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# Introduction

This thesis explores how households' financial decisions shape macroeconomic outcomes, and how this in turn determines the effects of macroeconomic policies. The first chapter explores how households' need to self-insure against unemployment risk shapes the stabilization consequences of hiring subsidies provided to firms in an environment where conventional monetary policy is constrained. The second chapter investigates the interaction between government spending multipliers and the duration of unemployment insurance benefits. The third chapter offers a new perspective on the macroeconomic consequences of financial frictions in the banking system, through the role of banks as suppliers of liquid assets to households.

In Chapter 1, "Hiring Stimulus and Precautionary Savings in a Liquidity Trap," I explore the macroeconomic stabilization consequences of supply-side policies, and how this is shaped by the demand-side effects that come with household heterogeneity. In particular, I focus on hiring subsidies provided to firms. Using a tractable model, I provide a sharp analytical characterization of the effects of hiring subsidies. Hiring subsidies not only stimulate aggregate supply by reducing marginal costs. They stimulate aggregate demand, too. This is so because hiring subsidies, by stimulating job creation, reduce the unemployment risk faced by households. As a result, households' desire to accumulate precautionary savings falls, raising consumption and aggregate demand. Calibrating the model to the US economy, I find that the ensuing fall in inflation renders the hiring stimulus effective precisely when the central bank cannot further support aggregate demand. Thus, the demand-side effects render policies targeted at the supply side of the economy central for business-cycle stabilization, even if monetary policy is constrained. In contrast, I find that absent idiosyncratic risk, and hence the demand-side effects, the hiring stimulus is crowded-out when the lower bound on the nominal interest rate binds.

Chapter 2, "Unemployment Insurance, Precautionary Savings, and Fiscal Multipliers," is joint work with Donghai Zhang (University of Bonn). We explore, both empirically and theoretically, the interaction between government spending multipliers and the generosity of unemployment insurance. Using US regional-level data, we first show that a longer duration of unemployment benefits renders local government spending multipliers smaller. We obtain this result using variations in unemployment insurance duration extensions that arise from measurement error in the regional unemployment rate. Moreover, we provide evidence that an increase in government spending leads to a shortening of the duration of UI benefits. We next interpret our empirical findings through a New Keynesian small open economy model with heterogeneous households, equilibrium unemployment, and stochastic duration of unemployment benefits. The model attributes the origin of state-dependent multipliers to the non-linear response of UI policy: an increase in government spending lowers unemployment, reducing the duration of UI benefits only to the extent that these have already been extended. As a result of lower insurance, households reduce consumption. Consequently, the size of the government spending multiplier is smaller.

Chapter 3, "Precautionary Savings and Financial Frictions," offers a new perspective on the macroeconomic consequences of financial frictions in the banking system, through the role of banks as suppliers of liquid assets to households. I show, both empirically and quantitatively, that tight financial conditions render the economy less resilient to shocks that lead households to demand more bank-issued demand deposits, the dominant liquid asset of households' portfolios. I first provide novel empirical evidence that one such shock, a shock to household income uncertainty, leads to a deeper recession and a muted creation of bank deposits when financial conditions are tight. I next rationalize these empirical findings in a formal business-cycle model with heterogeneous households, portfolio choice between liquid bank deposits and illiquid capital, and banks that perform liquidity transformation. Through the balance sheets of banks, constraints on bank lending restrict the supply of liquid deposits to households. Calibrating the model to the US economy, I show that it captures the gist of the empirical findings. Through a series of counterfactuals, I find that limited liquidity provision from banks is essential for this: a muted creation of liquid deposits accounts for half of the deeper recession when financial conditions are tight. This shows that banking frictions, over and beyond their effects on lending, are central because they restrict the supply of liquid assets to households.

# Chapter 1

# Hiring Stimulus and Precautionary Savings in a Liquidity Trap*

## 1.1 Introduction

Monetary policy is an integral part of business-cycle stabilization policies in modern economies. However, the current environment of low interest rates may often constrain conventional monetary stabilization. Thus, additional macroeconomic policies may need to provide the missing stimulus to aggregate demand. In this situation, stabilizing employment, and hence firms' hiring, becomes fundamental to support households' income and consumption. It follows, therefore, that policies targeted at firms may also spill over to the demand side of the economy, supporting aggregate demand at the same time as expanding aggregate supply. In this paper, I explore the demand-side effects of supply-side policies that aim to increase employment and their consequences for business-cycle stabilization.

