varying survival rate of employment relationships.

Finally, the share of short-term unemployed is given by

$$\omega_t = \frac{u^{ST}_t}{u^{LT}_t + u^{ST}_t}, \tag{4}$$

where short-term unemployed u^{ST}_t and long-term unemployed u^{LT}_t evolve according to the following laws of motion:

$$u^{ST}_t = u^{ST}_{t-1}\left(1-\rho^s_t\right)\left(1-\rho^\omega_t\right) + n_{t-1}\left(1-\rho_t\right), \tag{5}$$

$$u^{LT}_t = u^{LT}_{t-1}\left(1-\rho^s_t\overline{\sigma}\right) + u^{ST}_{t-1}\left(1-\rho^s_t\right)\rho^\omega_t, \tag{6}$$

where ρ^ω_t is the exogenous time-varying transition probability from being short-term to being long-term unemployed.

2.3 Households

Household members can be employed or unemployed; unemployed members can either receive unemployment insurance or not. Who is employed and unemployed, recipient of benefits and not, is decided every period by a lottery. At the start of each period, the household allocates a share of its assets to each member, in the form of cash, to be used for consumption. Since cash on hand needs to be decided before the employment status is revealed, all agents receive the same amount. After the employment status is determined, on top of cash, employed workers receive the wage, benefit recipients collect unemployment insurance, and the non-recipients collect a safety net transfer from the government. To provide cash to the agents, the household can use the net assets from previous period and borrow today up to a borrowing constraint. Savings for next period are determined after individual consumption takes place as the sum of all cash that wasn't spent by the agents. The household decides on aggregate borrowing and saving, cash on hand and individual consumption. Finally, employed members suffer a constant disutility cost from supplying labor.

Let $W_t\left(n_{t-1}, a_t, b_t\right)$ be the value function of the representative household, given beginning-of-period employment, n_{t-1}, beginning-of-period asset holdings, a_t, and beginning-of-period debt, b_t.[12] Let $u(\cdot)$ denote the instantaneous utility function, strictly increasing, strictly concave and satisfying the Inada conditions $\lim_{c\to\infty} u'(c) = 0$ and $\lim_{c\to 0} u'(c) = \infty$. The representative household chooses: consumption levels of individual household members that are contingent on their employment status (c_t^n if employed, c_t^{ur} if unemployed and recipients of benefits, and c_t^{un} if unemployed and not recipients of benefits); new debt, b_{t+1}; cash to transfer to individual household members for consumption, x_t; and end-of period assets, a_{t+1}, to solve

$$\begin{aligned} W_t\left(n_{t-1}, a_t, b_t\right) &= \max\left\{n_t\left(u\left(c_t^n\right) - \chi\right) + \left(1-n_t\right)\left(\nu_t u\left(c_t^{ur}\right) + \left(1-\nu_t\right) u(c_t^{un})\right)\right. \\ &\quad \left. + \beta E_t\left\{W_{t+1}\left(n_t, a_{t+1}, b_{t+1}\right)\right\}\right\} \end{aligned} \tag{7}$$

subject to six constraints. These are: the household budget constraint; the liquidity constraints of employed, benefit recipients, and non-recipients; the borrowing constraint; and the end-of-period asset equation. The household does not choose employment, but takes into account that it evolves according to the law of motion in (3). In the equation above, χ denotes the disutility of work, β is the household's discount factor, and ν_t is the share of unemployed receiving the unemployment benefits at period t. We also refer to ν_t as the recipiency rate.

The *household budget constraint* at the start of the period states that

$$x_t = \frac{b_{t+1}}{p_t} + \left(1+i_t\right)\frac{a_t}{p_t} - \left(1+i_t\right)\frac{b_t}{p_t}. \tag{8}$$

In words, the amount of cash that the household transfers to its members for consumption at the start of the period equals the value of new borrowings, plus the value of assets it owns, with interest income, minus the repayment of debt including interest payments.

Since employment is randomly allocated within the period, cash x_t is identically (and optimally) allocated to each household member. Further, intra-period transfers are ruled out. Then, household members face *liquidity constraints* that are specific to their employment status, given by

$$c_t^n \leq x_t + \left(1-\tau_t\right) w_t + \left(1-\tau_t\right) d_t \tag{9}$$

$$c_t^{ur} \leq x_t + \tau_t^u \tag{10}$$

$$c_t^{un} \leq x_t + \tau^s. \tag{11}$$

On top of the cash transfer, employed individuals can finance consumption with wage income w_t and dividend income d_t, net of taxes τ_t. Unemployed individuals, instead, also

[12] We use the time subscript t to capture the dependence of the value function from the aggregate state, $\mathbf{s}_t$, that is, we write $W_t\left(n_{t-1}, a_t, b_t\right)$ instead of $W\left(n_{t-1}, a_t, b_t; \mathbf{s}_t\right)$. We will use this convention throughout the paper.

collect unemployment insurance τ_t^u, if benefit recipient, and a safety net transfer τ^s, if non-recipients.

We assume a *borrowing constraint* that limits the household ability to raise new debt. Specifically, the real value of new debt is limited by an exogenous time-varying borrowing limit, $\overline{b}_t$:

$$b_{t+1} \leq p_t \overline{b}_t. \tag{12}$$

Household's *end-of-period assets* are the unspent funds of individual household's members,

$$\begin{aligned} \frac{a_{t+1}}{p_t} = \quad & x_t + (1-\tau_t) w_t n_t + (1-\tau_t) d_t n_t + \tau_t^u (1-n_t) \nu_t + \tau^s (1-n_t)(1-\nu_t) \\ & - \left(n_t c_t^n + (1-n_t) \nu_t c_t^{ur} + (1-n_t)(1-\nu_t) c_t^{un} \right), \end{aligned} \tag{13}$$

and equal the total funds available for consumption to household's members net of their total consumption.

To sum up, households choose $\{c_t^n, c_t^{ur}, c_t^{un}, x_t, b_{t+1}, a_{t+1}\}$ to solve (7) subject to (8)-(13).[13]

Note that equations (9)-(11) assume that the households own the firms, receive the dividends, and distribute them to the employed workers. In the data, only a fraction of the population participates in the stock market. Stock market participants typically earn higher income and are wealthier. As there is no wealth distribution in our model, we assign the dividends to the workers with the highest income. Since dividend recipients decide on the inter-temporal allocation of profits and firms' hiring, firms discount the future with factor

$$\Lambda_{t,t+1} \equiv \beta E_t \left\{ \frac{(1-\tau_{t+1}) u' \left(c_{t+1}^n\right)}{(1-\tau_t) u' \left(c_t^n\right)} \right\}. \tag{14}$$

2.4 Hiring Firms and Wage Bargaining

Wholesale goods firms hire workers in a frictional labor market and produce the wholesale good. We will refer for simplicity to wholesale goods firms as simply firms. To hire workers, firms must post vacancies at a per-period cost κ. Firms produce wholesale goods with a linear technology in labor. Let $F_t(n_{t-1})$ be the value function of the representative firm, given beginning-of-period employment, n_{t-1}. Firms then choose vacancies, v_t, and employment, n_t, to solve

$$F_t(n_{t-1}) = \max \left\{ q_t z_t n_t - w_t n_t - \kappa v_t + E_t \left\{ \Lambda_{t,t+1} F_{t+1}(n_t) \right\} \right\}, \tag{15}$$

[13]When solving her maximization problem, the household takes total dividends $D_t \equiv d_t n_t$ as given. This comes from the assumption that households, rather than individual employed workers, own the firms. This assumption is more appropriate in presence of *iid* employment states.

subject to

$$n_t = \rho_t n_{t-1} + \rho_t^v v_t, \tag{16}$$

where q_t is the relative price of the wholesale good in terms of the final good, z_t is aggregate productivity and firms discount the future with factor $\Lambda_{t,t+1}$ defined in (14).

Firms and workers divide the joint match surplus via Nash bargaining. For the firm, the relevant surplus is the value of an additional worker to the firm, $F_{n,t} \equiv \partial F_t / \partial n_t$:

$$F_{n,t} = q_t z_t - w_t + E_t \left\{ \rho_{t+1} \Lambda_{t,t+1} F_{n,t+1} \right\}. \tag{17}$$

Similarly, for the household, the relevant surplus is the value of an additional employed member, $W_{n,t} \equiv \partial W_t / \partial n_t$:

$$W_{n,t} = u' \left(c_t^n \right) \left(1 - \tau_t \right) \left(w_t - \frac{\xi_t}{1 - \tau_t} \right) + \beta E_t \left\{ \left[\rho_{t+1} - \left[\omega_t + \overline{\sigma} \left(1 - \omega_t \right) \right] \rho_{t+1}^s \right] W_{n,t+1} \right\}, \tag{18}$$

where ξ_t denotes the opportunity cost of work, defined in equation (37) in Section 5.1.

Let w_t^* denote the bargained wage. The wage w_t^* is chosen to maximize the Nash product:

$$w_t^* = \arg\max \left(W_{n,t} \right)^{\eta} \left(F_{n,t} \right)^{1-\eta}, \tag{19}$$

where η denotes the workers' relative bargaining power.

Finally, we introduce real wage rigidity. We formalize it by assuming a simple wage schedule of the form

$$w_t = \gamma w_t^* + (1 - \gamma) \overline{w}, \tag{20}$$

where $\overline{w}$ is the steady state wage and $\gamma \in [0, 1]$ is an index of real wage rigidity.

2.5 Final Good Firms, Retailers and Price Setting

A competitive sector for final goods combines differentiated varieties of intermediate goods according to the production function

$$Y_t = \left(\int_0^1 y_{it}^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}}, \tag{21}$$

where y_{it} is the input of intermediate good i at time t and ϵ is the elasticity of substitution across varieties. Final goods firms purchase intermediate good i at price p_{it} and take as given the final goods price p_t. From cost minimization, it follows that the demand for variety i is given by

$$y_{it} = \left(\frac{p_{it}}{p_t} \right)^{-\epsilon} Y_t, \tag{22}$$

and the price index p_t is given by

$$p_t = \left(\int_0^1 p_{it}^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}}. \tag{23}$$

A measure one of monopolistic competitive retailers buy a wholesale good from wholesale firms, differentiate it into varieties y_{it} with a technology that transforms one unit of wholesale good into one unit of intermediate good and sell it to the final goods producers. Retailers set prices infrequently as in Calvo (1983) with probability of revision θ. At each revision date, a retailer producing variety i chooses an optimal price p_{it}^* to maximize expected future profits, subject to the demand for its own variety. As retailers are owned by employed workers, they discount the future with factor $\Lambda_{t,t+1}$ defined in (14). The price setting problem of retailer i at each revision date t can be written as

$$\max_{p_{it}^*} \Pi_t \left(p_{it} \right), \tag{24}$$

with

$$\Pi_t \left(p_{it} \right) = d_t \left(p_{it} \right) + (1 - \theta) \beta \Lambda_{t,t+1} \Pi_{t+1} \left(p_{it+1} \right), \tag{25}$$

and

$$d_t \left(p_{it} \right) = \left(\frac{p_{it}}{p_t} - q_t \right) y_{it}, \tag{26}$$

and subject to the demand equation (22).

Finally, the dividends from the retailers are given by

$$\int_i d_t \left(p_{it} \right) di = Y_t - q_t z_t n_t, \tag{27}$$

which can be summed to the dividends from wholesale goods firms, d_t^w, given by

$$d_t^w = q_t z_t n_t - w_t n_t - \kappa v_t. \tag{28}$$

to obtain total dividends, D_t, distributed to employed workers,

$$D_t \equiv d_t n_t = \int_i d_t \left(p_{it} \right) di + d_t^w. \tag{29}$$

2.6 Government and the Tax and Transfer System

The government provides unemployment insurance τ_t^u to benefit recipients $(1 - n_t) \nu_t$ and a safety net transfer τ^s to non-recipients $(1 - n_t)(1 - \nu_t)$; it also collects taxes τ_t on labor and dividend incomes to satisfy its budget constraint

$$\tau_t^u (1-n_t)\,\nu_t + \tau^s (1-n_t)(1-\nu_t) = \tau_t w_t n_t + \tau_t d_t n_t. \tag{30}$$

Benefit recipiency, ν_t, and benefit compensation, τ_t^u, are set by the government according to two policy rules. The recipiency rule gives the share of unemployed workers receiving benefits, ν_t, as a function of unemployment in the previous period, as

$$\nu_t = \overline{\nu}\left(\frac{u_{t-1}}{\overline{u}}\right)^{\Gamma_\nu} e^{\varepsilon_{\nu t}}, \tag{31}$$

where $\overline{\nu}$ is a scale parameter, $\overline{u}$ is average unemployment, Γ_ν is a parameter governing the cyclicality of ν_t, and $\varepsilon_{\nu t}$ is a policy shock. The rule in equation (31) is meant to proxy for the actual policy of extensions of benefit duration. The actual policy is implemented by increasing the maximum duration an unemployed worker can receive benefits. In our model, whether an unemployed worker receives the benefit is independent of the duration of her unemployment spell and determined by a lottery, whereby the probability of receiving benefits is given by the share of recipients. Since benefit extensions naturally increase the share of unemployed workers receiving the benefit, this probability is a proxy in the model for the duration of unemployment benefits. When the duration of unemployment benefits is extended, each unemployed worker has a higher probability of being a recipient of unemployment insurance.

The government sets the benefit level according to the following rule:

$$\tau_t^u = \overline{\tau}^u\left(\frac{u_{t-1}}{\overline{u}}\right)^{\Gamma_\tau}, \tag{32}$$

where $\overline{\tau}^u$ is a scale parameter and Γ_τ denotes the elasticity of τ_t^u to deviations of past unemployment from trend. Since countercyclical compensation is not a typical dimension of U.S. policy, we use this rule only for counterfactual experiments.

Finally, the government sets the nominal interest rule according to a Taylor rule of the form

$$1 + i_{t+1} = (1+\bar{i})\left(\frac{p_t}{p_{t-1}}\right)^{\phi} e^{\varepsilon_{it}}, \tag{33}$$

where ε_{it} is a monetary policy shock.

2.7 Model Equilibrium

An equilibrium is a set of policies $\{c_t^n, c_t^{ur}, c_t^{un}, b_{t+1}, a_{t+1}, x_t, n_t, v_t, d_t^w, y_{it}, d_{it}\}$, prices $\{p_t, p_{it}, w_t, w_t^*, q_t\}$, aggregate quantities $\{s_t, \omega_t, u_t^{ST}, u_t^{LT}, n_t, Y_t, D_t\}$, value functions $\{W_t(n_{t-1}, a_t, b_t), F_t(n_{t-1})\}$, and government policies $\{i_{t+1}, \nu_t, \tau_t^u, \tau_t\}$ such that: i) the households maximize (7) subject to (8)-(13); ii) the hiring firms maximize (15) subject to (16); iii) the final good firms behave according to (22) and (23); iv) the retailers maximize (24) subject to (22), (25) and (26); v) the wages are set according to (19) and (20); vi) the labor market variables behave according to (2)-(6); vii) the government policy is set according to (30)-(33); viii) the assets, dividends, and goods markets clear.[14]

2.8 The Role of Intra-Period Borrowing

A key element of our model is the intra-period borrowing structure. The household can raise debt at the start of the period, up to an exogenous limit. Before the realization of idiosyncratic risk, it distributes an equal share of the new borrowing to its members according to (8). After that, members receive income conditional on their employment state and consumption decisions are made. In equilibrium, the household borrows up to the limit (12), unemployed members face binding liquidity constraints (10) and (11), while employed face slack constraints (9) and are able to save according to (13). The intra-period asset market equilibrium requires that beginning-of-period borrowing must equal end-of-period savings, so that both equal the borrowing limit ($a_{t+1} = b_{t+1} = p_t \bar{b}_t$). The interest rate adjusts to clear the assets market. The structure allows for short-term debt, enabling partial consumption smoothing across individual employment states, but rules out long-term savings, avoiding the need to keep track of assets, in the aggregate and across agents.

Despite its tractability, this structure preserves a number of desirable features relative to other tractable setups present in the literature. First, it makes it possible to derive predictions for the effects of a credit tightening on households (a driver gaining prominence since the Great Recession). A tightening of the borrowing limit restrains the ability to smooth consumption across employment states and directly reduces consumption of liquidity-constrained unemployed. This prediction is similar to that of a richer model with a non-degenerate asset distribution, which would also predict a one-to-one decrease in the consumption of constrained agents. Also, the lower consumption in the unemployment state constitutes greater risk for the employed and hence will raise precautionary motives. In a richer model, unconstrained agents would likewise raise precautionary savings against higher future risk of hitting the borrowing limit. Our model thus accommodates borrowing shocks and delivers similar predictions to a model with a richer asset structure.

A second advantage of intra-period borrowing is that it permits to match the difference in consumption of employed and unemployed workers via the calibration of the exogenous borrowing limit, rather than having to rely entirely on the calibration of the

[14] We have used $d_{it} \equiv d_t(p_{it})$ and n_t to denote both firm-level and aggregate employment, to save on notation.

government transfers to the unemployed (benefit compensation and safety net). Recall that the borrowing limit determines how much cash is distributed to the unemployed and hence their total income. The two government transfers can then be chosen to match other relevant moments in the data, precisely the replacement rate and the average drop in consumption associated with benefit exhaustion. The resulting calibration strategy significantly improves our confidence in the quantitative predictions of the model, specifically those related to the effects of benefit compensation and benefit recipiency.[15]

3 Calibration

We adopt a monthly calibration. We assume CRRA utility for the individual utility of household members, with relative risk aversion coefficient denoted with ι.

There are 15 parameters in the model for which we must select values. We calibrate 5 of the parameters using external sources. Three are specific to the search and matching framework: the bargaining power parameter, η; the elasticity of matches to searchers, α; and the matching function constant, α_m. We calibrate them to conventional values. To maintain comparability with much of the existing literature, we set the bargaining power parameter η to be equal to 0.5. We choose the elasticity of matches to unemployment α to be equal to 0.5, the midpoint of values typically used in the literature. This choice is within the range of plausible values of $0.5 - 0.7$ reported by Petrongolo and Pissarides (2001) in their survey of the literature on the estimation of the matching function. We then note that the parameter α_m can be normalized. A larger value of this parameter only results in a smaller value of average vacancies without affecting the steady-state properties or the dynamics of the model. The fourth parameter that we calibrate using external sources is the elasticity of substitution across varieties of intermediate goods, ϵ. This parameter is conventional in the New Keynesian literature and we set it to 6, implying a steady-state markup of 20 percent. The last parameter is the relative risk aversion of the household members, ι. We set it to 1 to correspond to log utility. Externally calibrated parameters are summarized in Table 1.

The remaining ten parameters are jointly calibrated to match model-relevant steady-state moments measuring: the relative consumption of unemployed to employed workers; the difference in consumption of unemployed who receive benefits and those who do not; the replacement rate; the share of unemployed receiving benefits; the separation

[15] The alternative most common tractable framework achieves tractability by assuming a zero borrowing limit. See, among others, Ravn and Sterk (2017) and Challe (2020). These setups rely on optimizing individual agents rather than on an household/family structure, but assume a zero debt limit, implying that agents consume their current income. While the aggregate demand structure is similar to our setup (e.g., the form of the Euler equation), such frameworks cannot accommodate borrowing shocks and need to rely on government transfers to match differences in consumption, which would be unappealing to study unemployment insurance.

Parameter values		
Bargaining power	η	0.5
Matching elasticity	α	0.5
Matching efficiency	α_m	1
Elasticity of substitution	ϵ	6
Relative risk aversion	ι	1

Table 1: Externally calibrated parameters

rate; the unemployment rate; duration-dependent job finding rates; the share of short-term unemployed; the Frisch elasticity of labor supply; and the nominal interest rate. We calibrate the borrowing limit, $\overline{b}$; the safety net transfer, τ^s; the average benefit amount, $\overline{\tau}^u$; the average share of eligible unemployed, $\overline{\nu}$; the average retention rate, $\overline{\rho}$; the vacancy cost, κ; the relative search efficiency of long-term unemployed, $\overline{\sigma}$; the average inflow rate to long-term unemployment, $\overline{\rho}^\omega$; the disutility of work, χ; and the discount factor, β. Although there is not a one-to-one mapping of parameters to moments, there is a sense in which the identification of particular parameters is more informed by certain moments than others. We use this informal mapping to provide a heuristic argument of how the various parameters are identified.

We calibrate $\overline{b}$ to target a relative consumption expenditure of unemployed to employed workers of 0.72, from Chodorow-Reich and Karabarbounis (2016).[16] Holding everything constant, a higher $\overline{b}$ implies a higher consumption of unemployed workers, whether benefit recipients or not, and hence a higher ratio $\frac{\overline{\nu}\overline{c}^{ur}+(1-\overline{\nu})\overline{c}^{un}}{\overline{c}^n}$. We recover $\overline{b} = 0.448$. We calibrate τ^s to target a 17 percent consumption difference of benefit recipients and non-recipients, normalized by the consumption of employed, from Ganong and Noel (2019).[17] The higher is the safety net transfer, τ^s, the higher is the consumption of the unemployed not receiving the benefits, $\overline{c}^{un}$, and the lower is the normalized consumption difference, $\frac{\overline{c}^{ur}-\overline{c}^{un}}{\overline{c}^n}$. We recover $\tau^s = 0.164$. We calibrate $\overline{\tau}^u$ to target an average replacement rate of 40.67 percent, as estimated by the Department of Labor for the 2001-2018 period. We set $\frac{\overline{\tau}^u}{\overline{w}(1-\overline{\tau})}$ equal to 0.4067 and recover $\overline{\tau}^u = 0.324$.

We set $\overline{\nu}$ to match the empirical share of unemployment insurance recipients of 0.41 from 1972 to 2014, from McKenna (2015). The parameter $\overline{\sigma}$ is chosen to match a relative job finding rate of long-term unemployed of 0.5, as estimated in Kroft et al. (2016).[18] We calibrate $\overline{\rho}^\omega$ to match an average 73 percent share of short-term unemployed workers from BLS data. Given job finding and separation rates, a higher probability of becoming

[16] Our preferred estimate of 0.72 comes from the Consumer Expenditure Survey (CE) for food, clothing, recreation, vacation, over the years 1983-2012, reported in the third column of their Table 2.

[17] The consumption difference between benefit recipients and non-recipients increases with the duration of unemployment in the non-recipiency state. Ganong and Noel (2019) compute a range of 12 to 19 percent, as a ratio of the consumption of the employed, but truncate the unemployment spell at 11 months. We then pick a value between 12 and 19 percent but toward the higher end of the range.

[18] Using CPS data from 2002 to 2007, Kroft et al. (2016) estimate that the job finding rate of unemployed for more than 6 months is 47 to 53 percent of the job finding rate of unemployed for less than a month. We pick the mean of the range.

	Description	Value	Target
$\bar{b}$	Borrowing limit	0.448	Unemployed to employed cons. ratio (0.72)
τ^s	Safety net transfer	0.164	Recipients to non-recipients cons. diff. ($0.17c^n$)
$\bar{\tau}^u$	Benefit compensation	0.324	Replacement rate (0.4067)
$\bar{\nu}$	Recipiency rate	0.41	Share of recipients (0.41)
$\bar{\rho}$	Retention rate	0.9646	Separation probability (0.0354)
κ	Flow vacancy cost	0.638	Unemployment rate (0.062)
$\bar{\sigma}$	Search efficiency LTU	0.5	Relative LTU job finding rate (0.5)
$\bar{\rho}^\omega$	STU-LTU probability	0.3	Share of STU (0.73)
χ	Disutility of work	0.42	FOC for hours worked and Frisch elasticity (1)
β	Discount factor	0.9725	Interest rate (0.003)

Table 2: Internally calibrated parameters

long-term unemployed, $\bar{\rho}^\omega$, implies a lower share of short-term unemployed workers. We recover $\bar{\rho}^\omega = 0.3$. We calibrate $\bar{\rho}$ to match an average separation rate of 0.0354 from the Job Openings and Labor Turnover Survey (JOLTS) for the 2001-2018 period and recover a retention rate $\bar{\rho} = 1 - 0.0354 = 0.9646$. The hiring cost parameter, κ, determines the resources that firms place into recruiting, and hence influences the equilibrium unemployment rate. We set equilibrium unemployment to match an average unemployment rate of 6.2 percent from BLS data for 2001-2018 and then calibrate κ to be consistent with it. We obtain $\kappa = 0.638$.

To calibrate the preference parameter χ we proceed as follows. While the model abstracts from variation in labor at the intensive margin, we use the implicit first-order condition for the choice of hours worked evaluated at the steady state. We assume a disutility of work of the form $\chi = \frac{\tilde{\chi}}{1+1/\psi} h^{1+\frac{1}{\psi}}$, where $\tilde{\chi}$ is a scale parameter, h denotes hours of work, and ψ the Frisch elasticity of labor supply. The implicit first-order condition equates the marginal benefit of hours to the match, qz, to the marginal cost, $\tilde{\chi} h^{\frac{1}{\psi}}$. (See the Online Appendix for a short derivation). Normalizing hours of work to 1 and calibrating the Frisch elasticity to 1, we recover $\chi = 0.42$.[19,20]

Finally, we calibrate β to target a monthly nominal interest rate of 0.003. The steady state version of equation (43) determines a negative relation between the nominal interest rate and β, for given consumption and population shares of the agents. We recover $\beta = 0.9725$, which is lower than what a representative agents model would imply, given the target. The full list of internally calibrated parameter values and targeted moments is given in Table 2.

We also need to assign values to four parameters that affect the model dynamics but not the steady state determination and to the standard deviations and autocorrelations of

[19] Frisch elasticity estimates vary significantly by age and gender with values around 0.4 for young men and above 1 for older men and women. See for example French (2005). See also Reichling and Whalen (2012) for a summary of available estimates.

[20] The calibrated value of χ implies a relative value of non-work, given by $\bar{\xi}/\overline{qz}\,(1-\bar{\tau})$, which is close to conventional values in the literature. We estimate 0.695 that is almost identical to the value of 0.71 in Hall and Milgrom (2008).

Parameter	Description	Value	Target
θ	Price stickiness	0.2	Average price duration (5 months)
γ	Wage rigidity	0.08	Wage elasticity to productivity (0.449)
ϕ	Taylor rule	2	Within range of values in the literature
Γ_ν	Recipiency rule	0.6329	Estimated, U.S. Depart. of Labor, 2001-2017

Table 3: Calibration, dynamics

the six shocks that we consider. The four parameters are: the degree of price stickiness, θ; the degree of wage rigidity, γ; the parameter of the Taylor rule, ϕ; and the elasticity to unemployment in the recipiency rule, Γ_ν. We calibrate θ to be equal to 0.2, implying an average price duration of 5 months, as in Bils and Klenow (2004). We calibrate γ to 0.08, to match the elasticity of wages to productivity of 0.449 from Hagedorn and Manovskii (2008). We set the Taylor rule parameter, ϕ, to 2, within the range of values standard in the literature.[21] The elasticity of eligibility Γ_ν and the parameters of the exogenous processes are estimated from the data, as we discuss in Section 6, with the exception of the monetary shock whose parameters are set as in McKay and Reis (2016). Table 3 reports the four model parameters that only matter for model dynamics. The parameters of the exogenous processes are presented in the Online Appendix.

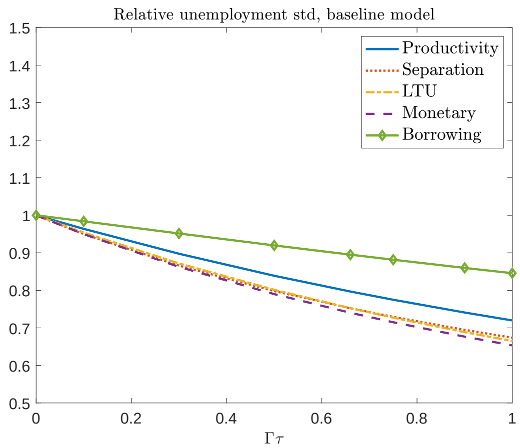
4 The Stabilizing Effect of Unemployment Insurance

This section assesses the stabilizing effect of cyclical unemployment insurance taking as a metric the standard deviation of the unemployment rate. We consider insurance policy in terms of both recipiency ν_t and compensation τ_t^u. We compute the standard deviation of unemployment at different degrees of policy countercyclicality, as captured by the parameters Γ_ν and Γ_τ from equations (31) and (32). We normalize the standard deviation of unemployment relative to the acyclical case where Γ_τ and Γ_ν equal zero.

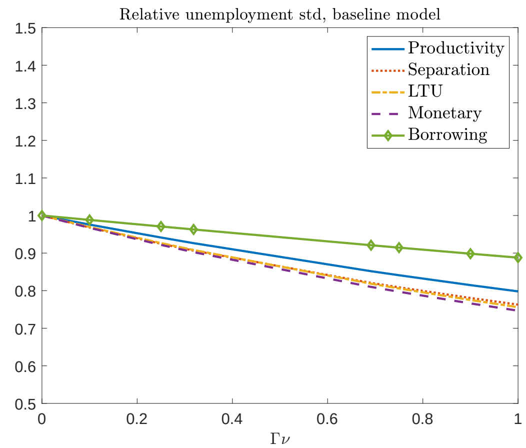
Figure 1 plots the relative standard deviation of the unemployment rate as a function of Γ_τ, in the left panel, and Γ_ν, in the right panel. In both cases, the model is subject to alternative driving forces: productivity shocks (blue solid lines); shocks to the separation rate (red dotted lines); shocks to the probability that short-term unemployed workers become long-term unemployed (yellow dashed-dotted lines); monetary shocks (violet dashed lines); and shocks to the borrowing limit (green lines with diamonds).

The figure shows that the volatility of unemployment unambiguously decreases as unemployment insurance becomes more countercyclical, though with different slopes de-

[21] Estimated values for the Taylor rule coefficient on inflation typically range between 1.5 and above 2 (e.g., Sala, Söderström and Trigari (2008)). A well-known issue in models with incomplete markets and countercyclical idiosyncratic risk is that the Taylor principle is not sufficient to guarantee determinacy (see for example Bilbiie (2018) and Ravn and Sterk (2021)). We pick a value at the higher side of the range to ensure the determinacy of the model in all simulations.



(a) Benefit compensation



(b) Benefit duration

Figure 1: Unemployment volatility as a function of benefit elasticities, different shocks

pending on the driving force of fluctuations. That is, our baseline model predicts that *countercyclical* unemployment insurance plays a *stabilizing* role in response to several types of shocks, when taking the form of either cyclical compensation or recipiency. The negative slopes are the outcome of contrasting mechanisms through which unemployment insurance affects the economy response to aggregate shocks and whose relative strength and net effect also depend on the calibration. For this reason, before inspecting these mechanisms analytically in Section 5, we compare the stabilizing role of unemployment insurance across six alternative models. As these models differ by the mechanisms that they incorporate, the comparison of the slopes of the volatility curves is informative about the direction of the impact of alternative mechanisms.

We start by considering a representative agent (RA) version of the model with flexible prices and flexible wages, as in Mitman and Rabinovich (2020). We then augment the RA model with sticky real wages, first, and sticky prices, then.[22] Further incorporating heterogeneous agents (HA) gives our baseline model, described in Section 2. Finally, we consider two additional versions of the baseline model, one with flexible prices and one where the opportunity cost of employment ξ_t is held fixed. Figure 2 reports the results. Each panel plots unemployment volatility as a function of policy cyclicality for each of the six alternative models. The top panels consider the separation shock (a supply shock) as the driving force; the bottom panels the borrowing shock (a demand shock). As in Figure 1, the left panels refer to policy in terms of benefit compensation, and the right panels in terms of recipiency.

The top panels of Figure 2 focus on separation shocks and emphasize the following

[22]To preserve comparability of quantitative predictions, when calibrating RA versions of the model we keep the same targets with the following exceptions. We set the value of the borrowing limit, $\overline{b}$, and the difference of benefit compensation and safety net transfer, $\overline{\tau}^u - \tau^s$, as in the baseline calibration, even though consumption is equalized in all employment states. We also set the disutility of work, χ, to maintain the same relative value of non-work, $\overline{\xi}/\overline{qz}\,(1-\overline{\tau})$.

pattern: countercyclical insurance amplifies unemployment volatility in the RA model with flexible prices and wages (blue solid lines); relative to this model, the destabilizing effect of unemployment insurance is reduced by essentially the same extent in three models - the RA model with flexible prices but sticky wages (red dotted lines), the RA model with sticky prices and wages (yellow dashed-dotted lines), and the HA model with sticky wages but flexible prices (green lines with diamonds); unemployment insurance becomes stabilizing within our HA model with sticky prices and wages (violet dashed lines) and to a greater extent when the opportunity cost of employment is held fixed (light blue dotted lines with dots). We note that we observe the same pattern for the other supply shocks, productivity and LTU, whose plots are reported in the Online Appendix.

What is the intuition behind these results? Consider first the RA model with flexible prices and wages. In this model, cyclical unemployment insurance affects unemployment volatility only through the labor market channel: a more (less) generous unemployment insurance, in response to rising (decreasing) unemployment, raises (reduces) workers' outside option relative to the acyclical case, which puts upward (downward) pressure on wages and discourages (encourages) hiring. Put simply, countercyclical unemployment insurance amplifies the economy response to shocks by dampening the responsiveness of bargained wages. For example, with separation shocks, at the value for Γ_{ν} of 0.633 that we estimate in Section 6, unemployment volatility raises by 6.64 percent relative to the acyclical case.[23]

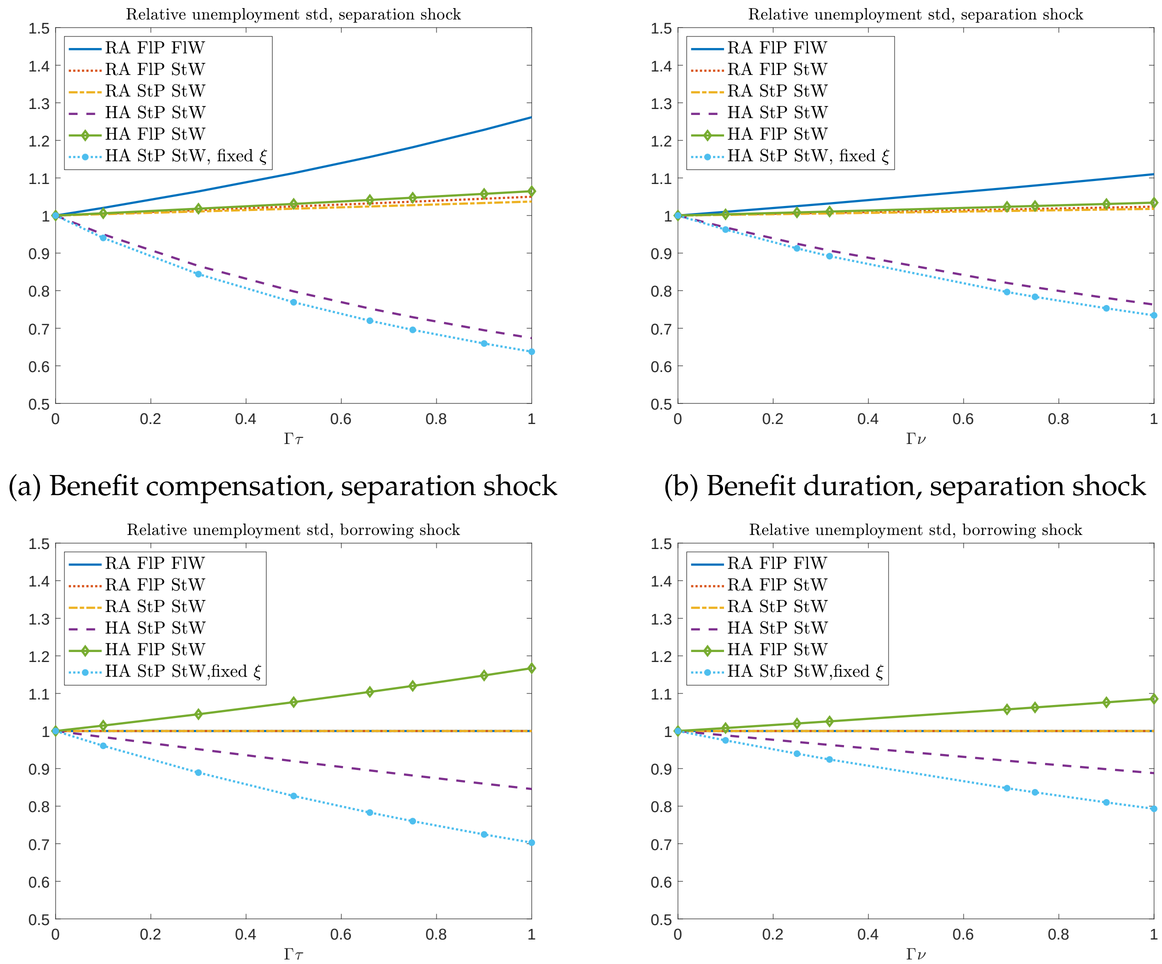
Adding real wage rigidity produces the second model we examine. Wage stickiness not only delivers higher unemployment volatility in absolute terms[24], but also significantly decreases the response of unemployment volatility to cyclical unemployment insurance. The reason for this is that wage rigidity reduces the pass-through of countercyclical benefit policy to wages, and hence to job creation, limiting the strength of the labor market channel. Countercyclical benefit duration now only raises unemployment volatility by 1.48 percent with separation shocks, at the same Γ_{ν}.

The next model we consider is one where we further add price stickiness. Figure 2 emphasizes that the volatility slopes are almost indistinguishable from those of the RA model with flexible prices, that is, adding price rigidity within a RA model has a negligible impact on the stabilizing effect of cyclical insurance. Indeed, within a RA framework in which workers can perfectly insure any idiosyncratic risk, unemployment insurance will play no role for aggregate demand.

Allowing next for heterogeneous agents gives our baseline HA model with sticky prices and wages. Countercyclical unemployment insurance moves from having a desta-

[23]The amplification is stronger in the model with heterogeneous agents and flexible wages and prices (not reported in the figure). There, at the same Γ_{ν}, unemployment volatility raise by 9.94 in response to separation shocks.

[24]A well-known result emphasized, among others, in Shimer (2005), Hall (2005) and Gertler and Trigari (2009).



(a) Benefit compensation, separation shock

(b) Benefit duration, separation shock

(c) Benefit compensation, borrowing shock

(d) Benefit duration, borrowing shock

Figure 2: Unemployment volatility as a function of benefit elasticities, different models

bilizing effect on unemployment to a stabilizing one. The reason is simple: our baseline model also allows for an aggregate demand channel. As unemployment rises in response to a negative shock, the increase in unemployment insurance generosity stabilizes aggregate demand. It does so by redistributing resources to liquidity-constrained unemployed workers - either by raising benefit compensation or by extending duration - and by limiting the increase in idiosyncratic risk - with either a higher chance of receiving benefits or a higher expected benefit level - which in turn limits the rise in precautionary motives. The aggregate demand channel counteracts the destabilizing labor market channel and, importantly, under our baseline calibration it dominates it. Specifically, accounting for both channels, at $\Gamma_\nu = 0.633$, it stabilizes unemployment volatility relative to the acyclical case by 16.72 percent in response to separation shocks.

We finally consider two alternative versions of our baseline HA model. The first assumes that prices are flexible. The figure shows that the volatility slopes turn positive and close to those in the RA model with sticky wages and either sticky or flexible prices.

Indeed, flexible prices mute the aggregate demand effects of unemployment insurance.

The second version switches off cyclical fluctuations in the opportunity cost of labor, ξ_t, by fixing it at its steady state value. The top panels of Figure 2 clearly show that the volatility slopes become steeper than in the baseline HA model. As it will be clear from Section 5, by fixing the opportunity cost of labor we mute the impact of cyclical unemployment insurance on wages and thus turn off the labor market channel. Given the absence of destabilizing labor market effects, this specification permits to quantify the extent of stabilization from the aggregate demand channel in response to selected shocks. With separation shocks, for example, the aggregate demand channel reduces unemployment volatility by 19.03 percent at $\Gamma_\nu = 0.633$.

Finally, the bottom panels of Figure 2 report relative unemployment volatility in response to the borrowing shock. We first note that the borrowing shock plays no role in RA models. The shock, however, generates a pattern consistent with that of supply shocks in the models in which it has an impact. The volatility slope is negative in the baseline model, but turns positive when aggregate demand effects are muted by assuming flexible prices. This also applies to the monetary shock, whose plots are reported in the Online Appendix: while the monetary shock plays no role in models with flexible prices, the volatility slope is positive in the RA model but turns negative in our baseline HA model. Further, holding ξ_t fixed makes unemployment insurance more stabilizing, as it occurs with supply shocks. At the estimated value of $\Gamma_\nu = 0.6329$, countercyclical unemployment insurance stabilizes unemployment volatility by 7.26 percent in the baseline model and by 14.10 percent when ξ_t is held fixed.

5 Inspecting the Mechanisms

The starting point to inspect the mechanisms through which unemployment insurance impacts the economy's response to aggregate shocks is the job creation condition.

The solution to the firm problem stated in equations (15) and (16), gives

$$\kappa = \rho_t^v F_{n,t}, \tag{34}$$

where κ is the per period cost of keeping a vacancy open, ρ_t^v the job filling probability, and $F_{n,t}$ the value to the firm of an additional worker employed, given by

$$F_{n,t} = q_t z_t - w_t + E_t \left\{ \Lambda_{t,t+1} \rho_{t+1} F_{n,t+1} \right\}. \tag{35}$$

A raise in $F_{n,t}$ incentivizes firms to post vacancies v_t. Vacancies are posted until the job creation condition (34) is met, which happens via a reduction in the job filling probability

ρ_t^v.

Unemployment insurance changes the firm's incentives to post vacancies by affecting the value of an additional employed worker, $F_{n,t}$, in two ways. A first way is through its impact on the bargained wage w_t^*. The solution to the Nash bargaining problem in (19) gives

$$w_t^* = \eta \left[q_t z_t + E_t \left\{ \Lambda_{t,t+1} \kappa \left[\omega_t + \overline{\sigma} \left(1 - \omega_t\right) \right] \frac{\rho_{t+1}^s}{\rho_{t+1}^v} \right\} \right] + \left(1 - \eta\right) \frac{\xi_t}{1 - \tau_t}, \tag{36}$$

which in turn determines w_t according to the wage schedule (20). Unemployment insurance alters the opportunity cost of employment, ξ_t, a key determinant of bargained wages. Specifically, a more generous unemployment insurance that raises ξ_t, will put upward pressure on the wage, reducing $F_{n,t}$ and discouraging hiring. We have referred to this channel as the "labor market" channel.

A second way in which unemployment insurance changes $F_{n,t}$ is via changes in q_t, which is both the relative price of wholesale goods and the real marginal cost faced by sticky price retailers. Changes in q_t summarize the real effects that driving forces, including aggregate demand, have on the economy due to price stickiness. As aggregate demand increases, those intermediate good firms who would like to raise prices but cannot, will accommodate the higher demand with higher production. Higher production of intermediate goods, which uses as inputs wholesale goods, implies in turn higher marginal costs or, equivalently, a higher relative price of wholesale goods. With flexible prices, instead, changes in aggregate demand are fully offset by adjustments in prices and q_t is unaffected. Unemployment insurance, in turn, affects aggregate demand, c_t, by changing the consumption of agents who face heterogeneous liquidity constraints in presence of unemployment risk. Specifically, a more generous unemployment insurance raises c_t, which in presence of nominal rigidities raises q_t. The rise in q_t increases $F_{n,t}$ and stimulates hiring. We have referred to this channel as the "aggregate demand" channel of unemployment insurance.

In what follows, we derive equations that characterize the direct effect of unemployment insurance on the value of non work, ξ_t, and aggregate consumption, c_t. We consider both the impact of recipiency and benefit compensation.