Concretely, I focus on hiring subsidies provided to firms. Such subsidies have been a central component of the stimulus packages provided by several governments over the last recessions.[1] What makes a hiring subsidy particularly attractive for the question at hand is that it directly targets a fundamental margin for the income, and

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1. Examples of these are the zero-charges program enacted by the French President in 2008, the Hire Incentives to Restore Employment (HIRE) Act signed into law by President Obama in 2010, and, more recently, the Canada Recovery Hiring Plan (CRHP) enacted during the Covid-19 crisis. Further hiring subsidies measures are described in OECD (2010).

thus consumption, of the household sector: job creation. To probe into the stabilization consequences of hiring subsidies, I build a tractable New Keynesian model with equilibrium unemployment, sticky real wages (Hall (2005)), and incomplete markets as in Ravn and Sterk (2017). Firms, owned by perfectly-insured entrepreneurs, post vacancies to hire workers in a frictional labor market (Mortensen and Pissarides (1994)). Employed workers seek to self-insure against unemployment risk through inside risk-free bonds. A no-borrowing constraint means that, in equilibrium, every worker consumes her own current income.

Calibrating the model to the US economy, I assess the aggregate consequences of a persistent increase in hiring subsidies. On the supply side, the hiring subsidy reduces firms' marginal costs and inflation. At a time when monetary policy is constrained, this channel alone would increase the real interest rate, reducing the effectiveness of the hiring stimulus.[2] The demand-side effects, instead, are ambiguous. Two channels are at work. To the extent that wages rise but unemployment risk persists, employed workers wish to save more to smooth consumption. This consumption growth channel, through intertemporal substitution, depresses aggregate demand and employment rather than raising it. On the other hand, there is a precautionary savings channel: hiring subsidies reduce unemployment risk, stimulating demand. Quantitatively, I find that the precautionary demand-side channel dominates. The increase in aggregate demand, and the ensuing raise in inflation expectations, render the hiring stimulus effective precisely when monetary policy is constrained. Thus, a hiring stimulus not only raises aggregate supply, but it also stabilizes aggregate demand when it is needed the most.

More in detail, I analyze the demand-side effects of hiring subsidies in three steps. First, I consider a scenario with flexible prices. I find that the natural interest rate – the real interest rate prevailing with flexible prices – rises after the hiring stimulus. The increase in the natural interest rate results from the desire of households to reduce savings and increase consumption, showing that the precautionary savings channel dominates. In a second step, I introduce sticky prices, such that aggregate demand affects equilibrium employment dynamics. I consider an increase in hiring subsidies during normal times, with an unconstrained central bank. In this case, the increased demand for goods renders the hiring stimulus inflationary and more effective than with flexible prices. In a final step, I consider a liquidity trap experiment. I find that the inflationary pressures generated by the decline in precautionary savings reduce the real interest rate, further stimulating consumption and amplifying the hiring stimulus.

The previous logic suggests that absent the precautionary savings channel the demand-side effects of the hiring stimulus are weaker. I verify this intuition in a representative agent economy. In normal times, absent the counteracting force of

2. This finding is in line with the literature, which finds strong crowding-out effects of supply-side policies when monetary policy is constrained (e.g. Eggertsson (2011))

the decline in precautionary savings, the consumption growth channel significantly dampens the hiring stimulus. Yet, the central bank cuts the nominal interest rate in response to the deflationary pressures, reducing the real rate and hence sustaining the demand for consumption goods. At the zero lower bound, however, the deflationary forces raise the real interest rate. A higher real interest rate crowds-out consumption and renders hiring subsidies ineffective.

The tractability of the model allows me to trace back this large disagreement between models to a second feature of incomplete markets: the intertemporal substitution motive triggered by the hiring stimulus is substantially weaker with incomplete markets. The reason is as follows. The representative family internalizes in its budget constraint that temporarily more members are working. A single employed worker in the incomplete markets economy does not, as she is constrained by her *own* current income – the real wage. As a result, the income of the representative family increases more than that of a single worker when unemployment falls. Thus, the representative agent has a stronger desire to increase savings to smooth consumption and the consequent drop in demand and inflation is sharp. I show this by considering a perfect insurance benchmark where unemployment risk is absent owing to a generous unemployment insurance scheme, but maintains the same income volatility as in the imperfect insurance economy. In this perfect insurance model, the demand-side effects of the hiring stimulus are dampened, as precautionary savings are absent, but stronger than with a representative agent, since the current income of an employed worker moves little.