5.1 The Labor Market Channel

In our model, the opportunity cost of employment is given by

$$\begin{aligned} \xi_t &= \left[\nu_t \tau_t^u + \left(1 - \nu_t\right) \tau^s \right] \\ &\quad + \left[c_t^n - \left(\nu_t c_t^{ur} + \left(1 - \nu_t\right) c_t^{un} \right) \right] \\ &\quad + \left(\lambda_t^n\right)^{-1} \left[\left(\nu_t u\left(c_t^{ur}\right) + \left(1 - \nu_t\right) u\left(c_t^{un}\right) \right) - \left(u\left(c_t^n\right) - \chi \right) \right], \end{aligned} \tag{37}$$

revealing three separate terms. The first term is the average transfer to the unemployed including the benefit compensation, τ_t^u, weighted by the share of benefit recipients, ν_t, and the safety net transfer, τ^s, weighted by the share of non-recipients, $1 - \nu_t$. The second term is the savings from the lower average consumption of the unemployed, $\nu_t c^u r_t + (1 - \nu_t)\, c_t^{un}$, relative to the consumption of the employed, c_t^n. The last term is the difference between the average utility from being unemployed, $\nu_t u\left(c_t^{ur}\right) + (1 - \nu_t)\, u\left(c_t^{un}\right)$, and the utility from being employed, $u\left(c_t^n\right) - \chi$, expressed in consumption units, with λ_t^n denoting the marginal utility of consumption of employed workers. The second and the third term originate from the lack of consumption insurance. Changes in benefit compensation, τ_t^u, and recipiency, ν_t, will affect all three components of the opportunity cost.

To compute the direct effect of unemployment insurance on the opportunity cost of employment, ξ_t, we use the household equilibrium conditions (8)-(13) and the Euler equation for employed workers, determining c_t^n, c_t^{ur} and c_t^{un}, together with equation (37). This gives us the opportunity cost ξ_t as a function of variables taken as given by the household: $\left\{\bar{b}_{t+s}, w_{t+s}, d_{t+s}, n_{t+s}, \tau_{t+s}, i_{t+s+1}, \pi_{t+s+1}, \tau_{t+s}^u, \nu_{t+s}\right\}_{s=0}^{\infty}$. We then take the partial derivative of ξ_t with respect to either dimension of unemployment benefit policy, τ_t^u or ν_t.

Consider first the impact of recipiency. The partial derivative of ξ_t with respect to ν_t gives

$$\frac{\partial \xi_t}{\partial \nu_t} = \left(\tau_t^u - \tau^s\right) - \left(c_t^{ur} - c_t^{un}\right) + \frac{u\left(c_t^{ur}\right) - u\left(c_t^{un}\right)}{\lambda_t^n}. \tag{38}$$

An increase in the recipiency rate raises the opportunity cost of employment by raising the share of unemployed receiving the benefit τ_t^u relative to the safety net τ^s (the first term) and by raising the average utility from being unemployed via a change in the composition toward benefit recipients away from non-recipients, with recipients enjoying higher consumption and thus higher utility than non-recipients (the third term); the same shift in composition, however, reduces the opportunity cost by lowering the savings from a lower average consumption of the unemployed relative to the employed, since the average consumption of the unemployed increases with recipiency (the second term). The first term is standard in the literature; the second and third terms are novel and associated to differences in consumption levels of benefit recipients and non-recipients.

Using the binding liquidity constraints in equations (10) and (11), given by $c_t^{ur} = x_t + \tau_t^u$ and $c_t^{un} = x_t + \tau^s$, the expression in (38) can be simplified to

$$\frac{\partial \xi_t}{\partial \nu_t} = \frac{u\left(c_t^{ur}\right) - u\left(c_t^{un}\right)}{\lambda_t^n}, \tag{39}$$

which shows that the partial derivative of ξ_t with respect to ν_t is unambiguously positive: an increase in recipiency directly raises the opportunity cost of employment.

Consider now the direct effect of benefit compensation. Taking the partial derivative of ξ_t from equation (37) with respect to τ_t^u gives

$$\frac{\partial \xi_t}{\partial \tau_t^u} = \nu_t - \nu_t \frac{\partial c_t^{ur}}{\partial \tau_t^u} + \nu_t \frac{\lambda_t^{ur}}{\lambda_t^n} \frac{\partial c_t^{ur}}{\partial \tau_t^u}, \tag{40}$$

with λ_t^{ur} denoting the marginal utility of consumption of unemployed receiving benefits. An increase in benefit compensation raises the opportunity cost of employment by raising the amount received by the share of recipients ν_t (the first term) and by raising the average utility from being unemployed via an increase in the consumption of the liquidity-constrained benefit recipients, c_t^{ur} , as the benefit, τ_t^u, rises (the third term); the increase in c_t^{ur}, at the same time, lowers the savings from a lower consumption of the unemployed relative to the employed (the second term). As in the case of recipiency, while the first term is standard in the literature, the second and the third are novel and associated to differences in consumption of employed and unemployed receiving benefits, the latter being liquidity-constrained.

From the binding liquidity constraint of benefit recipients in equation (10), we see that a change in benefit compensation implies a one-to-one change in consumption, that is, $\partial c_t^{ur}/\partial \tau_t^u = 1$. The partial derivative of ξ_t with respect to τ_t^u in (40) can then be simplified to

$$\frac{\partial \xi_t}{\partial \tau_t^u} = \nu_t \frac{u'\left(c_t^{ur}\right)}{u'\left(c_t^n\right)}, \tag{41}$$

which makes clear that the impact of τ_t^u on ξ_t is unambiguously positive.

Intuitively, the comparison of equations (39) and (41) shows that while the effects of changes in recipiency are determined by the difference in consumption of unemployed who receive the benefits and those who do not, the effects of changes in benefit compensation depend on the difference in consumption of the employed and the unemployed receiving the benefits. In either case, however, a more generous unemployment insurance raises the value of non-work, and as a consequence wages.

The key difference between our HA model and a RA version of it is that the first also features an aggregate demand channel of unemployment insurance, to which we turn shortly. The labor market channel, however, also differs across the two models. Within the RA version of the model, equations (38) and (40) would only include the first term and reduce to $\partial \xi_t/\partial \nu_t = \tau_t^u - \tau^s$, and $\partial \xi_t/\partial \tau_t^u = \nu_t$. The two additional terms present in equations (38) and (40) arise because of imperfect consumption insurance in the HA model and have a positive net effect.[25] That the value of non work ξ_t rises more in presence of heterogeneous agents, in response to either an increase in recipiency or benefit compensation, means that the destabilizing effect of the labor market channel is stronger

[25]In equation (40), $\lambda_t^{ur}/\lambda_t^n \geq 1$, since the benefit recipients have a lower (or equal) consumption level than the employed and thus higher (or equal) marginal utility of consumption. In equation (38), the positive net effect arises from the concavity of utility together with the lower consumption level of the non-recipients relative to the recipients.

in the HA model than in the RA model.[26] Intuitively, the reason for this is that the higher the difference in the consumption of the unemployed relative to the employed, the lower the opportunity cost of work. Hence, a more generous unemployment insurance, working either via an increase in the consumption of recipients or via an increase in their share, will raises the opportunity cost of employment via a standard effect that raises the average benefit compensation, but also via a non-standard effect that alleviates consumption differences across the unemployment and the employment state. The non-standard effect is absent from the RA version of the model where consumption is equalized across states.

5.2 The Aggregate Demand Channel

The equations that are relevant to the inspection of the effect of a change in the generosity of unemployment insurance on aggregate demand, via redistribution toward liquidity-constrained unemployed and precautionary motives of employed, are: the expression for aggregate consumption, c_t, given by

$$c_t = n_t c_t^n + (1 - n_t)\, \nu_t c_t^{ur} + (1 - n_t)\,(1 - \nu_t)\, c_t^{un}; \tag{42}$$

the binding liquidity constraints for benefit recipient and non-recipient in equations (10) and (11), given by $c_t^{ur} = x_t + \tau_t^u$ and $c_t^{un} = x_t + \tau^s$; and the Euler consumption equation for employed workers, given by

$$u'\left(c_t^n\right) = \beta E_t \left\{ \frac{1 + i_{t+1}}{\pi_{t+1}} \left[n_{t+1} u'\left(c_{t+1}^n\right) + (1 - n_{t+1}) \left(\nu_{t+1} u'\left(c_{t+1}^{ur}\right) + (1 - \nu_{t+1})\, u'\left(c_{t+1}^{un}\right) \right) \right] \right\}. \tag{43}$$

The Euler condition equates the current marginal utility of an employed worker with her future discounted expected marginal utility, augmented with interest rate returns. It captures in particular precautionary motives associated with uninsurable unemployment risk. Specifically, a worker employed today can be in one of three employment states tomorrow - employed, unemployed with benefits or unemployed without benefits - with the probability of each state equal to the relevant population weight, as implied by the assumption of *iid* idiosyncratic risk.

We start by considering the impact of recipiency via the redistribution effect. To compute the direct effect, we take the partial derivative of aggregate consumption from equa-

[26] Indeed, if we compare an HA and a RA model, both with flexible wages and prices, so that the aggregate demand effects are muted also in the HA model, we find that with separation shocks and at the estimated value for Γ_ν the volatility of unemployment increases by 6.64 percent in the RA model and by 9.94 percent in the HA model.

tion (42) with respect to ν_t[27],

$$\frac{\partial c_t}{\partial \nu_t} = (1 - n_t)\left(c_t^{ur} - c_t^{un}\right), \tag{44}$$

which is unambiguously positive. A raise in the recipiency rate changes aggregate consumption by the difference in consumption between recipients and non-recipients, $c_t^{ur} - c_t^{un}$, weighted by the number of unemployed workers, $1 - n_t$, who can change recipiency state. Further, as unemployed workers are liquidity constrained and consume their income, non-recipients gaining the benefit increase their consumption by the difference between the benefit, τ_t^u, and the safety net transfer, τ^s. The partial derivative in (44) can then be rewritten as

$$\frac{\partial c_t}{\partial \nu_t} = (1 - n_t)\left(\tau_t^u - \tau^s\right). \tag{45}$$

A similar redistributive effect arises in response to an increase in benefit compensation. Taking the partial derivative of c_t from equation (42) with respect to τ_t^u, using also the binding liquidity constraint for benefit recipients, gives

$$\frac{\partial c_t}{\partial \tau_t^u} = (1 - n_t)\,\nu_t, \tag{46}$$

where aggregate consumption varies by the measure of benefit recipients, $(1 - n_t)\nu_t$. Indeed, liquidity-constrained benefit recipients increase their consumption by change in benefit compensation.

In the model, an increase in either benefit recipiency or benefit compensation is financed with taxes on wages and dividends, redistributing resources from unconstrained employed workers to constrained unemployed workers. This result directly obtains from the assumptions that taxes balance the government budget. Section 5.3 provides a discussion of the role of taxes and the balanced-budget assumption.

When it comes to the precautionary motive effect, what matters is future unemployment insurance. A more generous unemployment insurance that is expected to persist into the future reduces the unemployment risk faced by employed workers and lowers their desired savings. Then, the higher is the consumption demand of employed workers, c_t^n, the higher is aggregate demand, c_t.

To characterize the impact of unemployment insurance on the precautionary motive,

[27] As in the previous sub-section, we use household equilibrium conditions to write aggregate consumption, c_t, from equation (42), as a function of variables taken as given by the household, $\{\bar{b}_{t+s}, w_{t+s}, d_{t+s}, n_{t+s}, \tau_{t+s}, i_{t+s+1}, \pi_{t+s+1}, \tau_{t+s}^u, \nu_{t+s}\}_{s=0}^{\infty}$.

it is useful to write the Euler equation (43) as

$$u'\left(c_t^n\right) = \beta E_t \left\{ \frac{1+i_{t+1}}{\pi_{t+1}} u'\left(c_{t+1}^n\right) \Omega_{t+1} \right\}, \tag{47}$$

where the term Ω_{t+1}, given by

$$\Omega_{t+1} \equiv \left(n_{t+1} + (1-n_{t+1})\, \nu_{t+1} \frac{u'\left(c_{t+1}^{ur}\right)}{u'\left(c_{t+1}^n\right)} + (1-n_{t+1})\,(1-\nu_{t+1}) \frac{u'\left(c_{t+1}^{un}\right)}{u'\left(c_{t+1}^n\right)} \right), \tag{48}$$

captures unemployment risk. The higher the risk (as measured by lower employment or recipiency rates or larger consumption difference across employment states), the higher the term Ω_{t+1} (given $c_{t+1}^n > c_{t+1}^{ur} > c_{t+1}^{un}$ and strict concavity of period utility), the higher the desire to save for precautionary reasons.

To compute the direct effect of future recipiency, we then take the partial derivative of Ω_{t+1} with respect to ν_{t+1}.[28] This gives

$$\frac{\partial \Omega_{t+1}}{\partial \nu_{t+1}} = (1-n_{t+1}) \frac{u'\left(c_{t+1}^{ur}\right) - u'\left(c_{t+1}^{un}\right)}{u'\left(c_{t+1}^n\right)}, \tag{49}$$

which is unambiguously negative. A raise in ν_{t+1} increases the probability that the worker, if unemployed next period, will be in the highest consumption state, c_{t+1}^{ur}, rather than in the lowest one, c_{t+1}^{un}. This reduces unemployment risk and incentives to save this period. The magnitude of the effect depends on the difference of next period marginal utilities of consumption of recipients and non-recipients, $u'\left(c_{t+1}^{ur}\right) - u'\left(c_{t+1}^{un}\right)$, scaled by the next period marginal utility of employed $u'\left(c_{t+1}^n\right)$, and next period probability of being unemployed, $1-n_{t+1}$.

The direct effect of future benefit compensation can be similarly computed taking the partial derivative of Ω_{t+1} with respect to τ_{t+1}^u, using also the binding liquidity constraint for benefit recipients given by $c_t^{ur} = x_t + \tau_t^u$, to obtain

$$\frac{\partial \Omega_{t+1}}{\partial \tau_{t+1}^u} = (1-n_{t+1})\, \nu_{t+1} \frac{u''\left(c_{t+1}^{ur}\right)}{u'\left(c_{t+1}^n\right)}. \tag{50}$$

This partial derivative is also unambiguously negative. A raise in τ_{t+1}^u increases next period consumption in the benefit recipient state. Higher consumption in that state reduces incentives to save. The magnitude of the effect is affected by the change in the marginal utility of consumption for benefit recipients, $u''\left(c_{t+1}^{ur}\right)$, scaled by the next period marginal utility of employed $u'\left(c_{t+1}^n\right)$, and next period probability of the recipiency state,

[28] Here we use the household equilibrium conditions to write the measure of unemployment risk, Ω_{t+1}, from equation (48), as a function of $\left\{\bar{b}_{t+s}, w_{t+s}, d_{t+s}, n_{t+s}, \tau_{t+s}, i_{t+s+1}, \pi_{t+s+1}, \tau_{t+s}^u, \nu_{t+s}\right\}_{s=1}^{\infty}$.

$(1 - n_{t+1}) \, \nu_{t+1}$.

To conclude, it is useful to emphasize the absence of any of the aggregate demand effects of unemployment insurance discussed here in a RA version of the model. To see this, we impose perfect consumption insurance, implying equal consumption across agents, in the relevant equations. First, aggregate consumption c_t will simply equal the individual consumption levels. Accordingly, the Euler equation simplifies to $u'(c_t) = \beta E_t \{[(1 + i_{t+1}) / \pi_{t+1}] \, u'(c_{t+1})\}$. The household budget constraint can be written as $a_{t+1}/p_t = x_t + w_t n_t + d_t n_t - c_t$, where we have also used the government budget constraint (30). Both the Euler equation and the household budget constraint clearly allow no role for unemployment insurance. The aggregate demand channel is absent in a RA version of the model.

5.3 Discussion

We next discuss several issues involving the robustness of the assumptions that underlie our analysis and the plausibility of the quantitative predictions of our model.

5.3.1 Taxes and Government Balanced Budget

So far, our discussion of the mechanisms has abstracted from the effect of unemployment insurance policy on taxes. Our balanced-budget assumption implies that the tax rate τ_t adjusts each period to cyclical changes in τ_t^u and ν_t so as to satisfy the government budget constraint. How do taxes affect the transmission mechanisms of unemployment insurance?

It is straightforward to see from the expression of the bargained wage (36) that tax adjustments amplify the destabilizing labor market effects of unemployment insurance. A more generous unemployment insurance raises bargained wages directly, via an increase in the opportunity cost of employment ξ_t, and indirectly, via the increase in the tax rate τ_t that is needed to finance the higher benefits. Intuitively, higher taxes on income from work raise the opportunity cost of employment expressed in terms of net labor income, $\xi_t/(1 - \tau_t)$ in equation (36).[29]

Conversely, aggregate demand effects of unemployment insurance are dampened by the tax adjustments implied by the balancing of the government budget. The increase in taxes associated with more generous benefits reduces the resources available to employed workers for their consumption, limiting the rise in aggregate demand. To see this formally, we expand equation (44), capturing the effect of extensions on aggregate consumption, to

[29] In taking the derivative of ξ_t from equation (37) with respect to either ν_t or τ_t^u, we have also abstracted from the effect of τ_t on c_t^u. In the Online Appendix we show that this can make the derivative larger or smaller, depending on the calibration. While our calibration makes it smaller, the total effect of taxes on the strength of labor market channel is quantitatively small.

take into account the effect of ν_t on taxes (via the government budget constraint) and the effect of taxes on the consumption of employed workers (via their liquidity constraint). This gives:

$$\frac{\partial c_t}{\partial \nu_t} = (1-n_t)\left(c_t^u - c_t^{ui}\right) + n_t \frac{\partial c_t^n}{\partial \tau_t}\frac{\partial \tau_t}{\partial \nu_t} = (1-n_t)\left(\tau_t^u - \tau^{ss}\right)\left(1 - \frac{\partial c_t^n}{\partial Y_t^n}\right), \tag{51}$$

where $Y_t^n \equiv x_t + (1-\tau_t)(w_t + d_t)$ denotes total income of employed workers. (See the Online Appendix for a short derivation, where we also expand equation (46).) The term in the last parenthesis represents the difference in the marginal propensities to consume of unemployed and employed workers. It shows that the consumption response of employed workers, via changes in taxes, dampens the effect of redistribution. The effect of redistribution of course remains positive, given that employed workers have lower marginal propensity to consume than unemployed workers.

At the other extreme of a balanced-budget assumption is one of constant taxes, whereby countercyclical unemployment insurance results in countercyclical government deficits.[30] Rather than explicitly introducing government debt, we proxy this alternative assumption in the model by fixing taxes at their steady state value.[31] We find that this alternative assumption has a negligible impact on the quantitative predictions of the model, in particular on those relating to extensions. For example, the (maximum) effect on the unemployment rate of the discretionary extensions implemented during the Great Recession, which we compute in Section 6, changes from -0.1665 percentage points, with variable taxes, to -0.1534 percentage points, with fixed taxes. Further, the extent to which the model fits the data during that period is not affected in any detectable manner.

5.3.2 Binding Liquidity Constraints and Persistence of Employment States

Our modeling of the aggregate demand side relies for tractability on two features. First, all unemployed workers are liquidity-constrained, regardless of the duration of their unemployment spell. This implies that their marginal propensity to consume out of government transfers is one, i.e., they increase consumption by the additional income from either benefits or safety net transfers. Second, employment states are *iid*. A richer model would allow, first, for persistent employment states and, second, for the possibility that unemployed workers may only become constrained as their unemployment spell persists over time. While simplified in certain dimensions, our formulation yet produces plausible

[30]Indeed, benefit extensions during the Great Recession were part of a large stimulus package (the American Recovery and Reinvestment Act), which included tax incentives rather than tax increases.

[31]By doing this, we implicitly assume that the government operates under balanced budget on average, rather than every period, and finances short-term deficits with foreign debt while saving in foreign assets in periods with surpluses. The foreign debt assumption ensures that there is no effect of changes in government debt on the equilibrium asset structure of the economy. We also implicitly abstract from interest payments on foreign debt.

predictions in response to redistribution and precautionary motives.

Consider first redistribution. Our calibration strategy ensures that the model is able to capture the overall effect of benefit extensions via redistribution as well as a richer model would do. This is attained by targeting the *average* difference in *consumption* of unemployed workers before and after the loss of benefits. A richer model would achieve this by matching both the drop in income at the time of benefit expiration and the changes in the marginal propensity to consume over the unemployment spell, which together should imply the decreasing path in consumption that is observed in the data as the worker remains unemployed. Indeed, in such richer model, the effect of benefit extensions on consumption will differ at the individual level by both the duration of unemployment and the level of savings. We instead directly calibrate the difference between the income of benefit recipients and non-recipients (in our model, the difference between the unemployment benefit and the safety net transfer) to match the average consumption difference associated to the benefit loss in the data, given the unitary marginal propensity to consume. This makes the model able to capture the effect of extensions on aggregate consumption in response to redistribution.

Disciplining the precautionary saving motive is less straightforward, and this is true in any model. Relative to a richer model, our framework will overestimate predictions in certain dimensions and underestimate them in others, but overall capture the key forces. Among the key forces is the extent of the risk faced by the agents, both on average and over the cycle. A second aspect is whether unemployed agents also save for precautionary motives.

Starting from the latter, while the model rules out the possibility that some unemployed may be unconstrained and choose to save for precautionary reasons, say to insure against the risk of benefit loss, there is little evidence of that phenomena.[32] Thus, by only letting the employed agents be unconstrained and save for precautionary reasons, we may actually be quite close to reality.

Consider now the average risk faced by a worker in employment. The *iid* nature of risk implies that the probabilities of future employment states are given by the population weights, i.e. by the unconditional distribution of employment states. As a consequence, relative to a model with persistent states, our model implies that on average the risk of unemployment in the immediate term (next period) is higher for workers currently employed (the unemployment rate is higher than the probability of separating to unemployment) and lower for workers currently unemployed (the unemployment rate is lower than the probability of not finding a job).[33] However, over time, the conditional dis-

[32] Ganong and Noel (2019) compute an average 12 percent consumption drop at benefit expiration. They argue this cannot be rationalized within a model of forward-looking agents with liquidity constraints. In such model, agents would optimally accumulate savings to smooth the expected income drop, implying a gradual decrease in consumption.

[33] We similarly overestimate the immediate term risk for a currently employed of moving to the non-recipient unem-

tribution will converge to the unconditional one, and the convergence is relatively quick, which is important as the decision to save for precautionary motives is a forward-looking one.[34] Furthermore, the average risk faced by employed workers also depends on the consumption levels in the three future employment states. This dimension is disciplined by matching relative consumption differences.

Turning to the cyclicality of risk, it is driven by both the cyclicality of the transition probabilities among states and the cyclicality of the relative consumption levels across states. We first note that both with *iid* and persistent employment states, the probabilities of becoming unemployed, at different horizons, co-move positively with current and future separation rates and negatively with current and future job finding rates, though the extent of co-movement may differ across the two setups. While our model may overestimate the cyclicality of short-term unemployment risk, if the separation rate is less cyclical than the unemployment rate, conditional probabilities converge to unconditional ones at longer horizons. At the same time, our model will likely underestimate the cyclicality of risk associated to variation in relative consumption levels across states. This happens because consumption in the unemployment state does not directly respond to risk in our model. In a richer model, instead, an increase in risk may cause some unconstrained unemployed workers to save for precautionary reasons and decrease consumption. The lower consumption in the (future) unemployment state constitutes further risk for workers employed today, a cyclical component that is absent from our model with unemployed always liquidity-constrained. (Though, as said above, existing evidence indicates this effect is likely small).

5.3.3 Opportunity Cost of Employment with Household-Level Bargaining

Our model assumes wage bargaining at the household level. As a consequence, the opportunity cost of employment that enters the wage equation and affects the firms' hiring decision is an average among household members, including benefit recipients and non-recipients. A richer model would instead have wages bargained at the worker level. Furthermore, differential asset accumulation among employed and unemployed workers in the richer model may introduce additional components to the cost of moving from unemployment to employment.

Nonetheless, the predictions of the richer model for the effect of benefit extensions on firms' hiring decisions will be largely comparable to those of our model.[35] This hap-

ployed state relative to the recipient state.

[34]For example, under the current calibration, an employed worker would face a conditional probability of being unemployed next month equal to 3.5 percent (the separation rate) and a conditional probability of being unemployed 6 months ahead equal to 5.9 percent, which is already very close to the unconditional probability of 6.2 percent (the unemployment rate). Full convergence occurs after 17 months (first four decimal digits are the same).

[35]See Chodorow-Reich and Karabarbounis (2016) for a similar argument.

pens for two reasons. First, the decision to post vacancies depends on the wages that firms expect to pay to the workers they are yet to meet. In a richer model, those expected wages will depend on the expected opportunity cost of employment within the pool of searching workers. Accordingly, the relevant opportunity cost will similarly be given by a population-weighted average of the opportunity cost of employment of agents with different outside options, in particular the option to receive benefits. This implies that, abstracting from differential asset positions across employment states, the average opportunity cost of employment implied by individual bargaining will coincide with the opportunity cost implied by household-level bargaining and given in equation (37). We show this formally in the Online Appendix. Second, the additional component associated to differential asset accumulation is likely to be little affected by changes in benefit duration and compensation, as we argue in the Online Appendix. This is true in particular as most unemployed workers will be liquidity constrained, especially those impacted by benefit extensions, and hence choose future assets at the borrowing limit.

That the opportunity cost is comparable in the two setups make us confident about the predictions of our model for the effects of benefits on wages and hiring, via the opportunity cost of work.

6 Explaining Unemployment

In this section we evaluate the ability of our model to account for unemployment dynamics. To do this, we estimate a number of exogenous shocks, feed them into the model and compare simulated unemployment dynamics to actual data. To keep with the literature, we start with productivity shocks as the single driving force and consider a relatively long sample. We then restrict attention to the Great Recession and explore additional sources of aggregate fluctuations. In both cases, we allow for both automatic and discretionary extensions, which we separately measure in the data. We further quantify the stabilizing effect of the unprecedented benefit extensions introduced during the Great Recession and evaluate the contribution of each channel in shaping that effect.

6.1 Measuring Automatic and Discretionary Extensions

To estimate automatic and discretionary extensions from U.S. data, we use the monthly recipiency rate - the share of unemployed workers receiving unemployment insurance - from McKenna (2015), available starting January 1972. The series comprises both regular programs, in particular State Unemployment Insurance, and Federal programs, including Extended Benefits (EB) and other emergency benefits, among which for example the 2008 Emergency Unemployment Compensation (EUC08).

To distinguish between automatic and discretionary extensions, we use a loglinear version of the recipiency rule in (31), given by

$$\log(\nu_t) - \log(\overline{\nu}_t) = \Gamma_\nu \left(\log(u_{t-1}) - \log(\overline{u}_{t-1})\right) + \varepsilon_{\nu t}, \tag{52}$$

to regress the deviation of the recipiency rate ν_t from its trend $\overline{\nu}_t$ (computed with an HP filter) on deviations of past unemployment u_{t-1} from its trend $\overline{u}_{t-1}$, and use the residual $\varepsilon_{\nu t}$ as an exogenous series.

The first component, $\Gamma_\nu \left(\log(u_{t-1}) - \log(\overline{u}_{t-1})\right)$, is endogenous and taken to capture the automatic extensions embedded in the U.S. system and triggered by increases in unemployment above certain thresholds. One example of these extensions are those prescribed by the Extended Benefits program. We note that while benefit duration is usually changed in a discrete way, say from a maximum of 26 to 39 weeks, the recipiency rate changes smoothly.[36] As a result, we can estimate a rule that makes the recipiency rate a smooth function of past unemployment.

The second component, $\varepsilon_{\nu t}$, is exogenous and taken to capture discretionary changes in benefit duration, for example those introduced by EUC08. Even though these extensions naturally occur during periods of particularly high unemployment, they are not guaranteed by law and their amount and timing is fully discretionary. Yet, our estimation strategy allows for part of the discretionary extensions to be captured by the endogenous component. This is consistent with an interpretation of the first component as capturing extensions implied by either automatic provisions built-in into the system or recurrent discretionary provisions at times of high unemployment. Accordingly, the exogenous component of the rule captures deviations of extensions from those normally implied by the evolution of unemployment and thus likely includes most of the discretionary extensions.

We estimate an elasticity of automatic extensions to unemployment, Γ_ν, equal to 0.6329. We then fit an AR(1) process on the recipiency residual, $\varepsilon_{\nu t}$, and recover an autocorrelation coefficient, ρ_ν, equal to 0.9492, and a standard deviation, σ_ν, equal to 0.0214. Figure 3 plots recipiency process $\varepsilon_{\nu t}$. When the recipiency process takes values above zero, duration policy is more generous than what current economic conditions would normally imply. As expected, the figure shows that the discretionary component is usually above zero after recessions, consistently with the idea that policymakers choose to extend benefits after recessions. Values below zero instead capture a less generous duration than what is implied by the historical policy behavior.

[36] At a given time, the discreet changes in maximum duration only bind for the subset of unemployed workers who find themselves at benefit exhaustion. The effect of extensions on the recipiency rate is thus smoothed out over time by taking the average of a recipiency status indicator function across unemployed workers.

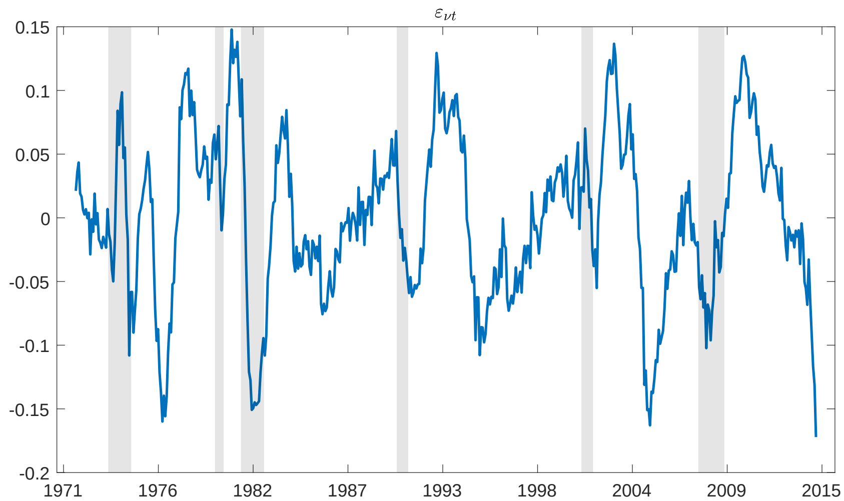


Figure 3: Recipiency process, $\varepsilon_{\nu t}$

6.2 Tracking Unemployment, with Productivity Shocks

In keeping with most of the literature, we first consider productivity as the single driving force. We take productivity to be quarterly real output per person in the non-farm business sector, from the Bureau of Labor Statistics (BLS), and estimate an AR(1) process on the HP-filtered log productivity series. (See the Online Appendix for the plot of the estimated productivity process). We then feed-in the residual into the model, assuming that the autocorrelation coefficient and the variance of the process is known to the agents, and obtain the simulated unemployment rate. We similarly feed-in the estimated recipiency process, to also allow for the discretionary component of extensions.[37]

Figure 4 plots actual unemployment (blue solid line) against unemployment from the model (red dotted line). For completeness, we also plot the trend from HP filtering the data (grey thin line). The figure shows that the model matches the behavior of unemployment reasonably well over the almost 50-years sample considered. Remarkably, the standard deviation of unemployment in the model (not targeted) is almost identical to that in the data (1.56 versus 1.57). The correlation between the model's unemployment rate and the actual rate is 0.77, but only 0.26 if we consider their cyclical components. Overall, unemployment from the model tracks actual unemployment closely at the beginning of the sample, but less so starting the 1990s and especially during the Great Recession.

Figure 5 zooms in on the Great Recession. Panel 5a plots the levels of unemployment in the data and from the model as in Figure 4, in percent of the labor force. Panel 5b plots the cyclical components, in percent deviation from the trend. The figure clearly indicates that productivity shocks are not a good candidate to explain unemployment during the Great

[37]We calibrate the model to 1972-2017 averages for unemployment (6.33 percent) and the STU share (81 percent), given that these are available starting 1972. Results are fully robust to using the targets in Table 2.

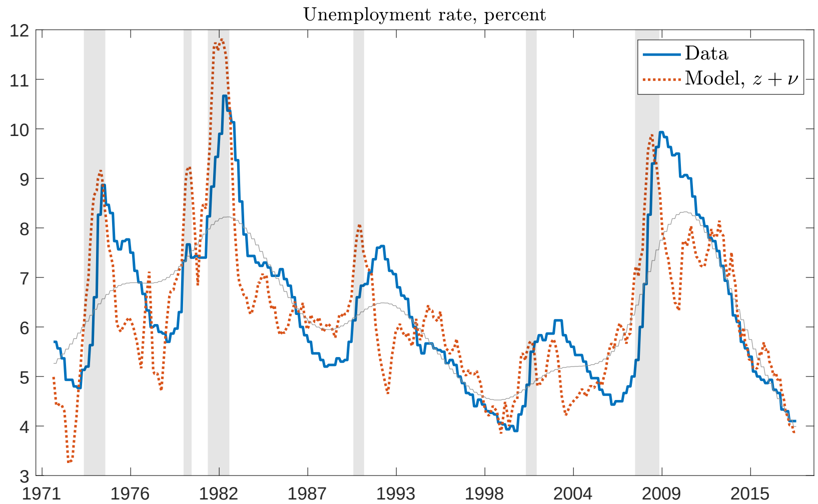
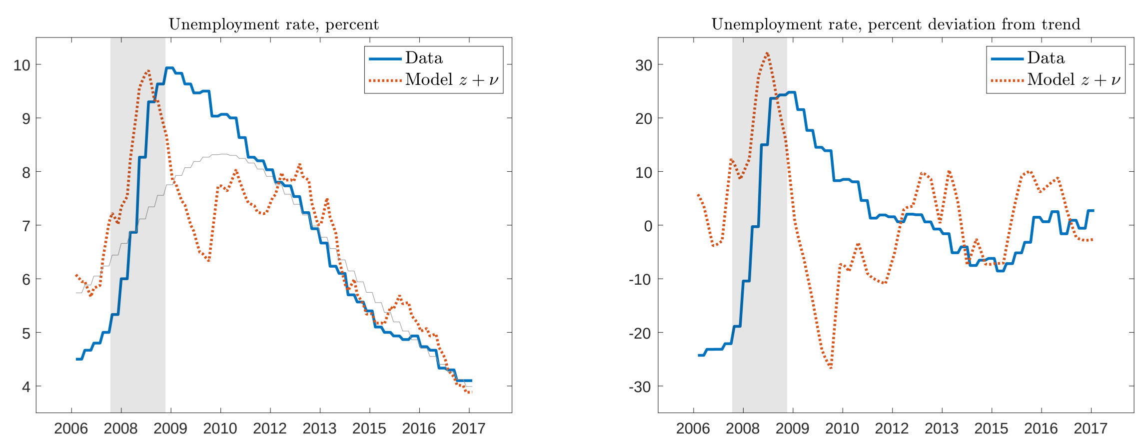


Figure 4: Actual vs. model unemployment, with productivity shocks

Recession. The timing of unemployment dynamics that is induced by the productivity shock is off: the productivity rebounds fast after the end of the recession and drives down unemployment from the model, while actual unemployment persists elevated into the recovery. The correlation between the model and the actual rate during the five years following the 2007 business cycle peak is 0.10 and drops to 0 if we consider the cyclical components.



(a) Percent of labor force

(b) Percent deviation from trend

Figure 5: Great Recession, with productivity shocks

That the model cannot track unemployment during the Great Recession when productivity shocks drive fluctuations does not come as a surprise. Indeed, the economic literature has identified alternative more promising candidate driving forces, including credit tightening and mass layoffs. For instance, Mian and Sufi (2014) show that more than half of the fall in employment can be accounted for by a deterioration in household net worth, which lowered consumer demand through a negative wealth effect and a tightening of the borrowing capacity.[38] At the same time, Ravn and Sterk (2017) show that during the Great Recession, a sharp burst in layoffs largely contributed to the sharp increase in unemployment, while the persistence of high unemployment can be explained by the unprecedented incidence of long-term unemployment, with long-term unemployed finding jobs at lower rates. We next focus on the Great Recession and explore such alternative forces that our rich model can accommodate.

6.3 The Great Recession

The alternative driving forces that we consider are shocks to the exogenous borrowing limit $\bar{b}_t$, to the exogenous separation rate $1-\rho_t$, and to the exogenous probability of becoming long-term unemployed ρ_t^{ω}. We first explain how we estimate the exogenous processes and then present the results of the feed-in exercise, including the role of automatic and discretionary extensions.

6.3.1 Estimating Borrowing, Separation and LTU Shocks

We focus on the 2006-2017 period, around the Great Recession, but estimate the shocks starting 2001, to avoid the beginning-of-sample problem of the HP filter.

To compute separation shocks, we use monthly layoffs and discharges in the non-farm sector from JOLTS. We normalize layoffs and discharges (JTSLDL series) by employment (PAYEMS series) in the same sector and subtract it from 1 to obtain the retention rate. To estimate the borrowing process, we use quarterly debt securities and loans for households and nonprofit organizations (liability, level, CMDEBT series) from the Fed Board and take the percentage change from a year ago.[39] Finally, to construct the LTU shock, we use the laws of motion for STU and LTU from the model, given by equations (5) and (6). We sum the two equations to obtain the job finding rate per unit of search intensity as

$$\rho_t^s = \frac{u_t^{new} + u_{t-1} - u_t}{u_{t-1}^{ST} + \bar{\sigma} u_{t-1}^{LT}}, \tag{53}$$

where $u_t^{new} \equiv (1-\rho_t)n_{t-1}$ denotes the number of newly unemployed workers, in the spirit of Shimer (2005). Given ρ_t^s, we use equation (5) (or equation (6)) to obtain the LTU

[38] Guerrieri and Lorenzoni (2017) use an heterogeneous agents model to show that a tightening in consumers' borrowing capacity can lead to a sharp drop in output by forcing constrained agents to reduce their consumption and by inducing unconstrained agents to raise their precautionary savings. In their model, labor market risk is exogenous.

[39] We use the change in debt rather than the level because it better corresponds to the interpretation of debt in the model. In the model, debt is used for current consumption; in the data, it is more likely that newly issued debt (or the change in the debt) is used for current consumption rather than the overall stock of debt.

transition rate as

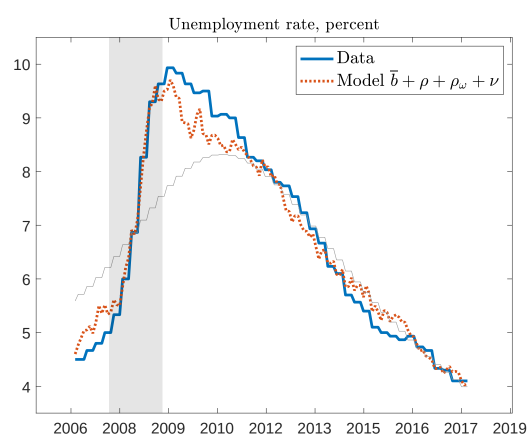
$$\rho_t^{\omega} = \frac{u_t^{LT} - u_{t-1}^{LT}\left(1 - \rho_t^s \overline{\sigma}\right)}{u_{t-1}^{ST}\left(1 - \rho_t^s\right)}. \tag{54}$$

We compute ρ_t^{ω} using data on unemployment by duration from the BLS. We measure u_t^{new} with the number of workers unemployed for 0 to 4 weeks; u_t^{LTU} with the number of unemployed for 27 weeks and over; and u_t^{STU} with the number of unemployed for less than 27 weeks. We set $\overline{\sigma} = 0.5$, as in our calibration. We smooth out the resulting LTU series by taking a six-months moving average.

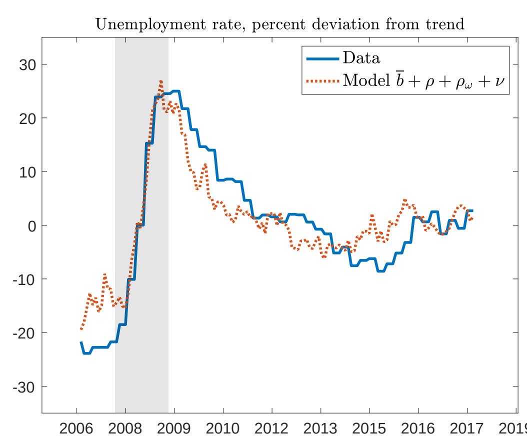
We finally estimate AR(1) processes on the (logged) HP-filtered series and use the residuals as exogenous inputs to the model. The resulting series appear in the Online Appendix.

6.3.2 Tracking Unemployment, with Borrowing, Separations and LTU Shocks

Figure 6 compares actual unemployment during the Great Recession to unemployment simulated from the model based on borrowing, separation and LTU shocks, as well as the recipiency shock. Panel 6a plots the levels in percent of the labor force, panel 6b the cyclical components in percent deviation from the trend. The figure clearly demonstrates that the model's unemployment rate with the four shocks tracks closely the actual rate. The correlation between unemployment from the model and in the data in the five years that follow the 2007 business cycle peak is remarkable: 0.97 for the levels and 0.94 for the cyclical components (compared to 0.10 and 0 in Figure 5 when productivity shocks drive fluctuations).



(a) Percent of labor force



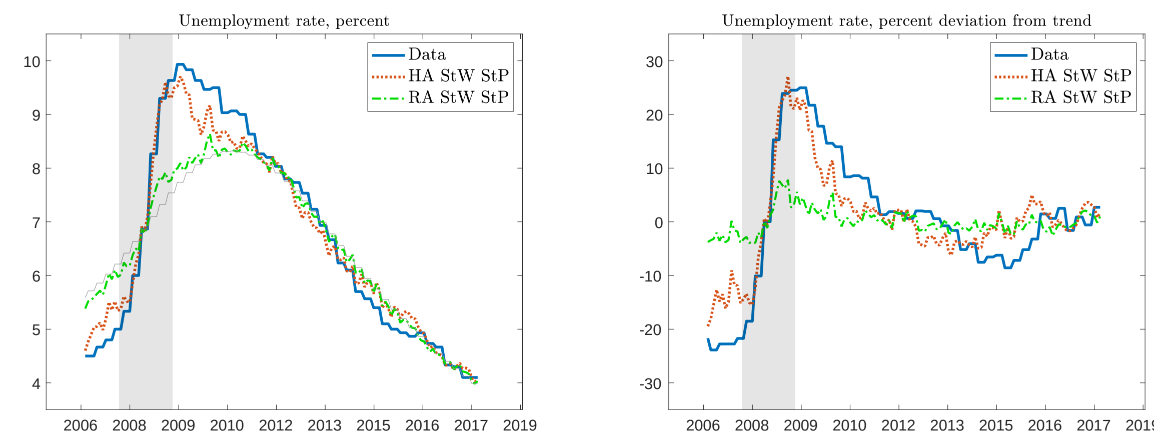
(b) Percent deviation from trend

Figure 6: Great Recession, with borrowing, separation and LTU shocks

Before digging deeper into the reasons behind the model's success, we note that even though the nominal interest rate becomes negative in our simulations of the Great Recession period, we abstract from incorporating a binding zero lower bound. In fact, to fully capture the actual extent of monetary policy accommodation over that period, one would also need to account for the unconventional monetary policies (quantitative easing and forward guidance), implemented to make up for the conventional monetary policy shortfall. Indeed, Lombardi and Zhu (2018) show that a shadow policy rate that also reflects unconventional policy drops significantly below zero during the Great Recession. In light of this and given the lack of a clear superior alternative strategy, we consider that the most correct approach is to let the nominal interest rate become negative and keep the same monetary policy rule in this instance.[40]

6.3.3 The Role of Heterogeneous Agents

To show that allowing for heterogeneous agents is key to the model's ability to track actual unemployment, Figure 7 compares the unemployment rate generated by our HA model (red dotted line) to the rate generated by a nested RA model (green dashed-dotted line) with the same four shocks. The figure shows that the unemployment rate from the RA model does not track well the actual rate: it misses to a great extent the magnitude of the increase during the downturn.



(a) Percent of labor force

(b) Percent deviation from trend

Figure 7: HA vs. RA model, with borrowing, separation and LTU shocks

There are two main reasons for this. The first is that the borrowing shock only plays a role in the HA model. In this model, short-term borrowing sustains consumption of unemployed workers, permitting to smooth consumption across individual states and partially insuring against idiosyncratic risk. The credit tightening that we estimate during the Great Recession thus causes a large drop in aggregate demand, in turn causing a

[40]We could in principle proxy the binding zero lower bound via a less (or more) aggressive monetary policy. Since there is no obvious way to calibrate the shadow interest rate rule, we let it replicate the rule that applies outside it.

significant increase in unemployment. In the RA model, instead, consumption in different states is fully insured and the credit contraction has no impact on aggregate demand.[41]

The second reason why the HA model better captures the rise in unemployment, is that the interaction of precautionary motives with endogenous idiosyncratic risk amplifies the response of the economy to any aggregate shock, as we discuss in Section A.5 of the Online Appendix.[42]

6.3.4 Quantifying the Impact of Automatic and Discretionary Extensions

Having shown that with borrowing, separation and LTU shocks unemployment from the model closely tracks actual unemployment during the Great Recession, we now assess whether extensions have either played a stabilizing or a destabilizing role, and quantify their effect.