The rest of the paper is organized as follows. I discuss next the relation to the literature. Section 1.2 describes the economic environment. Section 1.3 calibrates the model. Section 1.4 presents the main quantitative results and mechanism. It provides an analytical and quantitative characterization of the demand-side effects of hiring subsidies and the consequences that this has for aggregate demand and employment stabilization. A final section concludes. The appendix provides additional results and robustness checks.

### Related literature

This paper relates to several strands of the literature. First, I contribute to the literature studying fiscal policies at the zero lower bound. Most of this research has been carried out in a complete markets framework, and hence entirely abstracting from the main channel highlighted in this paper. Woodford (2011) shows analytically how the government spending multiplier exceeds one under an interest rate peg, owing to the increase in inflation expectations. Christiano *et al.* (2011) quantify the government spending multiplier in a rich quantitative model. More broadly, Correia *et al.* (2013) show how to optimally circumvent the zero lower bound with sufficiently flexible taxes. More related to this paper, Eggertsson (2011) shows that supply-side policies, in particular labor tax cuts, are contractionary at the zero lower bound with a representative agent. I also find that, with complete markets, hiring subsidies can be detrimental at the zero lower bound, but show how precautionary savings can overturn this result. An exception to the previous papers is Kekre (2021). That paper shows how unemployment benefit extensions can be expansionary at the zero lower bound owing to a higher marginal propensity to consume of unemployed workers. Contrary to Kekre (2021), I focus on a precautionary savings channel and abstract from policies that directly redistribute income.

Second, my paper is related to the literature incorporating equilibrium unemployment into New Keynesian models. Examples are Blanchard and Galí (2010), Thomas (2008), Ravenna and Walsh (2011), and Faia (2009). These papers have predominantly focused on studying how frictional labor markets affect the optimal conduct of monetary policy in a complete markets framework. I contribute to this literature by showing that the interaction of unemployment and incomplete markets affects the transmission of other policies, hiring subsidies, in a New Keynesian framework.

Third, I contribute to literature focusing on heterogeneous agents with nominal rigidities. This literature has mainly analyzed how heterogeneity may shape and amplify demand disturbances. I, instead, show that accounting for incomplete markets is crucial to assess the effects of supply policies. Ravn and Sterk (2017) show how the feedback between precautionary savings and output can propagate labor market shocks, but they abstract from the zero lower bound and do not analyze supply-side policies. Ravn and Sterk (2020) study the equilibrium properties of the same model that I use in this paper. Importantly, they show analytically that contractionary TFP shocks can be deflationary in the presence of uninsured unemployment risk. They, however, abstract from hiring subsidies and their effects at the zero lower bound. Challe (2020) asks how monetary policy should be conducted when the same transmission mechanism is present. That paper finds that the optimal monetary policy response is to cut nominal rates after a contractionary productivity shock if there is imperfect insurance against unemployment, contrary to the result with complete markets. Relative to Challe (2020) I focus on the zero lower bound and explain how, in addition to precautionary savings, an intertemporal substitution channel shapes the differences between incomplete and complete markets. McKay and Reis (2021) find that uninsured unemployment risk calls for stronger automatic stabilizers in form of higher unemployment benefits. Relative to McKay and Reis (2021), I show how hiring subsidies can be used to insure workers as well by ensuring that job finding rates are high. Bayer *et al.* (2019) show how exogenous increases in idiosyncratic risk can lead to a recession, owing to a portfolio rebalancing channel from illiquid physical capital to liquid government bonds. I abstract from the portfolio choices of households, but allow the changes in idiosyncratic risk to be endogenous to labor market conditions and, hence, to policy. Gornemann *et al.* (2016) show in a richer model than the one that I consider how wealthy households favor an inflation-targeting monetary policy, in contrast to poorer households that are better off under a central bank that targets more unemployment volatility. Den Haan *et al.*

(2018) shows how the presence of precautionary savings and sticky nominal wages can amplify business cycles. That paper also shows that unemployment benefits can help to stabilize the economy, but abstracts from supply-side policies as considered here.