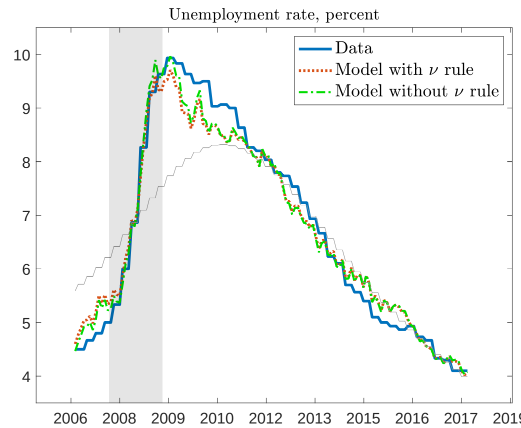
We first consider the role of automatic extensions, which is illustrated in the top panels of Figure 8. The left panel plots the actual unemployment rate (blue solid line) against unemployment from both our baseline model (red dotted line) and a counterfactual model (green dashed-dotted line) where we shut off automatic extensions by setting the elasticity parameter of the recipiency rule, Γ_ν, equal to 0. The right panel plots the difference of unemployment in the baseline and the counterfactual model, that is, the net effect of automatic extensions.

The figure demonstrates that automatic extensions contributed to stabilizing unemployment during the Great Recession, that is, unemployment has been lower rather than higher as a consequence of the automatic increases in duration embedded in the the U.S system. However, the impact is not quantitatively large: at their peak effect, automatic extensions lowered unemployment by 0.29 percentage points. One reason for this is the presence of offsetting channels of unemployment insurance, as we discussed in Section 4. The timing of the effect is intuitive: the extent of stabilization raises over the recession as unemployment increases and peaks around the business cycle trough in June 2009, when it reaches a rate close to 10 percent.

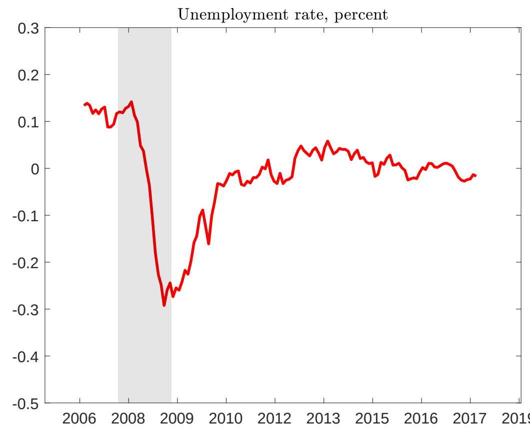
The impact of discretionary extensions is illustrated in the bottom panels of Figure 8. In this case, the counterfactual model is one where we close discretionary extensions by shutting off the exogenous recipiency process $\varepsilon_{\nu t}$. Not surprisingly, the model predicts that also discretionary extensions played a stabilizing role for unemployment. Indeed, the stabilizing and destabilizing channels of unemployment insurance embedded in our model will similarly play out in net in response to both types of extensions. What is more

[41] Figure C.4 in the Online Appendix makes clear that the borrowing shock is the main driver of the different predictions. When the borrowing shock is shut off, unemployment from our model becomes much closer to unemployment from the RA model.

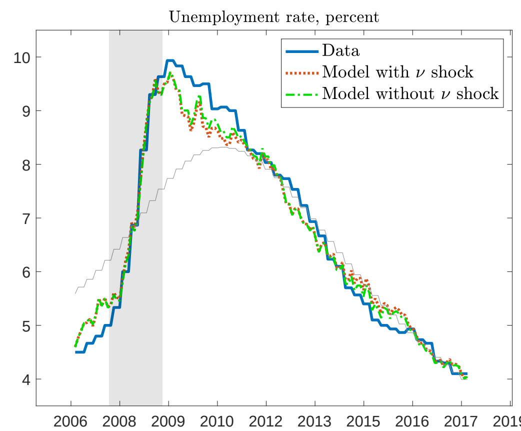
[42] The amplification relative to a RA model with no idiosyncratic risk is illustrated in Figure C.5, in response to separation and LTU shocks, though it is not quantitatively large.



(a) Automatic extensions, levels



(b) Automatic extensions, difference



(c) Discretionary extensions, levels

(d) Discretionary extensions, difference

Figure 8: Impact of automatic vs. discretionary extensions

interesting is the extent and the timing of the response to discretionary extensions, as these are also influenced by the properties of the estimated recipiency process. We find that the quantitative effect of discretionary extensions is not large, as for automatic extensions. The timing of their stabilizing effect is instead different, as discretionary extensions played out mostly in the recovery phase. The largest stabilizing effect occurred in September 2010 and decreased unemployment by 0.17 percentage points.

As previously discussed, the estimated recipiency process captures extensions beyond those normally implied by the evolution of the unemployment rate. In Figure 3, we recover a negative process at the start of the Great Recession since at that time unemployment was increasing fast and extensions were lagging behind. When the EUC08 program was signed into law in June 2008, the recipiency rate started to increase. It then accelerated after the expansion of the program in November 2009, reaching a peak of almost 70 percent in mid 2010, after which benefit duration began to decline in some of the states. However, starting mid 2009, while the actual recipiency rate was still rising as a consequence of the extensions prescribed by the ARRA, unemployment began to gradually revert. This explains why the largest positive values of the recipiency process occur in 2010, almost a year after the official end of the recession, and why in the bottom right panel of Figure 8 we observe the strongest stabilizing effect during the recovery rather than the recession phase. Unsurprisingly, it takes time to design and implement discretionary measures.

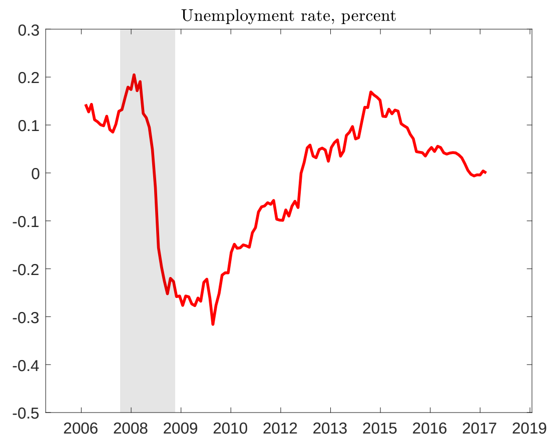


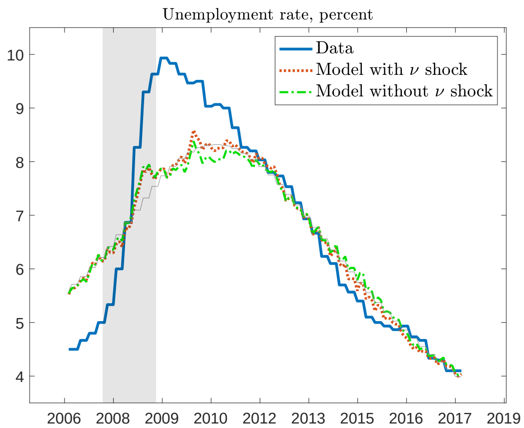
Figure 9: Joint impact of automatic and discretionary extensions

Figure 9 combines the net effect of automatic and discretionary extensions on unemployment. The total peak effect of extensions occurred in July 2010 and stabilized the unemployment rate by 0.31 percentage points. Importantly, such quantitative impact falls within the range of estimates in Chodorow-Reich, Coglianese and Karabarbounis (2018). These authors estimate that the effect of benefit extensions on unemployment during the Great Recession is between -0.5 and 0.3 percentage points. The comparison is relevant since their estimation strategy is likely to capture both aggregate demand and labor market effects of unemployment insurance, as we have argued in the related literature section.

6.3.5 Quantifying the Contribution of the Channels

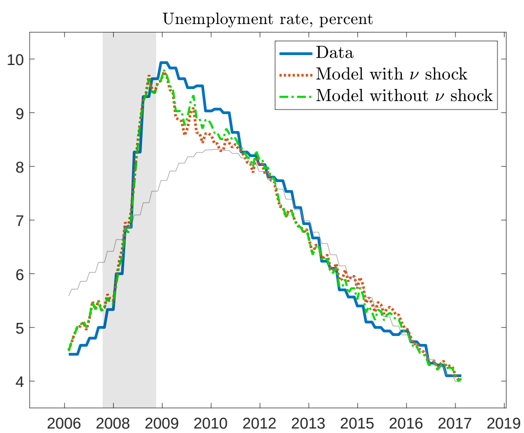
This section quantifies the contribution of each channel of unemployment insurance to the net stabilizing effect of extensions on unemployment. We focus on discretionary extensions.

The top panels of Figure 10 report the impact of discretionary extensions when aggregate demand effects are shut off by assuming flexible prices. Absent price rigidity, benefits mainly affect the economy via their effect on outside options and wages. To give the labor market channel its maximum strength, we also assume flexible wages. The figure clearly shows that absent aggregate demand effects, discretionary extensions would have increased the unemployment rate during the recovery phase by 0.25 percentage points.



(a) Labor market channel (flex prices), levels

(b) Labor market channel (flex prices), difference



(c) Aggregate demand channel (ξ_t fixed), levels

(d) Aggregate demand channel (ξ_t fixed), difference

Figure 10: Discretionary extensions: impact of transmission channels

This result is in line with the analysis in Mitman and Rabinovich (2020) who consider a RA model and find that benefit extensions increase unemployment in recessions. Our results demonstrate the importance of taking into account aggregate demand effects via worker heterogeneity.[43]

To close the labor market channel we fix the opportunity cost of employment, ξ_t, to its steady state value. The bottom panels of Figure 10 present the results. Relative to the impact when both channels are present, extensions become more stabilizing. The largest impact of discretionary extensions during the recovery from the Great Recession almost doubles, from a reduction of unemployment of 0.17 percentage points when both channels are present to a reduction of 0.27 percentage points when the labor market channel

[43] We note that the effect of extensions via labor market effects in Mitman and Rabinovich (2020) appears to be stronger quantitatively. This happens for two reasons. Consistent with data on the consumption drop at benefit exhaustion, we calibrate a *net* benefit of extensions, given by the difference of the benefit and the safety net transfer. We also calibrate a lower opportunity cost of employment, using micro evidence on replacement rates and labor supply elasticity.

is switched off. These results emphasize the importance of microfounding the effect of benefits on average wages for assessing the stabilizing effects of extensions.

7 Conclusions

We study the stabilizing effect of cyclical benefit extensions in a rich but tractable model that incorporates the two key transmission mechanisms of unemployment insurance, a labor market and an aggregate demand channel. The setup also allows for amplification of precautionary motives via endogenous unemployment risk and accommodates shocks to the consumers' borrowing capacity. We consider both automatic and discretionary extensions.

We calibrate the model to the U.S. economy and find that both channels are quantitatively important, but that the stabilizing aggregate demand channel mildly prevails. We analytically characterize each mechanism and show that differences in consumption by employment states are key to both. We show that considering both channels within a unified framework is important. For example, the labor market channel is stronger in presence of heterogeneous agents. We also show that unemployment from the model tracks actual unemployment during the Great Recession remarkably well, if estimated shocks to borrowing capacity, layoffs and transitions to long-term unemployment are fed into the model. The unprecedented benefit extensions implemented since 2008 contributed to stabilizing unemployment, but their effect has not been large. Overall, extensions stabilized unemployment by a peak effect of 0.31 percentage points in 2010. Importantly, the magnitude of this effect falls within the range of empirical estimates in the literature.

We leave for future research the use of the model to assess the impact of the unemployment insurance provisions put into effect by the U.S. government during the current Covid recession.

References

Bilbiie, Florin Ovidiu. 2018. "Monetary policy and heterogeneity: An analytical framework."

Bils, Mark, and Peter J Klenow. 2004. "Some evidence on the importance of sticky prices." *Journal of political economy*, 112(5): 947–985.

Boone, Christopher, Arindrajit Dube, Lucas Goodman, and Ethan Kaplan. 2021. "Unemployment Insurance Generosity and Aggregate Employment." *American Economic Journal: Economic Policy*, 13(2): 58–99.

Calvo, Guillermo A. 1983. “Staggered Prices in a Utility-Maximizing Framework.” *Journal of Monetary Economics*, 12(3): 383–398.

Challe, Edouard. 2020. “Uninsured unemployment risk and optimal monetary policy in a zero-liquidity economy.” *American Economic Journal: Macroeconomics*, 12(2): 241–83.

Chodorow-Reich, Gabriel, and Loukas Karabarbounis. 2016. “The Cyclicality of the Opportunity Cost of Employment.” *Journal of Political Economy*, 124(6): 1563–1618.

Chodorow-Reich, Gabriel, John Coglianese, and Loukas Karabarbounis. 2018. “The Macro Effects of Unemployment Benefit Extensions: a Measurement Error Approach.” *The Quarterly Journal of Economics*, 134(1): 227–279.

Di Maggio, Marco, and Amir Kermani. 2016. “The Importance of Unemployment Insurance as an Automatic Stabilizer.” National Bureau of Economic Research.

Dieterle, Steven, Otávio Bartalotti, and Quentin Brummet. 2020. “Revisiting the Effects of Unemployment Insurance Extensions on Unemployment: A Measurement-Error-Corrected Regression Discontinuity Approach.” *American Economic Journal: Economic Policy*, 12(2): 84–114.

Faig, Miquel, Min Zhang, and Shiny Zhang. 2016. “Effects of Extended Unemployment Insurance Benefits on Labor Dynamics.” *Macroeconomic Dynamics*, 20(5): 1174–1195.

Farber, Henry S, and Robert G Valletta. 2015. “Do Extended Unemployment Benefits Lengthen Unemployment Spells? Evidence from Recent Cycles in the US Labor Market.” *Journal of Human Resources*, 50(4): 873–909.

French, Eric. 2005. “The effects of health, wealth, and wages on labour supply and retirement behaviour.” *The Review of Economic Studies*, 72(2): 395–427.

Ganong, Peter, and Pascal Noel. 2019. “Consumer Spending During Unemployment: Positive and Normative Implications.” *American Economic Review*, 109(7): 2383–2424.

Gertler, Mark, and Antonella Trigari. 2009. “Unemployment Fluctuations with Staggered Nash Wage Bargaining.” *Journal of Political Economy*, 117(1): 38–86.

Guerrieri, Veronica, and Guido Lorenzoni. 2017. “Credit crises, precautionary savings, and the liquidity trap.” *The Quarterly Journal of Economics*, 132(3): 1427–1467.

Hagedorn, Marcus, and Iourii Manovskii. 2008. “The cyclical behavior of equilibrium unemployment and vacancies revisited.” *American Economic Review*, 98(4): 1692–1706.

Hagedorn, Marcus, Fatih Karahan, Iourii Manovskii, and Kurt Mitman. 2019. "Unemployment Benefits and Unemployment in the Great Recession: The Role of Macro Effects." *Unpublished manuscript*.

Hall, Robert E. 2005. "Employment Fluctuations with Equilibrium Wage Stickiness." *American Economic Review*, 95(1): 50–65.

Hall, Robert E, and Paul R Milgrom. 2008. "The limited influence of unemployment on the wage bargain." *American Economic Review*, 98(4): 1653–74.

Johnston, Andrew C, and Alexandre Mas. 2018. "Potential Unemployment Insurance Duration and Labor Supply: The Individual and Market-Level Response to a Benefit Cut." *Journal of Political Economy*, 126(6): 2480–2522.

Kekre, Rohan. 2021. "Unemployment Insurance in Macroeconomic Stabilization." *Unpublished manuscript*.

Kroft, Kory, Fabian Lange, Matthew J Notowidigdo, and Lawrence F Katz. 2016. "Long-Term Unemployment and the Great Recession: The Role of Composition, Duration Dependence, and Nonparticipation." *Journal of Labor Economics*, 34(S1): S7–S54.

Lombardi, Marco J, and Feng Zhu. 2018. "A shadow policy rate to calibrate US monetary policy at the zero lower bound." *56th issue (December 2018) of the International Journal of Central Banking*.

McKay, Alisdair, and Ricardo Reis. 2016. "The Role of Automatic Stabilizers in the US Business Cycle." *Econometrica*, 84(1): 141–194.

McKay, Alisdair, and Ricardo Reis. 2021. "Optimal Automatic Stabilizers." *The Review of Economic Studies*. rdaa038.

McKenna, Claire. 2015. "The job ahead: Advancing opportunity for unemployed workers." *National Employment Law Project, February*.

Mian, Atif, and Amir Sufi. 2014. "What explains the 2007–2009 drop in employment?" *Econometrica*, 82(6): 2197–2223.

Mitman, Kurt, and Stanislav Rabinovich. 2020. "Do Unemployment Benefit Extensions Explain the Emergence of Jobless Recoveries?" *Unpublished manuscript*.

Petrongolo, Barbara, and Christopher A Pissarides. 2001. "Looking into the black box: A survey of the matching function." *Journal of Economic literature*, 39(2): 390–431.

Ravn, Morten O, and Vincent Sterk. 2017. "Job Uncertainty and Deep Recessions." *Journal of Monetary Economics*, 90: 125–141.

Ravn, Morten O, and Vincent Sterk. 2021. "Macroeconomic fluctuations with HANK & SAM: An analytical approach." *Journal of the European Economic Association*, 19(2): 1162–1202.

Reichling, Felix, and Charles Whalen. 2012. "Review of estimates of the Frisch elasticity of labor supply."

Rothstein, Jesse. 2011. "Unemployment Insurance and Job Search in the Great Recession." *Brookings Papers on Economic Activity*, 143–214.

Sala, Luca, Ulf Söderström, and Antonella Trigari. 2008. "Monetary policy under uncertainty in an estimated model with labor market frictions." *Journal of Monetary Economics*, 55(5): 983–1006.

Shimer, Robert. 2005. "The Cyclical Behavior of Equilibrium Unemployment and Vacancies." *American Economic Review*, 95(1): 25–49.

For Online Publication: Appendix for Assessing the (De)Stabilizing Effects of Unemployment Benefit Extensions

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May 5, 2021

Appendix A presents derivations of the model equilibrium conditions, as well as the full equilibrium system. It also presents the derivation of the condition we use to calibrate the disutility of work. Finally, it discusses key aspects of the model that underlie its dynamics. Appendix B presents further proofs, derivations and results related to the transmission channels of unemployment insurance. Appendix C reports additional tables and figures cited but not included in the main text.

A Model Derivations

A.1 Household FOCs

Let λ_t^B, λ_t^{CN}, λ_t^{CUR}, λ_t^{CUN}, λ_t^{BC}, λ_t^A, be the multipliers associated with the following constraints in the main text: the household budget constraint (equation (8)), the liquidity constraint for employed (equation (9)), the liquidity constraint for benefit recipients (equation (10)), the liquidity constraint for non-recipients (equation (11)), the borrowing constraint (equation (12)), the end-of-period asset constraint (equation (13)). The household first-order conditions are:

w.r.t. x_t:

$$\lambda_t^B - \lambda_t^A + \lambda_t^{CN} + \lambda_t^{CUR} + \lambda_t^{CUN} = 0 \tag{A.1}$$

w.r.t. c_t^n:

$$n_t u'\left(c_t^n\right) - \lambda_t^{CN} + n_t \lambda_t^A = 0 \tag{A.2}$$

with

$$\lambda_t^{CN}\left(x_t + \left(1-\tau_t\right) w_t + \left(1-\tau_t\right) d_t - c_t^n\right) = 0 \tag{A.3}$$

w.r.t. c_t^{ur}:

$$\left(1-n_t\right) \nu_t u'\left(c_t^{ur}\right) - \lambda_t^{CUR} + \left(1-n_t\right) \nu_t \lambda_t^A = 0 \tag{A.4}$$

with

$$\lambda_t^{CUR}\left(x_t + \tau_t^u - c_t^{ur}\right) = 0 \tag{A.5}$$

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w.r.t. c_t^{un}:

$$\left(1-n_t\right)\left(1-\nu_t\right)u'\left(c_t^{un}\right)-\lambda_t^{CUN}+\left(1-n_t\right)\left(1-\nu_t\right)\lambda_t^{A}=0 \tag{A.6}$$

with

$$\lambda_t^{CUN}\left(x_t+\tau^s-c_t^{un}\right)=0 \tag{A.7}$$

w.r.t. b_{t+1}:

$$-\frac{1}{p_t}\lambda_t^{B}-\lambda_t^{BC}+\beta E_t\left\{\frac{\partial W\left(n_t,a_{t+1},b_{t+1}\right)}{\partial b_{t+1}}\right\}=0 \tag{A.8}$$

with

$$\lambda_t^{BC}\left(p_t\bar{b}_t-b_{t+1}\right)=0 \tag{A.9}$$

w.r.t. a_{t+1}:

$$\frac{1}{p_t}\lambda_t^{A}+\beta E_t\left\{\frac{\partial W\left(n_t,a_{t+1},b_{t+1}\right)}{\partial a_{t+1}}\right\}=0 \tag{A.10}$$

The envelope conditions are:

$$\frac{\partial W\left(n_{t-1},a_t,b_t\right)}{\partial a_t}=-\frac{\left(1+i_t\right)}{p_t}\lambda_t^{B} \tag{A.11}$$

$$\frac{\partial W\left(n_{t-1},a_t,b_t\right)}{\partial b_t}=\frac{\left(1+i_t\right)}{p_t}\lambda_t^{B} \tag{A.12}$$

We next solve for the multipliers. In general, which among the inequality constraints are binding will depend on the calibration of the model. We are interested in the solution of the model that implies different consumption levels by employment states. In particular, we calibrate the model to have $\bar{c}^n>\bar{c}^{ur}>\bar{c}^{un}$ and a positive borrowing limit $\bar{b}$.[1] In that case, the liquidity constraints of unemployed workers are binding, while the liquidity constraint of employed is not. This implies $\lambda_t^{CN}=0$. Then, from (A.2), we get

$$\lambda_t^{A}=-u'\left(c_t^{n}\right), \tag{A.13}$$

from (A.4) we get

$$\lambda_t^{CUR}=\left(1-n_t\right)\nu_t\left(u'\left(c_t^{ur}\right)-u'\left(c_t^{n}\right),\right) \tag{A.14}$$

and from (A.6) we get

$$\lambda_t^{CUN}=\left(1-n_t\right)\left(1-\nu_t\right)\left(u'\left(c_t^{un}\right)-u'\left(c_t^{n}\right).\right) \tag{A.15}$$

Substitute these into (A.1) to obtain:

$$\begin{aligned}\lambda_t^{B} &= \lambda_t^{A}-\left(\lambda_t^{CUR}+\lambda_t^{CUN}\right) \\ &= -u'\left(c_t^{n}\right)-\left(1-n_t\right)\left[\nu_t\left(u'\left(c_t^{ur}\right)-u'\left(c_t^{n}\right)\right)+\left(1-\nu_t\right)\left(u'\left(c_t^{un}\right)-u'\left(c_t^{n}\right)\right)\right] \\ &= -n_tu'\left(c_t^{n}\right)-\left(1-n_t\right)\left(\nu_tu'\left(c_t^{ur}\right)+\left(1-\nu_t\right)u'\left(c_t^{un}\right)\right)\end{aligned} \tag{A.16}$$

[1] We also check that the order of consumption levels is preserved in the dynamic simulations.