Finally, I add to the literature studying labor market policies over the business cycle. Most of it has abstracted from nominal rigidities. For example, Mitman and Rabinovich (2015) show that the optimal path of unemployment benefits is pro-cyclical. Jung and Kuester (2015) compute the optimal labor market policy-mix over the business cycle under flexible prices. They find that hiring subsidies should be increased in recessions. I show how the interaction of precautionary savings and sticky prices amplify the positive effects of this hiring stimulus. An exception is Campolmi *et al.* (2011), they study hiring subsidies with nominal rigidities and under an operating Taylor rule, with a representative agent. That paper finds that hiring subsidies can display larger multipliers than government spending, owing to the fact that the deflationary forces of the former induce a decline in the real rate in normal times. I show that these same deflationary forces can, with complete markets, render hiring subsidies contractionary at the zero lower bound. Cahuc *et al.* (2018) provide empirical evidence of the effectiveness of hiring subsidies enacted by France during the Great Recession.

## 1.2 Model

The model builds on Ravn and Sterk (2017).[3] The main features are incomplete markets, nominal rigidities in the form of price stickiness and search and matching frictions in labor markets. There is some ex-ante heterogeneity, and by assumption there are perfectly-insured entrepreneurs, who own firms but do not work, and workers. As a result of incomplete financial markets there is heterogeneity ex-post, between employed and unemployed workers, giving rise to precautionary savings against unemployment risk. Because this risk depends on the measured slackness in the labor market, the need to self-insure fluctuates with economic activity and, consequently, it will be affected by policy.

### 1.2.1 Labor market

There is a continuum of worker households of measure 1 indexed by $i$. At the beginning of the period there is a mass of $N_{t-1}$ employed workers. Of these, an exogenous fraction $\delta$ separate from the firm and instantaneously join the pool of unemployed workers, at which point it becomes $1-(1-\delta)N_{t-1}$, ready to be hired within the same period. The labor market is frictional. Firms must open vacancies $V_t$ in order

3. For similar frameworks see McKay and Reis (2021), Challe (2020), and Ravn and Sterk (2020).

to be matched with a currently unemployed worker. New matches are denoted by $M_t$ and are formed according to the function:

$$M_t = \chi V_t^{1-\eta}\left(1-(1-\delta)N_{t-1}\right)^{\eta}, \tag{1.2.1}$$

where $\eta \in (0,1)$ is the elasticity of matches with respect to unemployment and $\chi$ represents matching efficiency.

Labor market tightness is defined as the ratio of vacancies over unemployment $\theta_t \equiv V_t/(1-(1-\delta)N_{t-1})$. An unemployed worker finds a job with probability $f_t \equiv M_t/(1-(1-\delta)N_{t-1})$ and a vacancy is filled with probability $q_t \equiv f_t/\theta_t$. Therefore, the law of motion for employment is given by:

$$N_t = (1-\delta)N_{t-1} + f_t\left(1-(1-\delta)N_{t-1}\right). \tag{1.2.2}$$

### 1.2.2 Households

The household sector is composed by two type of agents, entrepreneurs and workers. Workers can be either employed or unemployed $N_{i,t} \in \{1,0\}$. Entrepreneurs have mass $\lambda$ and are the shareholders of firms, but do not participate in the labor market. All households can save in a risk-free bond, subject to a no-borrowing constraint. In addition, firm-owners participate in the equity market and can trade firm shares with each other.

The problem of a worker is to choose consumption $C_{i,t}$ and savings $A_{i,t}$ subject to the budget constraint and the no-borrowing constraint:

$$V\left(N_{i,t},A_{i,t-1}\right) = \max_{C_{i,t},A_{i,t}\geq 0} \frac{C_{i,t}^{1-\sigma^{-1}}-1}{1-\sigma^{-1}} + \beta_t \mathbb{E}_t V\left(N_{i,t+1},A_{i,t}\right) \tag{1.2.3}$$

subject to

$$C_{i,t} + A_{i,t} = N_{i,t}W_t + \left(1-N_{i,t}\right)B_t + A_{i,t-1}\frac{1+i_{t-1}}{1+\pi_t}, \tag{1.2.4}$$

where $\beta_t$ is the, potentially time-varying, time discount factor. $1+i_t$ denotes the gross nominal interest rate paid on real risk-free bonds $A_{i,t}$, set by the monetary authority. $1+\pi_t = P_t/P_{t-1}$ is the gross inflation rate and $P_t$ the price level of the consumption good. If employed, a worker receives a real wage $W_t$. On the other hand, when a worker falls into unemployment she receives unemployment benefits $B_t < W_t$ provided by the government.

The surplus of a worker is hence given by:

$$\Delta_{u,t}^{e} = V\left(1,A_{i,t-1}\right) - V\left(0,A_{i,t-1}\right). \tag{1.2.5}$$

I denote by $C_{F,t}$ and $A_{F,t}$ the consumption and saving choices of the representative entrepreneur, who solves:

$$V\left(A_{F,t-1},X_{t-1}\right) = \max_{C_{F,t},A_{F,t}\geq 0} \frac{C_{F,t}^{1-\sigma^{-1}}-1}{1-\sigma^{-1}} + \beta_t \mathbb{E}_t V\left(A_{F,t},X_t\right) \tag{1.2.6}$$

subject to

$$\lambda C_{F,t} + \lambda A_{F,t} + P_{X,t}X_t = \left(P_{X,t}+D_t\right)X_{t-1} + \xi - \lambda A_{F,t-1}\frac{1+i_{t-1}}{1+\pi_t} - T_t, \tag{1.2.7}$$

where $D_t$ are real dividends paid out by firms, to be specified below, $\xi$ is home production and $T_t$ a lump-sum tax paid to the fiscal authority. $X_t$ denotes firm shares and $P_{X,t}$ their price.

The division between firm-owners and workers is motivated by the uneven distribution of income sources and equity holdings observed in the data. Whereas the majority of households earn mostly labor income, only a few have a significant share of financial income in their total income (see e.g. Gornemann *et al.* (2016)). This is not inconsequential, as the cyclicality of dividends affects the volatility of income and hence the consumption-saving choices of households in response to aggregate shocks.[4] Yet, in Appendix 1.A, I show that the main conclusions of this paper are robust to allowing workers to receive financial income.

### 1.2.3 Firms

The supply side of the economy has three layers of production: competitive final good producers, that produce a final consumption good; wholesale good producers, that operate in monopolistic competition and face nominal rigidities; and competitive labor good firms, that hire workers in a frictional labor market.

#### Final good producers

Final good producers buy differentiated wholesale inputs $Y_{j,t}$ at price $P_{j,t}$ and bundle them into a homogeneous final consumption good $Y_t$ using a CES technology $Y_t = \left(\int_0^1 Y_{j,t}^{\frac{\varepsilon-1}{\varepsilon}} dj\right)^{\frac{\varepsilon}{\varepsilon-1}}$, where $\varepsilon > 1$ measures the elasticity of substitution across goods. The final good is sold to households at competitive price $P_t$. The problem of the representative final good producer delivers a set of isoelastic demand functions:

$$Y_{j,t} = \left(\frac{P_{j,t}}{P_t}\right)^{-\varepsilon} Y_t, \tag{1.2.8}$$

and a price index $P_t = \left(\int_0^1 P_{j,t}^{1-\varepsilon} dj\right)^{\frac{1}{1-\varepsilon}}$.

4. Broer *et al.* (2020) discuss the role of profits for the transmission of monetary policy shocks in a similar worker-capitalist framework.

**Wholesale Good Firms**

Wholesale good producers operate under monopolistic competition. They buy homogeneous labor goods at a competitive price $P_t^J$, expressed in terms of the consumption good. Using a linear technology, they convert them into differentiated wholesale goods. I denote by $Q_{t,t+1} = \beta_t \left(\frac{C_t^F}{C_{t+1}^F}\right)^{\sigma-1}$ the discount factor of firms.

A typical wholesale firm $j$ has per period real profits:

$$D_{j,t}^W = Y_{j,t}\left[\frac{P_{j,t}}{P_t} - P_t^J\right], \tag{1.2.9}$$

These firms face nominal rigidities à la Calvo. In particular, every period only a fraction $(1-\alpha)$ of firms is able to reset its price. In equilibrium, conditional on resetting their prices, all firms are alike and will behave in the same way, so we can drop the $j$ subscript to summarize their optimal decisions. I denote by $P_t^*$ the optimal price chosen by optimizing firms, in terms of final goods' price. This is given by:

$$P_t^* = \frac{\varepsilon}{\varepsilon - 1}\frac{P_t^A}{P_t^B} \tag{1.2.10}$$

where

$$P_t^A = Y_t P_t^J + \alpha \mathbb{E}_t \left(1 + \pi_{t+1}\right)^{\varepsilon} Q_{t,t+1} P_{t+1}^A, \tag{1.2.11}$$

$$P_t^B = Y_t + \alpha \mathbb{E}_t \left(1 + \pi_{t+1}\right)^{\varepsilon-1} Q_{t,t+1} P_{t+1}^B. \tag{1.2.12}$$