To solve for λ_t^{BC}, sum (A.8) and (A.10), using also (A.11) and (A.12), to obtain:

$$\begin{aligned}
\lambda_t^{BC} &= \frac{1}{p_t}\lambda_t^A - \frac{1}{p_t}\lambda_t^B \\
&= -\frac{1}{p_t}u'\left(c_t^n\right) + \frac{1}{p_t}\left[n_t u'\left(c_t^n\right) + (1-n_t)\left(\nu_t u'\left(c_t^{ur}\right) + (1-\nu_t)\, u'\left(c_t^{un}\right)\right)\right] \\
&= \frac{1}{p_t}(1-n_t)\left(\nu_t u'\left(c_t^{ur}\right) + (1-\nu_t)\, u'\left(c_t^{un}\right) - u'\left(c_t^n\right)\right) > 0
\end{aligned} \tag{A.17}$$

Because the multiplier λ_t^{BC} is positive, the borrowing constraint must be binding.

To derive the Euler equation, combine (A.10) with (A.11) and use previous results:

$$\begin{aligned}
\frac{1}{p_t}\lambda_t^A &= -\beta E_t\left\{\frac{\partial W\left(n_t, a_{t+1}, b_{t+1}\right)}{\partial a_{t+1}}\right\} \\
\frac{1}{p_t}\lambda_t^A &= \beta E_t\left\{\frac{1+i_{t+1}}{p_{t+1}}\lambda_{t+1}^B\right\} \\
\lambda_t^A &= \beta E_t\left\{\frac{1+i_{t+1}}{\pi_{t+1}}\lambda_{t+1}^B\right\} \\
u'\left(c_t^n\right) &= \beta E_t\left\{\frac{1+i_{t+1}}{\pi_{t+1}}\left[n_{t+1}u'\left(c_{t+1}^n\right) + (1-n_{t+1})\left(\nu_{t+1}u'\left(c_{t+1}^{ur}\right) + (1-\nu_{t+1})\, u'\left(c_{t+1}^{un}\right)\right)\right]\right\}
\end{aligned} \tag{A.18}$$

We finally derive the discount factor $\Lambda_{t,t+1}$ and the value of an additional employed member to the household $W_{n,t}$, equations (14) and (18) in the main text.

The discount factor is obtained as follows:

$$\begin{aligned}
\Lambda_{t,t+1} &\equiv \beta E_t\left\{\frac{\partial W\left(n_t, a_{t+1}, b_{t+1}\right)}{\partial D_{t+1}} \Big/ \frac{\partial W\left(n_{t-1}, a_t, b_t\right)}{\partial D_t}\right\} \\
&= \beta E_t\left\{\frac{\frac{(1-\tau_{t+1})}{n_{t+1}}\lambda_{t+1}^{CN} - (1-\tau_{t+1})\,\lambda_{t+1}^A}{\frac{(1-\tau_t)}{n_t}\lambda_t^{CN} - (1-\tau_t)\,\lambda_t^A}\right\} \\
&= \beta E_t\left\{\frac{(1-\tau_{t+1})\, u'\left(c_{t+1}^n\right)}{(1-\tau_t)\, u'\left(c_t^n\right)}\right\}
\end{aligned} \tag{A.19}$$

The value of $W_{n,t}$ is obtained via the following steps:

$$\begin{aligned}
W_{n,t} &\equiv \frac{\partial W\left(n_{t-1},a_t,b_t\right)}{\partial n_t} \qquad \text{(A.20)}\\
&= u\left(c_t^n\right)-\chi-\left(\nu_t u\left(c_t^{ur}\right)+\left(1-\nu_t\right)u\left(c_t^{un}\right)\right)-\left(1-\tau_t\right)D_t n_t^{-2}\lambda_t^{CN}\\
&\quad -\left[\left(1-\tau_t\right)w_t-\tau_t^u\nu_t-\tau^s\left(1-\nu_t\right)-c_t^n+\nu_t c_t^{ur}+\left(1-\nu_t\right)c_t^{un}\right]\lambda_t^A\\
&\quad +\beta E_t\left\{\frac{\partial W\left(n_t,a_{t+1},b_{t+1}\right)}{\partial n_t}\right\}\\
&= u\left(c_t^n\right)-\chi-\left(\nu_t u\left(c_t^{ur}\right)+\left(1-\nu_t\right)u\left(c_t^{un}\right)\right)\\
&\quad +\left[\left(1-\tau_t\right)w_t-\tau_t^u\nu_t-\tau^s\left(1-\nu_t\right)-c_t^n+\nu_t c_t^{ur}+\left(1-\nu_t\right)c_t^{un}\right]u'\left(c_t^n\right)\\
&\quad +\beta E_t\left\{W_{n,t+1}\frac{\partial n_{t+1}}{\partial n_t}\right\}\\
&= u'\left(c_t^n\right)\Big[\left(1-\tau_t\right)w_t-\Big(\tau_t^u\nu_t+\tau^s\left(1-\nu_t\right)+\left(\nu_t c_t^{ur}+\left(1-\nu_t\right)c_t^{un}-c_t^n\right)\\
&\quad +\left(u'\left(c_t^n\right)\right)^{-1}\left[\nu_t u\left(c_t^{ur}\right)+\left(1-\nu_t\right)u\left(c_t^{un}\right)-\left(u\left(c_t^n\right)-\chi\right)\right]\Big)\Big]\\
&\quad +\beta E_t\left\{\left[\rho_{t+1}-\rho_{t+1}^s\left(\omega_t+\overline{\sigma}\left(1-\omega_t\right)\right)\right]W_{n,t+1}\right\}\\
&= u'\left(c_t^n\right)\left[\left(1-\tau_t\right)w_t-\xi_t\right]+\beta E_t\left\{\left[\rho_{t+1}-\rho_{t+1}^s\left(\omega_t+\overline{\sigma}\left(1-\omega_t\right)\right)\right]W_{n,t+1}\right\}
\end{aligned}$$

where we have used:

$$\begin{aligned}
\frac{\partial n_{t+1}}{\partial n_t} &= \frac{\partial\left(\rho_{t+1}n_t+\rho_{t+1}^s\left(1-n_t\right)\left(\omega_t+\overline{\sigma}\left(1-\omega_t\right)\right)\right)}{\partial n_t} \qquad \text{(A.21)}\\
&= \rho_{t+1}-\rho_{t+1}^s\left(\omega_t+\overline{\sigma}\left(1-\omega_t\right)\right)
\end{aligned}$$

RA Version of the Model

To obtain the representative agent version of our model we remove the liquidity constraints and have the household pool its members' incomes before taking consumption/saving decisions. The problem becomes:

$$\begin{aligned}
W_t\left(n_{t-1},a_t,b_t\right) &= \max\left\{n_t\left(u\left(c_t^n\right)-\chi\right)+\left(1-n_t\right)\left(\nu_t u\left(c_t^{ur}\right)+\left(1-\nu_t\right)u(c_t^{un})\right)\right. \qquad \text{(A.22)}\\
&\quad \left.+\beta E_t\left\{W_{t+1}\left(n_t,a_{t+1},b_{t+1}\right)\right\}\right\}
\end{aligned}$$

Subject to:

$$x_t=\frac{b_{t+1}}{p_t}+\left(1+i_t\right)\frac{a_t}{p_t}-\left(1+i_t\right)\frac{b_t}{p_t} \qquad \text{(A.23)}$$

$$b_{t+1}\leq p_t\overline{b}_t \qquad \text{(A.24)}$$

$$\begin{aligned}
\frac{a_{t+1}}{p_t} &= x_t+\left(1-\tau_t\right)w_t n_t+\left(1-\tau_t\right)d_t n_t+\tau_t^u\left(1-n_t\right)\nu_t+\tau^s\left(1-n_t\right)\left(1-\nu_t\right) \qquad \text{(A.25)}\\
&\quad -\left(n_t c_t^n+\left(1-n_t\right)\nu_t c_t^{ur}+\left(1-n_t\right)\left(1-\nu_t\right)c_t^{un}\right)
\end{aligned}$$

The FOCs are:

w.r.t. x_t:

$$\lambda_t^B - \lambda_t^A = 0 \tag{A.26}$$

w.r.t. c_t^n:

$$n_t u'\left(c_t^n\right) + n_t \lambda_t^A = 0 \tag{A.27}$$

w.r.t. c_t^{ur}:

$$\left(1-n_t\right)\nu_t u'\left(c_t^{ur}\right) + \left(1-n_t\right)\nu_t \lambda_t^A = 0 \tag{A.28}$$

w.r.t. c_t^{un}:

$$\left(1-n_t\right)\left(1-\nu_t\right) u'\left(c_t^{un}\right) + \left(1-n_t\right)\left(1-\nu_t\right)\lambda_t^A = 0 \tag{A.29}$$

w.r.t. b_{t+1}:

$$-\frac{1}{p_t}\lambda_t^B - \lambda_t^{BC} + \beta E_t\left\{\frac{\partial W\left(n_t, a_{t+1}, b_{t+1}\right)}{\partial b_{t+1}}\right\} = 0 \tag{A.30}$$

with

$$\lambda_t^{BC}\left(p_t \bar{b}_t - b_{t+1}\right) = 0 \tag{A.31}$$

w.r.t. a_{t+1}:

$$\frac{1}{p_t}\lambda_t^A + \beta E_t\left\{\frac{\partial W\left(n_t, a_{t+1}, b_{t+1}\right)}{\partial a_{t+1}}\right\} = 0 \tag{A.32}$$

The envelope conditions are:

$$\frac{\partial W\left(n_{t-1}, a_t, b_t\right)}{\partial a_t} = -\frac{\left(1+i_t\right)}{p_t}\lambda_t^B \tag{A.33}$$

$$\frac{\partial W\left(n_{t-1}, a_t, b_t\right)}{\partial b_t} = \frac{\left(1+i_t\right)}{p_t}\lambda_t^B \tag{A.34}$$

The solution implies that consumption in individual states is equalized (since $u'\left(c_t^n\right) = u'\left(c_t^{ur}\right) = u'\left(c_t^{ur}\right) = -\lambda_t^A$) and that the borrowing constraint is not binding (since $\lambda_t^{BC} = 0$).

A.2 Nash Bargained Wage

Here we derive the expression for the Nash bargained wage in equation (36) in the main text.

The wage bargaining problem reads:

$$w_t^* = \arg\max\left(W_{n,t}\right)^\eta \left(F_{n,t}\right)^{1-\eta}, \tag{A.35}$$

where

$$F_{n,t} = q_t z_t - w_t + E_t\left\{\rho_{t+1}\Lambda_{t,t+1}F_{n,t+1}\right\}. \tag{A.36}$$

and

$$W_{n,t} = u'\left(c_t^n\right)\left(1-\tau_t\right)\left(w_t - \frac{\xi_t}{1-\tau_t}\right) + \beta E_t\left\{\left[\rho_{t+1} - \left[\omega_t + \overline{\sigma}\left(1-\omega_t\right)\right]\rho_{t+1}^s\right]W_{n,t+1}\right\}. \tag{A.37}$$

The solution of the bargaining problem implies the following sharing rule:

$$\left(1-\tau_t\right)u'\left(c_t^n\right)\eta F_{n,t} = \left(1-\eta\right)W_{n,t}. \tag{A.38}$$

Substitute the expressions for $F_{n,t}$ and $W_{n,t}$ and divide both sides by $(1-\tau_t)\, u'(c_t^n)$:

$$\begin{aligned}&\eta\left(q_t z_t - w_t^* + E_t\left\{\rho_{t+1}\Lambda_{t,t+1}F_{n,t+1}\right\}\right) \\ &= (1-\eta)\left(\left(w_t^* - \frac{\xi_t}{1-\tau_t}\right) + \frac{1}{(1-\tau_t)\,u'(c_t^n)}\beta E_t\left\{\left[\rho_{t+1} - \left[\omega_t + \overline{\sigma}(1-\omega_t)\right]\rho_{t+1}^s\right]W_{n,t+1}\right\}\right).\end{aligned} \tag{A.39}$$

Use next period sharing rule, given by $W_{n,t+1} = (1-\tau_{t+1})\, u'\left(c_{t+1}^n\right)\frac{\eta}{1-\eta}F_{n,t+1}$:

$$\begin{aligned}&\eta\left(q_t z_t - w_t^* + E_t\left\{\rho_{t+1}\Lambda_{t,t+1}F_{n,t+1}\right\}\right) \\ &= (1-\eta)\left(\left(w_t^* - \frac{\xi_t}{1-\tau_t}\right) + \beta E_t\left\{\left[\rho_{t+1} - \left[\omega_t + \overline{\sigma}(1-\omega_t)\right]\rho_{t+1}^s\right]\frac{(1-\tau_{t+1})\,u'\left(c_{t+1}^n\right)}{(1-\tau_t)\,u'(c_t^n)}\frac{\eta}{1-\eta}F_{n,t+1}\right\}\right).\end{aligned} \tag{A.40}$$

Use the expression of the discount factor, given by $\Lambda_{t,t+1} = \beta\frac{(1-\tau_{t+1})u'\left(c_{t+1}^n\right)}{(1-\tau_t)u'(c_t^n)}$:

$$\begin{aligned}&\eta\left(q_t z_t - w_t^* + E_t\left\{\rho_{t+1}\Lambda_{t,t+1}F_{n,t+1}\right\}\right) \\ &= (1-\eta)\left(\left(w_t^* - \frac{\xi_t}{1-\tau_t}\right) + E_t\left\{\left[\rho_{t+1} - \left[\omega_t + \overline{\sigma}(1-\omega_t)\right]\rho_{t+1}^s\right]\frac{\eta}{1-\eta}\Lambda_{t,t+1}F_{n,t+1}\right\}\right).\end{aligned} \tag{A.41}$$

Solve for w_t^* and simplify, using also the firm's FOC at time $t+1$, given by $\kappa = \rho_{t+1}^v F_{n,t+1}$:

$$w_t^* = \eta\left(q_t z_t + E_t\left\{\Lambda_{t,t+1}\kappa\left[\omega_t + \overline{\sigma}(1-\omega_t)\right]\frac{\rho_{t+1}^s}{\rho_{t+1}^v}\right\}\right) + (1-\eta)\frac{\xi_t}{1-\tau_t}, \tag{A.42}$$

which gives equation (36) in the text.

A.3 Equilibrium System

Households:

Euler:

$$u'(c_t^n) = \beta E_t\left\{\frac{1+i_{t+1}}{\pi_{t+1}}\left[n_{t+1}u'\left(c_{t+1}^n\right) + (1-n_{t+1})\left(\nu_{t+1}u'\left(c_{t+1}^{ur}\right) + (1-\nu_{t+1})\,u'\left(c_{t+1}^{un}\right)\right)\right]\right\} \tag{A.43}$$

Constraints:

$$x_t = \frac{b_{t+1}}{p_t} + (1+i_t)\frac{a_t}{p_t} - (1+i_t)\frac{b_t}{p_t} \tag{A.44}$$

$$c_t^{ur} = x_t + \tau_t^u \tag{A.45}$$

$$c_t^{un} = x_t + \tau^s \tag{A.46}$$

$$\begin{aligned}\frac{a_{t+1}}{p_t} = {} & x_t + (1-\tau_t)\,w_t n_t + (1-\tau_t)\,d_t n_t + \tau_t^u(1-n_t)\,\nu_t + \tau^s(1-n_t)(1-\nu_t) \\ & - \left(n_t c_t^n + (1-n_t)\,\nu_t c_t^{ur} + (1-n_t)(1-\nu_t)\,c_t^{un}\right)\end{aligned} \tag{A.47}$$

Employment law of motion:

$$n_t = \rho_t n_{t-1} + \rho_t^s s_t \tag{A.48}$$

Searchers definition:

$$s_t = (1 - n_{t-1}) \left[\omega_{t-1} + \overline{\sigma} (1 - \omega_{t-1})\right] \tag{A.49}$$

Assets market equilibrium:

$$\frac{b_{t+1}}{p_t} = \frac{a_{t+1}}{p_t} = \overline{b}_t \tag{A.50}$$

Firms:

Optimal hiring:

$$q_t z_t - w_t + E_t \left\{ \Lambda_{t,t+1} \rho_{t+1} \frac{\kappa}{\rho_{f,t+1}} \right\} = \frac{\kappa}{\rho_{f,t}} \tag{A.51}$$

Dividends definition:

$$d_t^w = q_t z_t n_t - w_t n_t - \kappa v_t \tag{A.52}$$

Desired price:

$$\frac{p_t^*}{p_t} = \frac{p_t^A}{p_t^B} \tag{A.53}$$

with

$$p_t^A = \frac{\epsilon}{(\epsilon - 1)} q_t Y_t + E \left\{ \Lambda_{t,t+1} (1 - \theta) (\pi_{t+1})^{\epsilon} p_{t+1}^A \right\} \tag{A.54}$$

and

$$p_t^B = Y_t + E \left\{ \Lambda_{t,t+1} (1 - \theta) (\pi_{t+1})^{\epsilon - 1} p_{t+1}^B \right\} \tag{A.55}$$

Inflation:

$$\pi_t = \left(\frac{1 - \theta}{1 - \theta \left(\frac{p_t^*}{p_t} \right)^{1 - \epsilon}} \right)^{\frac{1}{1 - \epsilon}} \tag{A.56}$$

Output:

$$\varsigma_t Y_t = z_t n_t \tag{A.57}$$

Output loss due to price dispersion:

$$\varsigma_t = (1 - \theta) s_{t-1} \pi_t^{\epsilon} + \theta \left(\frac{p_t^*}{p_t} \right)^{-\epsilon} \tag{A.58}$$

Total dividends:

$$D_t = Y_t - q_t z_t n_t + d_t^w \tag{A.59}$$

Government:

Government budget constraint:

$$\tau_t^u (1 - n_t) \nu_t + \tau^s (1 - n_t) (1 - \nu_t) = \tau_t w_t n_t + \tau_t d_t n_t \tag{A.60}$$

Taylor rule:

$$1 + i_{t+1} = (1 + \bar{i}) \left(\frac{p_t}{p_{t-1}} \right)^{\phi} e^{\varepsilon_{it}} \tag{A.61}$$

UI rules:

$$\nu_t = \overline{\nu}\left(\frac{u_{t-1}}{\overline{u}}\right)^{\Gamma_\nu} e^{\varepsilon_{\nu t}} \tag{A.62}$$

$$\tau_t^u = \overline{\tau}^u\left(\frac{u_{t-1}}{\overline{u}}\right)^{\Gamma_\tau} \tag{A.63}$$

Labor market:

Job finding rate:

$$\rho_t^s = \alpha_m\left(\frac{v_t}{s_t}\right)^{1-\alpha} \tag{A.64}$$

Job filling rate:

$$\rho_t^v = \alpha_m\left(\frac{v_t}{s_t}\right)^{-\alpha} \tag{A.65}$$

Share of short-term unemployed:

$$\omega_t = \frac{u_t^{ST}}{u_t^{LT} + u_t^{ST}} \tag{A.66}$$

Short- and long-term unemployed:

$$u_t^{ST} = u_{t-1}^{ST}\left(1-\rho_t^s\right)\left(1-\rho_t^\omega\right) + n_{t-1}\left(1-\rho_t\right) \tag{A.67}$$

$$u_t^{LT} = u_{t-1}^{LT}\left(1-\rho_t^s\overline{\sigma}\right) + u_{t-1}^{ST}\left(1-\rho_t^s\right)\rho_t^\omega \tag{A.68}$$

Wages:

Bargained wage:

$$w_t^* = \eta\left(q_t z_t + E_t\left\{\Lambda_{t,t+1}\kappa\left[\omega_t + \overline{\sigma}\left(1-\omega_t\right)\right]\frac{\rho_{t+1}^s}{\rho_{t+1}^v}\right\}\right) + (1-\eta)\frac{\xi_t}{(1-\tau_t)} \tag{A.69}$$

Wage schedule:

$$w_t = \gamma w_t^* + (1-\gamma)\overline{w} \tag{A.70}$$

Shocks:

Productivity:

$$\log\left(z_t\right) = \left(1-\rho_z\right)\log\left(\overline{z}\right) + \rho_z\log\left(z_{t-1}\right) + \sigma_z\epsilon_{zt} \tag{A.71}$$

Separation:

$$\log\left(\rho_t\right) = \left(1-\rho_\rho\right)\log\left(\overline{\rho}\right) + \rho_\rho\log\left(\rho_{t-1}\right) + \sigma_\rho\epsilon_{\rho t} \tag{A.72}$$

Borrowing:

$$\overline{b}_t = \left(1-\rho_b\right)\overline{b} + \rho_b\overline{b}_{t-1} + \sigma_b\epsilon_{bt} \tag{A.73}$$

LTU:

$$\log\left(\rho_t^\omega\right) = \left(1-\rho_\omega\right)\log\left(\overline{\rho}^\omega\right) + \rho_\omega\log\left(\rho_{t-1}^\omega\right) + \sigma_\omega\epsilon_{\omega t} \tag{A.74}$$

Benefits:

$$\varepsilon_{\nu t} = \rho_\nu \varepsilon_{\nu t-1} + \sigma_\nu \epsilon_{\nu t} \tag{A.75}$$

Monetary policy:

$$\varepsilon_{it} = \rho_i \varepsilon_{it-1} + \sigma_i \epsilon_{it} \tag{A.76}$$

A.4 Calibration of the disutility of work χ

The implicit first-order condition for the choice of hours is obtained by augmenting the setup with variable hours of work, h_t, and choosing them to maximize the total surplus. This gives

$$\max_{h_t} \left\{ W_{n,t}\left(h_t\right) + F_{n,t}\left(h_t\right) \right\}, \tag{A.77}$$

where $F_{n,t}\left(h_t\right)$ is given by

$$F_{n,t}\left(h_t\right) = q_t z_t h_t - w_t + E_t\left\{ \rho_{t+1} \Lambda_{t,t+1} F_{n,t+1}\left(h_{t+1}\right) \right\}, \tag{A.78}$$

and $W_{n,t}\left(h_t\right)$ is given by

$$W_{n,t}\left(h_t\right) = u'(c_t^n)\left(1-\tau_t\right)\left(w_t - \frac{\xi_t(h_t)}{1-\tau_t}\right) + \beta E_t\left\{ \left[\rho_{t+1} - \left[\omega_t + \overline{\sigma}\left(1-\omega_t\right)\right] \rho_{t+1}^s\right] W_{n,t+1}\left(h_{t+1}\right) \right\}, \tag{A.79}$$

with

$$\begin{aligned} \xi_t(h_t) \quad = \quad & \nu_t \tau_t^u + \left(1-\nu_t\right)\tau^s + \left[c_t^n - \left(\nu_t c_t^{ur} + \left(1-\nu_t\right) c_t^{un}\right)\right] \\ & + \left(\lambda_t^n\right)^{-1}\left[\left(\nu_t u\left(c_t^{ur}\right) + \left(1-\nu_t\right) u\left(c_t^{un}\right)\right) - U\left(c_t^n, h_t\right)\right] \end{aligned} \tag{A.80}$$

and $U\left(c_t^n, h_t\right) = u\left(c_t^n\right) - \chi(h_t)$.