Note in particular that in the limit of flexible prices $\alpha \to 0$, all firms set the same price every period, implying that the price for labor goods is constant $P_t^J = \frac{\varepsilon-1}{\varepsilon}$. Next, using the price index we can express inflation as a function of $P_t^*$:

$$1 + \pi_t = \left[\frac{1}{\alpha} + \frac{\alpha - 1}{\alpha}\left(P_t^*\right)^{1-\varepsilon}\right]^{\frac{1}{\varepsilon-1}}. \tag{1.2.13}$$

Finally, using the optimality conditions from the final good firms, together with its zero-profit condition, we can write total dividends paid to firm-owners by wholesale firms as:

$$D_t^W = \int_0^1 D_{j,t}^W dj = Y_t\left(1 - P_t^J \Delta_t\right), \tag{1.2.14}$$

where $\Delta_t = \int_0^1 \left(\frac{P_{j,t}}{P_t}\right)^{-\varepsilon} dj \geq 1$ measures price dispersion.

### Labor good firms

Labor good firms are composed by a single worker and use a linear technology to produce labor goods. The value of a firm with a worker is denoted by $J_t$ and given by the sum of operating profits, $P_t^J - W_t$, and the continuation value of the job:

$$J_t \;=\; P_t^J - W_t + (1-\delta)\,\mathbb{E}_t Q_{t,t+1} J_{t+1}. \tag{1.2.15}$$

In order to produce, firms must hire a worker. Hiring a worker involves opening vacancies at a cost per vacancy $\kappa_v$. The government subsidizes vacancy posting at rate $\tau_t^v$, such that by providing hiring subsidies it reduces the cost of posting vacancies. Free entry implies that, in equilibrium, a firm posts vacancies until the expected gains from not doing so are zero, that is:

$$\kappa_v\left(1-\tau_t^v\right) \;=\; q_t J_t. \tag{1.2.16}$$

It is well-known that search and matching models as described here tend to deliver far too little unemployment volatility when wages are bargained according to a standard Nash protocol, featuring the so-called “Shimer Puzzle" (Shimer (2005)). A possible solution, consistent with the observed patters in the data, is to assume that real wages are sticky and fall to adjust sufficiently in recessions. I follow this approach and use a wage mechanism similar to Hall (2005) and Challe (2020), where the prevailing real wage is given by:

$$W_t \;=\; \left(W_t^{\text{Nash}}\right)^{1-\zeta}\left(W_{ss}\right)^{\zeta}, \tag{1.2.17}$$

where $W_{ss}$ is the constant steady state wage and $W_t^{\text{Nash}}$ is the solution to the Nash bargain problem between the firm and the worker:

$$W_t^{\text{Nash}} \;=\; \underset{W_t}{\arg\max} J_t^{\gamma}\left(\Delta_{u,t}^{e}\right)^{1-\gamma}, \tag{1.2.18}$$

where $\gamma$ denotes the bargaining power of the firm and $\Delta_{u,t}^e$ is the surplus of a worker, defined in (1.2.5). Hence $\zeta$ controls the rigidity of the real wage.

Total dividends from labor good firms are given by total operating profits net of after-subsidies vacancy posting costs:

$$D_t^J \;=\; N_t\left(P_t^J - W_t\right) - \left(1-\tau_t^v\right)\kappa_v V_t. \tag{1.2.19}$$

### 1.2.4 Government

The government is composed by a monetary and a fiscal authority. The monetary authority sets the nominal interest rates according to a Taylor rule that targets inflation deviations and is constrained by the zero lower bound. That is:

$$1 + i_t \ = \ \max\left\{\left(1+\bar{i}\right)\frac{\bar{\beta}}{\beta_t}\left(1+\pi_t\right)^{\phi_\pi}, 1\right\}, \tag{1.2.20}$$

where $\phi_\pi > 1$ is the endogenous response of the central bank to inflation, satisfying the Taylor principle, and $1+\bar{i}$ is the gross nominal interest rate in steady state. $\bar{\beta}$ is the steady state value of the discount factor and $\beta_t$ its time $t$ value.

The government provides hiring subsidies to firms and unemployment benefits to unemployed workers, financed by levying lump-sum taxes on firm-owners:

$$T_t \ = \ \tau_t^v \kappa_v V_t + \left(1 - N_t\right) B_t. \tag{1.2.21}$$

### 1.2.5 Market clearing

Equilibrium in the asset market requires that bonds are in zero net supply $\int_0^{1+\lambda} A_{i,t} di = 0 \ \forall t$ and the equity market clears $X_t = 1$ every period. Labor goods market clearing implies that $Y_t \Delta_t = N_t$. Finally, using the budget constraints of households and the government, we can write the resource constraint as:

$$N_t C_{e,t} + \left(1 - N_t\right) C_{u,t} + \lambda C_{F,t} \ = \ Y_t - \kappa_v V_t + \lambda \xi. \tag{1.2.22}$$

### 1.2.6 Equilibrium implications

Since bonds are in zero net supply and borrowing is not allowed, the equilibrium allocation coincides with financial autarky. That is, in equilibrium no agent holds bonds and, as a consequence, every household consumes its *own* income period by period. In particular, employed workers consume the real wage $C_{e,t} = W_t$, unemployed the unemployment benefits $C_{u,t} = B_t$ and firm-owners $\lambda C_{F,t} = D_t + \xi - T_t$.

Consistency with a zero net demand for bonds, in turn, requires that the real interest rate is sufficiently low, so that every agent optimally chooses to not save. In order to characterize such equilibrium interest rate, it is convenient to spell out the Euler equations characterizing the optimal saving choices of employed workers, unemployed workers and firm-owners, respectively:

$$1 \ \geq \ \mathbb{E}_t \beta_t \frac{1+i_t}{1+\pi_{t+1}} \left\{ \left[1 - \delta\left(1 - f_{t+1}\right)\right] \left(\frac{C_{e,t}}{C_{e,t+1}}\right)^{\frac{1}{\sigma}} + \delta\left(1 - f_{t+1}\right) \left(\frac{C_{e,t}}{C_{u,t+1}}\right)^{\frac{1}{\sigma}} \right\}, \tag{1.2.23}$$

$$1 \;\geq\; \mathbb{E}_t \beta_t \frac{1+i_t}{1+\pi_{t+1}} \left[ f_{t+1} \left( \frac{C_{u,t}}{C_{e,t+1}} \right)^{\frac{1}{\sigma}} + (1-f_{t+1}) \left( \frac{C_{u,t}}{C_{u,t+1}} \right)^{\frac{1}{\sigma}} \right], \tag{1.2.24}$$

$$1 \;\geq\; \mathbb{E}_t \beta_t \frac{1+i_t}{1+\pi_{t+1}} \left( \frac{C_{F,t}}{C_{F,t+1}} \right)^{\frac{1}{\sigma}}, \tag{1.2.25}$$

where the above equations hold with strict inequality if the no-borrowing constraint is binding.

Focusing on the steady state, note that employed workers have the strongest savings motive as they face the downward idiosyncratic risk of falling into unemployment. Unemployed workers, however, may become employed and hence would like to borrow against their higher future income. Consequently, they would be only willing to hold bonds at a higher steady-state real interest rate than employed workers. More formally, evaluating (1.2.23) and (1.2.24) at the steady state, and denoting by $r^{eq}$ the equilibrium interest rate at which every agent optimally chooses to not save we obtain:

$$\frac{1}{1+r^{eq}} \;\geq\; \frac{1}{1+r*} \;=\; \beta \left\{ 1+\delta(1-f) \left[ \left( \frac{C_e}{C_u} \right)^{\frac{1}{\sigma}} - 1 \right] \right\} \;>\; \beta \left\{ 1-f \left[ 1 - \left( \frac{C_u}{C_e} \right)^{\frac{1}{\sigma}} \right] \right\}, \tag{1.2.26}$$

where I have denoted by $r^*$ the real interest rate that leaves employed workers indifferent between holding or not holding bonds, and where the second inequality follows from $C_e > C_u$. It follows that, at the equilibrium interest rate $r^{eq}$, currently unemployed workers would like to borrow and consequently will be off their Euler equation.