The first-order condition reads

$$q_t z_t + \frac{\partial U\left(c_t^n, h_t\right)}{\partial h_t} = 0.$$

Assuming a labor disutility of the form

$$\chi\left(h_t\right) = \frac{\psi \tilde{\chi}}{1+\psi} h_t^{\frac{1+\psi}{\psi}},$$

and evaluating the first-order condition at steady state, gives

$$\tilde{\chi}\overline{h}^{-\frac{1}{\psi}} = \overline{q},$$

which can be simplified to $\tilde{\chi} = \overline{q}$, after normalizing $\overline{h}$ to 1. Combining, we finally obtain $\chi = \frac{\psi \overline{q}}{1+\psi}$.

A.5 Model characteristics

To gain some intuition, we discuss key aspects of our framework that underlie the dynamics of the model. Even though some aspects are shared with other selected models with heterogeneous agents and have been discussed in the literature, we briefly review their relevance within the context of our model.

A.5.1 Transmission of Desired Savings when Savings are Fixed

In our tractable model, the savings of employed workers are determined in equilibrium by the exogenous borrowing limit, so that employed workers cannot adjust consumption by changing savings. Thus, while in a richer heterogeneous agent model with a wealth distribution and variable savings, a change in individual desired savings also changes individual consumption, in our model it only results in adjustment of the equilibrium interest rate. While this is no different than in any standard representative agent model with zero or fixed aggregate assets, we briefly discuss the transmission of changes in desired savings to aggregate outcomes within the context of our model.

Consider for example a reduction in desired savings of employed workers for precautionary motives, caused in turn by a decrease in future unemployment risk. The higher consumption demand from employed workers raises aggregate demand and prompts firms to raise production by hiring more workers. The increase in hiring puts upward pressure on marginal costs, inducing firms who can change prices to raise them. The central bank responds to higher inflation by increasing nominal (and real) interest rates. Higher real rates counter the lower precautionary motives, ensuring that consumption of employed workers is consistent with fixed aggregate savings. In the meanwhile, however, aggregate consumption has increased and to a large extent due to composition effects, as employment has raised. Hence, the decrease in precautionary motive causes aggregate demand, employment and output to go up, despite fixed aggregate savings.

A.5.2 Amplification with Endogenous Idiosyncratic Risk

As any heterogeneous model with countercyclical idiosyncratic risk, our framework delivers amplification to aggregate shocks relative to a representative agent model.[2] We note that our model has *endogenous* countercyclical idiosyncratic risk due to unemployment.

Consider first the effect of a negative productivity shock within a RA version of our model (obtained by assuming that the household pools its members' incomes before choosing consumption, so that the liquidity constraints conditional on employment status in equations (9)-(11) are inoperative). The decrease in productivity reduces match surplus and induces firms to hire fewer workers and pay lower wages. At the same time, lower productivity raises marginal costs, so that firms that adjust prices will raise them. On the demand side, the central bank responds to higher inflation raising nominal (and real) interest rates. At the same time, lower employment and lower wages reduce the income of the household, who then wants to save less (or borrow more) to smooth consumption out of the temporary negative shock. The increase in interest rates, however, mitigates the desired reduction in savings to ensure that consumption decreases in line with the reduction in output. Overall, inflation increases and output and employment decrease.

Consider now our baseline model. Countercyclical idiosyncratic risk brings in additional effects. Because employment is now lower and will persist lower for some time, future idiosyncratic risk increases.

[2] See Challe et al. (2017) and Ravn and Sterk (2017) for early analyses of how cyclical unemployment risk provides additional amplification to aggregate shocks relative to the case of exogenous idiosyncratic risk.

Higher unemployment risk raises precautionary motives of employed workers, who want to reduce consumption. Relative to the RA version of the model, the reduction in demand for precautionary motives puts downward pressures on prices, so that inflation raises by less; at the same time, it leads to further reduction in hiring, further increase in risk and further reduction in demand, via a negative feed-back loop, so that output drops by more. Two opposite forces drive equilibrium interest rates: a positive pressure from the incentive to smooth consumption in face of the negative temporary shock and a negative pressure from the precautionary motive in face of higher risk. Amplification ceases when the reduction in interest rates due to the fall in inflation (relative to the initial increase) fully compensates the increase in precautionary saving motives due to higher risk. Overall, our baseline model predicts a larger response of output (and employment) and a smaller response of inflation to supply shocks. The impact on inflation can even switch sign if idiosyncratic risk is very countercyclical and the effect of precautionary motives on interest rates dominate that of aversion to intertemporal substitution.

A similar amplification process raises the response of output and inflation to demand shocks. The amplification can be analytically illustrated by comparison of the slopes of the aggregate demand curve in our baseline model and its RA version. Specifically, the countercyclicality of idiosyncratic risk reduces the slope of the aggregate demand curve and can even make it positive if it is strong enough. We next derive the aggregate demand relation that is implicit to our model, and perform a comparison of the slopes.

A.5.3 Aggregate Demand Formulation

The AD relation represents the equilibria of the assets market (or equivalently of the goods market) with the nominal interest rate governed by the monetary policy rule. In our setup, the assets market equilibrium implies $a_{t+1} = b_{t+1} = p_t \bar{b}$. Combining it with the household's budget constraint, the binding liquidity constraints for unemployed workers, and the end-of-period assets constraint, we can solve for the consumption of employed workers as a function of n_t (which we will use as the aggregate quantity in the formulation of the AD relation):

$$c_t^n(n_t) = (1-\tau_t)\, w_t + (1-\tau_t)\, d_t - \frac{1}{n_t}\bar{b} + \bar{b}. \tag{A.81}$$

In turn, consumption of employed workers satisfies the Euler equation, which we write using the consumption function $c_t^n(n_t)$ just derived, to obtain:

$$1 = \beta E_t \left\{ \frac{1+i_{t+1}}{\pi_{t+1}} \frac{u'\left(c_{t+1}^n(n_{t+1})\right)}{u'\left(c_t^n(n_t)\right)} \Omega(n_t) \right\}, \tag{A.82}$$

where

$$\Omega(n_t) = \left(n_{t+1} + (1-n_{t+1})\, \nu_{t+1} \frac{u'\left(c_{t+1}^{ur}\right)}{u'\left(c_{t+1}^{n}\right)} + (1-n_{t+1})(1-\nu_{t+1}) \frac{u'\left(c_{t+1}^{un}\right)}{u'\left(c_{t+1}^{n}\right)} \right). \tag{A.83}$$

Finally, substituting the monetary policy rule[3], given by

$$1 + i_{t+1} = \left(1 + \bar{i}\right) E_t \left\{\pi_{t+1}\right\}^{\phi}, \tag{A.84}$$

yields our formulation of the AD relation, in the space (n_t, π_{t+1}), given by

$$1 = \beta E_t \left\{ \left(1 + \bar{i}\right) \pi_{t+1}^{\phi - 1} \frac{u'\left(c_{t+1}^n\left(n_{t+1}\right)\right)}{u'\left(c_t^n\left(n_t\right)\right)} \Omega\left(n_t\right) \right\}. \tag{A.85}$$

We then compute the slope of the AD relation, given by the following derivative:

$$-\frac{u'\left(c_{t+1}^n\left(n_{t+1}\right)\right)}{\left(u'\left(c_t^n\left(n_t\right)\right)\right)^2} \Omega\left(n_t\right) u''\left(c_t^n\left(n_t\right)\right)\left(c^n\right)'\left(n_t\right) + \frac{u'\left(c_{t+1}^n\left(n_{t+1}\right)\right)}{u'\left(c_t^n\left(n_t\right)\right)} \Omega'\left(n_t\right) + \frac{u''\left(c_{t+1}^n\left(n_{t+1}\right)\right)}{u'\left(c_t^n\left(n_t\right)\right)} \Omega\left(n_t\right) \frac{\partial c^n\left(n_{t+1}\right)}{\partial n_t} \tag{A.86}$$

Evaluating the derivative around the steady state[4], it simplifies to:

$$-\left(c^n\right)'\left(n_t\right) \frac{\Omega\left(n\right)}{u'\left(c^n\left(n\right)\right)} u''\left(c^n\left(n\right)\right)\left(1 - \frac{\partial n_{t+1}}{\partial n_t}\right) + \Omega'\left(n_t\right) \tag{A.87}$$

The first component is related to consumption smoothing and is positive because the derivative of the consumption function is positive:

$$\left(c^n\right)'\left(n_t\right) = \left(1 - \tau_t\right) \frac{\partial w_t}{\partial n_t} + \left(1 - \tau_t\right) \frac{\partial d_t}{\partial n_t} + \frac{1}{\left(n_t\right)^2} \bar{b} > 0, \tag{A.88}$$

with $\frac{\partial n_{t+1}}{\partial n_t} < 1$. This component is the only component present in the RA version of the model (in which $\Omega\left(n\right) = 1$, given consumption equalization across states) and determines the negative slope of the AD curve. The second component is related to the cyclicality of risk and can be both positive and negative. To see this, compute its expression, given by:

$$\begin{aligned} \Omega'\left(n_t\right) \;=\; & \left[1 - \nu_{t+1} \frac{u'\left(c_{t+1}^{ur}\right)}{u'\left(c_{t+1}^n\right)} - \left(1 - \nu_{t+1}\right) \frac{u'\left(c_{t+1}^{un}\right)}{u'\left(c_{t+1}^n\right)}\right. \\ & \left. - \left(\left(1 - n_{t+1}\right) \nu_{t+1} \frac{u'\left(c_{t+1}^{ur}\right)}{\left(u'\left(c_{t+1}^n\right)\right)^2} + \left(1 - n_{t+1}\right)\left(1 - \nu_{t+1}\right) \frac{u'\left(c_{t+1}^{un}\right)}{\left(u'\left(c_{t+1}^n\right)\right)^2}\right) u''\left(c_{t+1}^n\right) \frac{\partial c_{t+1}^n}{\partial n_{t+1}}\right] \frac{\partial n_{t+1}}{\partial n_t} \gtrless 0 \end{aligned} \tag{A.89}$$

The first line in (A.89) captures the cyclicality of "pure" unemployment risk. Given consumption levels and their ranking, higher employment reduces the chance of being in the lower consumption states and hence the risk. Thus, the first line is negative. The second line, instead, captures the risk associated with cyclical consumption inequality. At given employment, a positive aggregate shock will likely increase the income of employed workers relative to that of unemployed workers, and hence raise consumption inequality. This raises risk and makes the second line positive. If the total derivative $\Omega'(n_t)$ is negative, meaning that unemployment risk (also accounting for cyclical consumption inequality) is countercyclical (as it is the case under our calibration), the slope of the AD curve becomes less negative (relative to the

[3]To simplify the exposition, we use future inflation and omit the monetary policy shock in the Taylor rule in this section.

[4]This is not needed for the argument, but simplifies the expression and makes the argument more transparent.

RA version of the model) and can even become positive if risk is very countercyclical. A less steep AD curve implies a stronger reaction of employment and output to aggregate shocks, relative to the RA model. It also implies a stronger reaction of inflation to demand shocks, but a weaker reaction to supply shocks.

B Unemployment Insurance Transmission Mechanisms

B.1 Proof that Labor Market Channel is Stronger with HA

In Section 5.1, we have argued that the destabilizing effect of the labor market channel, in response to both an increase in recipiency and compensation, is stronger in the HA model than in the RA version of the model. Here we formally prove that

$$\frac{\partial \xi_t}{\partial \nu_t} = \tau_t^u - \tau^s - \left(c_t^{ur} - c_t^{un}\right) + \frac{u\left(c_t^{ur}\right) - u\left(c_t^{un}\right)}{\lambda_t^n} \tag{B.1}$$

is larger than

$$\frac{\partial \xi_t}{\partial \nu_t} = \tau_t^u - \tau^s. \tag{B.2}$$

To do that, we need to show that $\frac{u(c_t^{ur})-u(c_t^{un})}{\lambda_t^n} - \left(c_t^{ur} - c_t^{un}\right)$ is positive. We can rewrite it as:

$$\frac{u\left(c_t^{ur}\right) - \lambda_t^n c_t^{ur} - u\left(c_t^{un}\right) + \lambda_t^n c_t^{un}}{\lambda_t^n}. \tag{B.3}$$

Since $c_t^n > c_t^{ur} > c_t^{un}$, it is enough to show that the function $u\left(c_t\right) - \lambda_t^n c_t$ is increasing in $c_t \in \left[c_t^{un}, c_t^n\right]$ for $c_t < c_t^n$. Recall that $\lambda_t^n = u'\left(c_t^n\right)$, so the function is $u\left(c_t\right) - u'\left(c_t^n\right) c_t$. The derivative of the function is given by:

$$u'\left(c_t\right) - u'\left(c_t^n\right). \tag{B.4}$$

Because the second derivative of the utility function is negative, the derivative of the function will be positive as long as $c_t < c_t^n$. The function is increasing in c_t on the interval of interest. Because the function is increasing, the sum of the second and third terms of equation (B.1) must be positive.

B.2 Further Derivations of the Effects of Taxes

Consider the labor market channel. In Section 5.3.1, we describe the effect of taking into account the adjustment of taxes on the bargained wage from equation (36), via the opportunity cost of employment expressed in terms of net labor income, $\xi_t/(1-\tau_t)$. As we mention in footnote 30, tax adjustments also change the partial derivative of ξ_t with respect to ν_t and τ_t, via their effect on the consumption of employed workers. Expanding equation (38) to account for taxes, we obtain

$$\begin{aligned}\frac{\partial\xi_t}{\partial\nu_t} &= \left(\tau_t^u-\tau^s\right)+\frac{\partial c_t^n}{\partial\tau_t}\frac{\partial\tau_t}{\partial\nu_t}-\left(c_t^{ur}-c_t^{un}\right)\\ &\quad+\frac{u\left(c_t^{ur}\right)-u\left(c_t^{un}\right)-u'\left(c_t^n\right)\frac{\partial c_t^n}{\partial\tau_t}\frac{\partial\tau_t}{\partial\nu_t}}{\lambda_t^n}\\ &\quad-\frac{\left[\nu_t u\left(c_t^{ur}\right)+\left(1-\nu_t\right)u\left(c_t^{un}\right)\right)-\left(u\left(c_t^n\right)-\chi\right]}{\left(\lambda_t^n\right)^2}\frac{\partial\lambda_t^n}{\partial c_t^n}\frac{\partial c_t^n}{\partial\tau_t}\frac{\partial\tau_t}{\partial\nu_t}.\end{aligned}\tag{B.5}$$

Using $\lambda_t^n = u'\left(c_t^n\right)$ permits to simplify out the new terms in the first and the second line. Using also $\partial\lambda_t^n/\partial c_t^n = u''\left(c_t^n\right)$, we can write

$$\begin{aligned}\frac{\partial\xi_t}{\partial\nu_t} &= \left(\tau_t^u-\tau^s\right)-\left(c_t^{ur}-c_t^{un}\right)+\frac{u\left(c_t^{ur}\right)-u\left(c_t^{un}\right)}{\lambda_t^n}\\ &\quad-\frac{\left[\left(\nu_t u\left(c_t^{ur}\right)+\left(1-\nu_t\right)u\left(c_t^{un}\right)\right)-\left(u\left(c_t^n\right)-\chi\right)\right]}{\left(\lambda_t^n\right)^2}u''\left(c_t^n\right)\frac{\partial c_t^n}{\partial\tau_t}\frac{\partial\tau_t}{\partial\nu_t},\end{aligned}\tag{B.6}$$

which gives us the same expression as in equation (38) minus an extra term, given by the second line above. The extra term can be both positive and negative, depending on the sign of the expression in squared parenthesis in the numerator. Under our calibration, this expression is positive, so that the extra term is negative (given strict concavity of period utility, a negative partial derivative of c_t^n with respect to τ_t, and a positive partial derivative of τ_t with respect to ν_t). Accounting for taxes and their effect on the consumption of employed workers hence reduces the impact of recipiency on ξ_t.

We can similarly compute how taxes change the effect of benefit compensation on the opportunity cost of employment, expanding equation (40) to obtain

$$\begin{aligned}\frac{\partial\xi_t}{\partial\tau_t^u} &= \nu_t-\nu_t\frac{\partial c_t^{ur}}{\partial\tau_t^u}+\frac{\partial c_t^n}{\partial\tau_t}\frac{\partial\tau_t}{\partial\tau_t^u}+\nu_t\frac{\lambda_t^{ur}}{\lambda_t^n}\frac{\partial c_t^{ur}}{\partial\tau_t^u}-\frac{u'\left(c_t^n\right)\frac{\partial c_t^n}{\partial\tau_t}\frac{\partial\tau_t}{\partial\tau_t^u}}{\lambda_t^n}\\ &\quad-\frac{\left[\nu_t u\left(c_t^{ur}\right)+\left(1-\nu_t\right)u\left(c_t^{un}\right)\right)-\left(u\left(c_t^n\right)-\chi\right]}{\left(\lambda_t^n\right)^2}\frac{\partial\lambda_t^n}{\partial c_t^n}\frac{\partial c_t^n}{\partial\tau_t}\frac{\partial\tau_t}{\partial\tau_t^u}\\ &= \nu_t-\nu_t\frac{\partial c_t^{ur}}{\partial\tau_t^u}+\nu_t\frac{\lambda_t^{ur}}{\lambda_t^n}\frac{\partial c_t^{ur}}{\partial\tau_t^u}\\ &\quad-\frac{\left[\nu_t u\left(c_t^{ur}\right)+\left(1-\nu_t\right)u\left(c_t^{un}\right)\right)-\left(u\left(c_t^n\right)-\chi\right]}{\left(\lambda_t^n\right)^2}u''\left(c_t^n\right)\frac{\partial c_t^n}{\partial\tau_t}\frac{\partial\tau_t}{\partial\tau_t^u}.\end{aligned}\tag{B.7}$$

The extra term is analogous to that in equation (B.6). Under our calibration, accounting for taxes reduces the impact of benefit compensation on the opportunity cost.

The effect of adjustment in taxes on aggregate demand effects from recipiency is illustrated in the text in equation (51), which expands equation (44). The second equality in equation (51) obtains from the following derivations. Compute the partial derivative of taxes from the government budget constraint in equation (30) with respect to the recipiency rate, to obtain

$$\frac{\partial\tau_t}{\partial\nu_t}=\frac{\left(\tau_t^u-\tau^{ss}\right)\left(1-n_t\right)}{\left(w_t+d_t\right)n_t},\tag{B.8}$$

and substitute it in the first equality of (51). Rearrange, using also $\partial Y_t^n / \partial \tau_t = w_t + d_t$, to obtain the second equality as follows:

$$
\begin{aligned}
\frac{\partial c_t}{\partial \nu_t} &= (1-n_t)\left(\tau_t^u - \tau^{ss}\right) + n_t \frac{\partial c_t^n}{\partial \tau_t}\frac{\partial \tau_t}{\partial \nu_t} \\
&= (1-n_t)\left(\tau_t^u - \tau^{ss}\right) + n_t \frac{\partial c_t^n}{\partial \tau_t}\frac{\left(\tau_t^u - \tau^{ss}\right)(1-n_t)}{(w_t+d_t)\,n_t} \\
&= (1-n_t)\left(\tau_t^u - \tau^{ss}\right)\left(1 + \frac{\partial c_t^n}{\partial \tau_t}\frac{1}{w_t+d_t}\right) \\
&= (1-n_t)\left(\tau_t^u - \tau^{ss}\right)\left(1 + \frac{\partial c_t^n}{\partial Y_t^n}\frac{\partial Y_t^n}{\partial \tau_t}\frac{1}{w_t+d_t}\right) \\
&= (1-n_t)\left(\tau_t^u - \tau^{ss}\right)\left(1 - \frac{\partial c_t^n}{\partial Y_t^n}\right).
\end{aligned} \tag{B.9}
$$

We can similarly expand equation (46) to account for the adjustment of taxes, as following:

$$
\begin{aligned}
\frac{\partial c_t}{\partial \tau_t^u} &= (1-n_t)\,\nu_t + n_t \frac{\partial c_t^n}{\partial \tau_t}\frac{\partial \tau_t}{\partial \tau_t^u} \\
&= (1-n_t)\,\nu_t + n_t \frac{\partial c_t^n}{\partial \tau_t}\frac{\nu_t(1-n_t)}{(w_t+d_t)\,n_t} \\
&= (1-n_t)\,\nu_t\left(1 + \frac{\partial c_t^n}{\partial \tau_t}\frac{1}{w_t+d_t}\right) \\
&= (1-n_t)\,\nu_t\left(1 - \frac{\partial c_t^n}{\partial Y_t^n}\right),
\end{aligned} \tag{B.10}
$$

where we have used the partial derivative of taxes from the government budget constraint with respect to the benefit amount, given by

$$
\frac{\partial \tau_t}{\partial \tau_t^u} = \frac{\nu_t(1-n_t)}{(w_t+d_t)\,n_t}. \tag{B.11}
$$

Equations (B.9) and (B.10) show that the response of consumption of employed workers to balanced-budget tax adjustments dampens the effect of unemployment insurance on aggregate consumption.

B.3 Opportunity Cost of Employment with Individual-Level Assets and Bargaining

We consider a model with individual-level assets and bargaining. We show that the average opportunity cost implied by this model is equal to the sum of the opportunity cost ξ_t from equation (37) in the main text and an additional component which is associated to individual asset positions. We argue that the predictions of the model for the effect of benefit extensions on the opportunity cost are robust to abstracting from this component.

Consider a worker with beginning-of-period assets, a_t, who is eligible for unemployment insurance. The value of being employed, $W_t^n(a_t)$, is defined as

$$
W_t^n(a_t) = u\left(c_t^n\right) - \chi + \beta E_t\left\{\rho_{t+1} W_{t+1}^n\left(a_{t+1}^n\right) + (1-\rho_{t+1})\, W_{t+1}^{ur}\left(a_{t+1}^n\right)\right\}, \tag{B.12}
$$

with budget constraint given by

$$c_t^n + a_{t+1}^n = (1-\tau_t)\, w_t + (1+r_t)\, a_t. \tag{B.13}$$

The value of being unemployed benefit recipient, $W_t^{ur}(a_t)$, is defined as

$$W_t^{ur}(a_t) = u\left(c_t^{ur}\right) + \beta E_t\left\{\rho_{t+1}^s W_{t+1}^n\left(a_{t+1}^{ur}\right) + \left(1-\rho_{t+1}^s\right) W_{t+1}^{ur}\left(a_{t+1}^{ur}\right)\right\}, \tag{B.14}$$

with budget constraint given by

$$c_t^{ur} + a_{t+1}^{ur} = \tau_t^u + (1+r_t)\, a_t. \tag{B.15}$$

The surplus from employment, $W_{n,t}(a_t)$, is the difference between the value functions defined by (B.12) and (B.14) and can be computed to be equal to[5]

$$W_{n,t}(a_t) = W_t^n(a_t) - W_t^{ur}(a_t) = u'\left(c_t^n\right)(1-\tau_t)\left(w_t - \frac{\tilde{\xi}_t^{ur}}{1-\tau_t}\right) + \beta E_t\left\{\left(\rho_{t+1} - \rho_{t+1}^s\right) W_{n,t+1}\left(a_{t+1}^n\right)\right\}, \tag{B.16}$$

which is the analog of our expression in equation (18) in the main text, and a function of the opportunity cost of employment, $\tilde{\xi}_t^{ur}$.

The opportunity cost, in turn, can be written as the sum of two components,

$$\tilde{\xi}_t^{ur} = \xi_t^{ur} + \xi_t^{ur,a}, \tag{B.17}$$

with the first given by

$$\xi_t^{ur} = \tau_t^u + \left(c_t^n - c_t^{ur}\right) - \frac{u\left(c_t^n\right) - \chi - u\left(c_t^{ur}\right)}{\lambda_t^n}, \tag{B.18}$$

and equivalent to the expression in equation (37) in the main text; and the second an additional component associated with different asset positions among employed and unemployed, and given by

$$\tilde{\xi}_t^{ur,a} = \left(a_{t+1}^n - a_{t+1}^{ur}\right) - \beta E_t\left\{\rho_{t+1}^s\left(W_{t+1}^n\left(a_{t+1}^n\right) - W_{t+1}^n\left(a_{t+1}^{ur}\right)\right) + \left(1-\rho_{t+1}^s\right)\left(W_{t+1}^{ur}\left(a_{t+1}^n\right) - W_{t+1}^{ur}\left(a_{t+1}^{ur}\right)\right)\right\}. \tag{B.19}$$

We can similarly derive the opportunity cost of employment for non-recipients, $\tilde{\xi}_t^{un}$, as the sum of a component equivalent again to the expression from equation (37) in the main text,

$$\xi_t^{un} = \tau^s + \left(c_t^n - c_t^{un}\right) - \frac{u\left(c_t^n\right) - \chi - u\left(c_t^{un}\right)}{\lambda_t^n} \tag{B.20}$$

and an extra component,

$$\xi_t^{un,a} = \left(a_{t+1}^n - a_{t+1}^{un}\right) - \beta E_t\left\{\rho_{t+1}^s\left(W_{t+1}^n\left(a_{t+1}^n\right) - W_{t+1}^n\left(a_{t+1}^{un}\right)\right) + \left(1-\rho_{t+1}^s\right)\left(W_{t+1}^{un}\left(a_{t+1}^n\right) - W_{t+1}^{un}\left(a_{t+1}^{un}\right)\right)\right\}. \tag{B.21}$$

Analogously to Chodorow-Reich and Karabarbounis (2016), the extra terms defined in (B.19) and (B.21) have each two components. The first is a budgetary loss associated to higher future assets chosen by the employed workers and the second is the welfare gain from having higher assets in the future.

[5] See Chodorow-Reich and Karabarbounis (2016) for similar derivations.

While computing the extra components is beyond the scope of this paper, we note that they entail both a loss and a gain, changing $\tilde{\xi}_t$ in opposite directions, and that they should not be largely affected by changes in benefit duration and compensation. If unemployed workers are borrowing constrained and thus choose their asset at the limit, changes in duration and compensation will not affect their asset accumulation. Hence, the components with a^{ur}_{t+1} and a^{un}_{t+1} will not be affected. This will likely hold for most unemployed workers, but especially for those who already had a long enough unemployment spell to have exhausted their savings, i.e. for the vast majority of those impacted by extensions. The components with a^{n}_{t+1} could in theory be affected by changes in compensation and extensions through changes in precautionary motives. The effect, however, is likely to be quantitatively small in this case, since the workers considered here are newly employed workers, hence unlikely to be eligible for benefits in the near future.

Finally, note that ξ^{ur}_t and ξ^{un}_t are individual opportunity costs. What drives hiring, instead, is the opportunity cost averaged across unemployed workers. The average will depend on the average transfers weighted by recipiency shares, as well as average consumption levels, utilities, and assets.

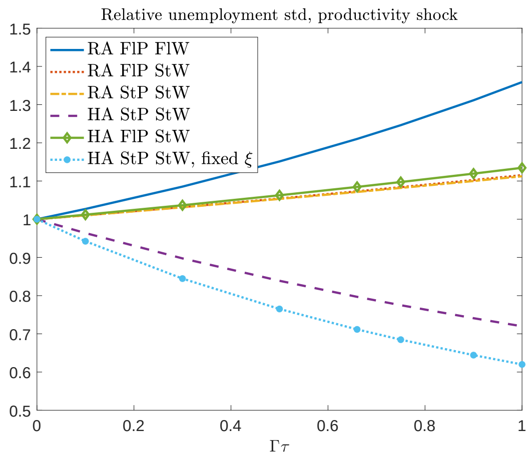
C Additional figures and tables

Table 1 presents the estimated parameters for the exogenous processes used in simulations.

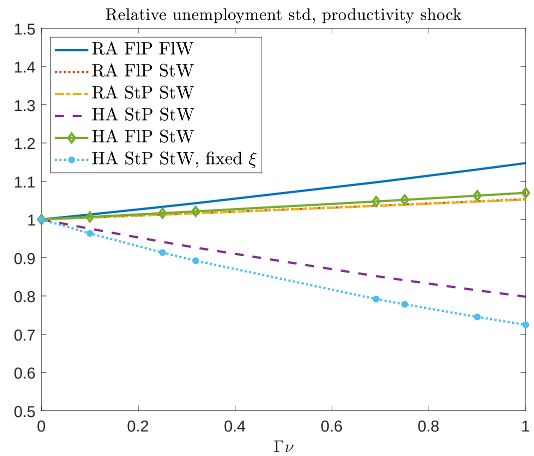
Parameter	Description	Value	Target
σ_z	STD, productivity shock	0.0020	Estimated, BLS, 1972-2017
ρ_z	AC, productivity shock	0.9073	Estimated, BLS, 1972-2017
σ_ρ	STD, retention shock	0.0008	Estimated, JOLTS, 2001-2017
ρ_ρ	AC, retention shock	0.6789	Estimated, JOLTS, 2001-2017
σ_b	STD, borrowing shock	0.0031	Estimated, Fed Board, 2011-2017
ρ_b	AC, borrowing shock	0.9545	Estimated, Fed Board, 2011-2017
σ_ω	STD, LTU shock	0.0499	Estimated, BLS, 2001-2017
ρ_ω	AC, LTU shock	0.8702	Estimated, BLS, 2001-2017
σ_v	STD, recipiency shock	0.0214	Estimated, U.S. Department of Labor, 2001-2017
ρ_v	AC, recipiency shock	0.9492	Estimated, U.S. Department of Labor, 2001-2017
σ_i	STD, monetary shock	0.0013	From McKay and Reis (2016)
ρ_i	AC, monetary shock	0.8527	From McKay and Reis (2016)

Table 1: Calibration, exogenous processes

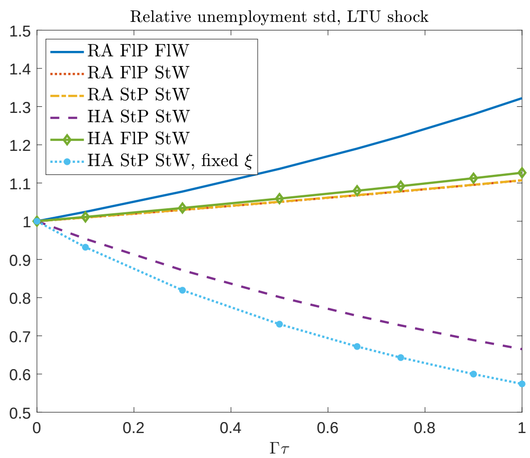
Figure C.1 presents the results for additional shocks discussed in Section 4.



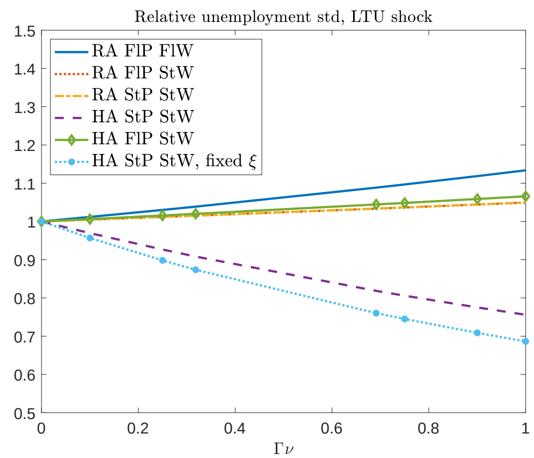
(a) Benefit compensation, product. shock



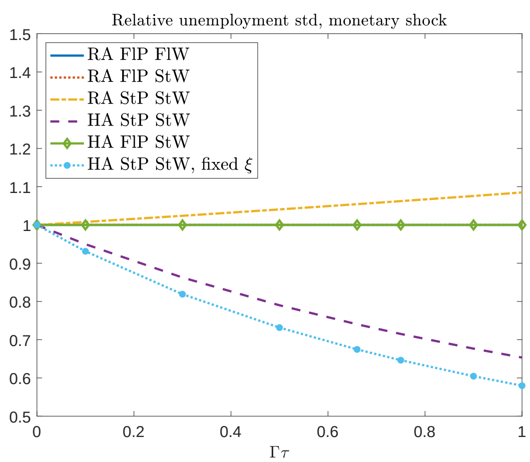
(b) Benefit duration, product. shock



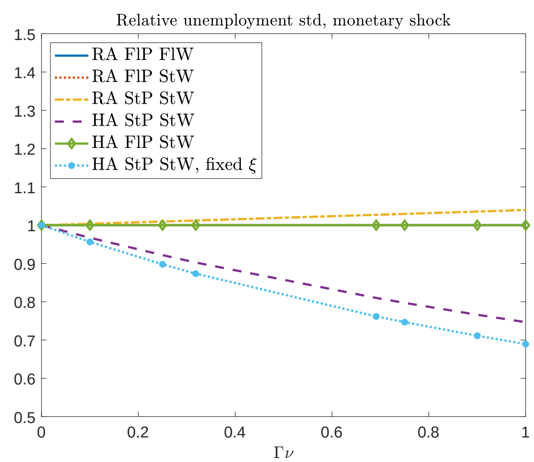
(c) Benefit compensation, LTU shock



(d) Benefit duration, LTU shock



(e) Benefit compensation, monetary shock



(f) Benefit duration, monetary shock

Figure C.1: Unemployment volatility as a function of benefit elasticities, additional shocks

Figure C.2 presents the productivity shock used in the simulations in Section 6.2.

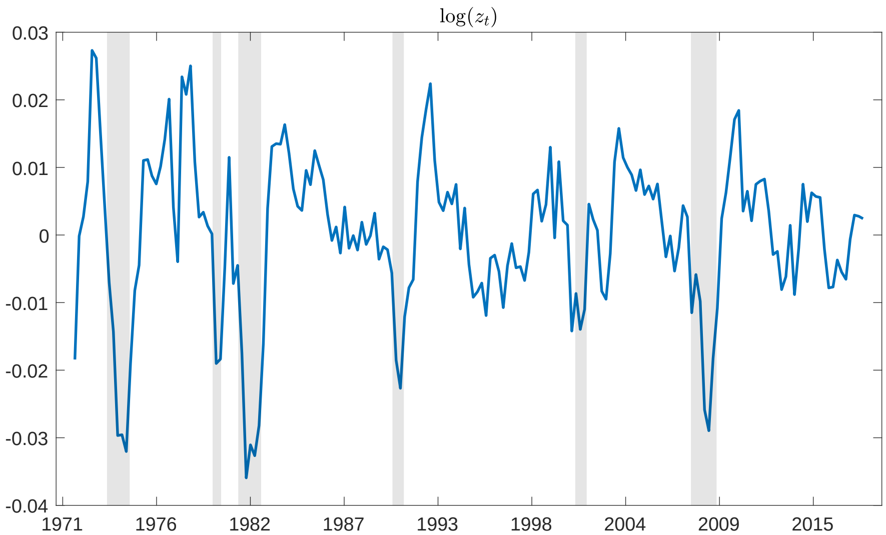
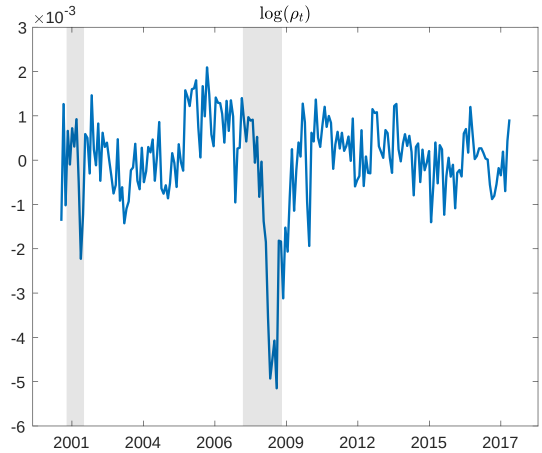
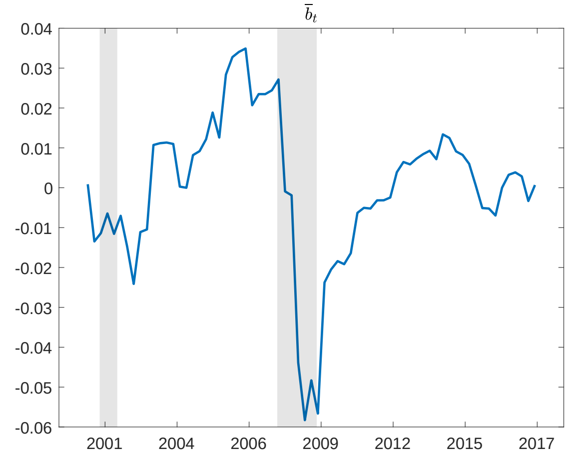


Figure C.2: Productivity shock, long sample ($\rho = 0.9189$, $\sigma = 0.0024$)

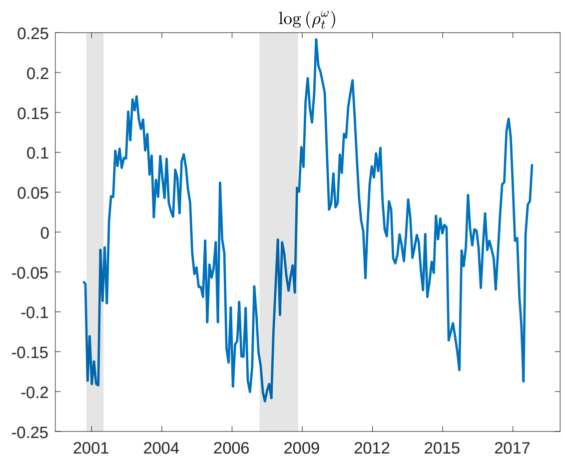
Figure C.3 presents the labor market and the borrowing shocks used in the simulations in Section 6.3.



(a) Separation (retention rate) shock



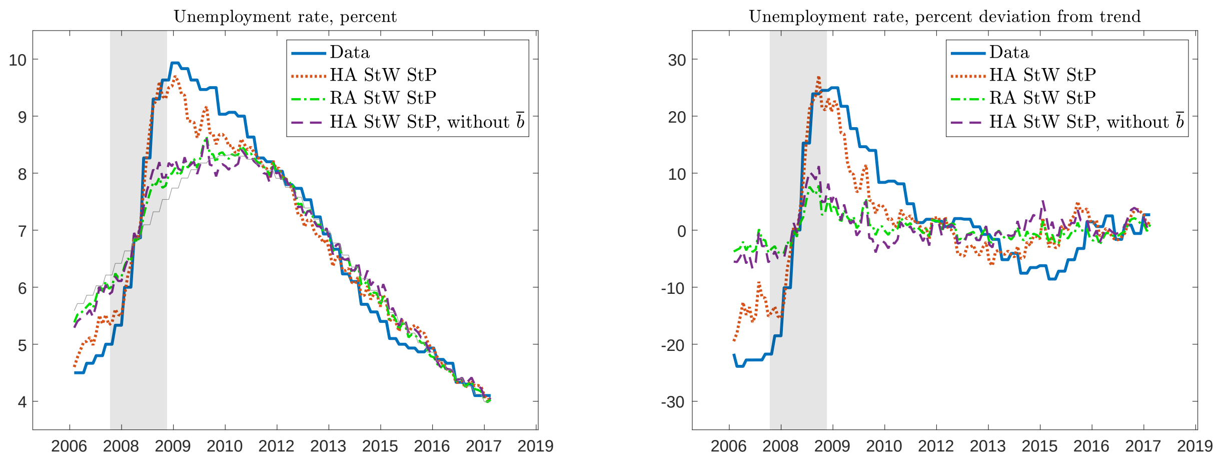
(b) Borrowing shock



(c) LTU inflow rate shock

Figure C.3: Shocks from the data, short sample

Figure C.4 presents the comparison of HA model with labor marker and with or without the borrowing shock and the RA model with the three shocks that we discuss in Section 6.3.3.

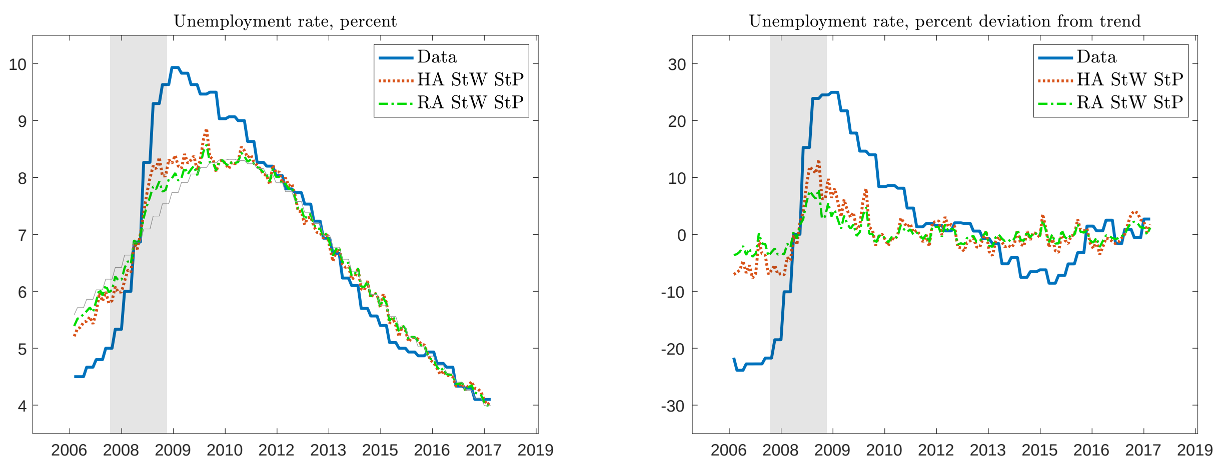


(a) Percent of labor force

(b) Percent deviation from trend

Figure C.4: HA vs. RA Model: the role of credit tightening

Figure C.5 presents the comparison of the HA and RA models with only the labor market shocks (without discretionary or automatic extensions) that we discuss in Section 6.3.3.



(a) Percent of labor force

(b) Percent deviation from trend

Figure C.5: HA vs. RA Model: the role of amplification from AD

References

Challe, Edouard, Julien Matheron, Xavier Ragot, and Juan F Rubio-Ramirez. 2017. "Precautionary saving and aggregate demand." *Quantitative Economics*, 8(2): 435–478.

Chodorow-Reich, Gabriel, and Loukas Karabarbounis. 2016. “The Cyclicality of the Opportunity Cost of Employment.” *Journal of Political Economy*, 124(6): 1563–1618.

McKay, Alisdair, and Ricardo Reis. 2016. “The Role of Automatic Stabilizers in the US Business Cycle.” *Econometrica*, 84(1): 141–194.

Ravn, Morten O, and Vincent Sterk. 2017. “Job Uncertainty and Deep Recessions.” *Journal of Monetary Economics*, 90: 125–141.