On the other hand, firm-owners face no idiosyncratic risk as they do not participate in the labor market. Hence, they are unwilling to save at any steady-state real interest rate below their time preference rate $1/\beta$. Again, evaluating their Euler equation for the bond (1.2.25), we obtain:

$$\frac{1}{1+r^{eq}} \;\geq\; \frac{1}{1+r*} \;=\; \beta \left\{ 1+\delta(1-f) \left[ \left( \frac{C_e}{C_u} \right)^{\frac{1}{\sigma}} - 1 \right] \right\} \;>\; \beta, \tag{1.2.27}$$

and, as consequence, firm-owners will be off their Euler equation as well. [5]

5. Note that, as emphasized in Ravn and Sterk (2020), the equilibrium allocation resulting in this model, where consumption equals income, does not necessarily imply that all agents have a marginal propensity to consume (MPC) of one. In partial equilibrium, firm-owners can use their equity holdings to smooth transitory income fluctuations. The model can be easily extended to reduce the MPC of employed workers as well, while obtaining the same equilibrium implications. Suppose that agents could borrow up to a fraction $\vartheta$ of their labor income, $A_{i,t} \geq -\vartheta W_t$, such that only employed

It follows, hence, that the agents willing to save at the lowest interest rate are employed workers, owing to their precautionary savings motive. In particular, note that any real interest rate below $r^*$ is consistent with a zero net demand for bonds. However, any $r^{eq} < r^*$ is not robust to the introduction of an arbitrarily small amount of positive supply of liquidity, for which there must be at least one agent willing to hold it.[6] Therefore, I focus on the equilibrium defined by $r^{eq} = r^*$, implying that employed workers price the bond and their Euler equation (1.2.23) holds with equality.

Following much of the literature, I will focus on fluctuations around this steady state as result of small aggregate shocks, and hence assume that the relevant equilibrium condition is still given by the Euler equation of employed workers.

### 1.2.7 Benchmark economies

In order to illustrate the transmission mechanism of hiring subsidies to employment in the imperfect insurance economy previously described, I confront its predictions with two benchmark economies.

#### 1.2.7.1 Representative agent economy

First, I consider an economy populated by a representative agent, or alternatively with complete markets and no ex-ante heterogeneity. The Euler equation of the representative household reads:

$$C_t^{-\sigma^{-1}} = \mathbb{E}_t \beta_t \frac{1+i_t}{1+\pi_{t+1}} C_{t+1}^{-\sigma^{-1}}, \tag{1.2.28}$$

where $C_t$ denotes aggregate consumption. The aggregate resource constraint states that total consumption must equal aggregate production net of resources spent on hiring:

$$C_t = Y_t - \kappa_v V_t. \tag{1.2.29}$$

The imperfect insurance economy differs from the representative agent along two key dimensions that, as I will show, shape the effects of hiring subsidies on employment. Both are related to the presence of incomplete financial markets.

With incomplete markets, the lack of risk-sharing implies that the consumption of a worker is constrained by her *own current income*. This has two consequences. First, the income drop upon unemployment should be absorbed to some extent by consumption, which implies that workers have a precautionary savings motive. Second, conditional on being employed, she only consumes her income – the real wage.

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workers could borrow. This formulation also implies that, in equilibrium, every agent in the economy consumes her own current income. However, the presence of debt would imply that only unemployed workers have an MPC of one, as in partial equilibrium employed workers can now borrow to smooth transitory income shocks.

6. See Werning (2015) and Krusell *et al.* (2011).

Consequently, the budget constraint of an employed worker is not directly affected by the fact that, during a hiring stimulus, more households may be working.

Complete markets break both features. Perfect risk-sharing in the economy is analogous to all workers pooling their own current income within the representative family. Hence, each worker consumes a constant fraction of *current aggregate income*, regardless of her employment status. Consequently, the precautionary savings motive vanishes, rendering the representative agent economy a natural benchmark to test the predictions of the imperfect insurance model. Second, owing to this income pooling result of full risk-sharing, the representative household internalizes in its budget constraint that more family's members may be working during a hiring stimulus. This implies that its income fluctuates through the number of workers and not only through the the real wage. Thus, even abstracting from precautionary savings, the saving choices of a single worker in the incomplete markets economy might differ substantially from that of the representative family owing to their different income volatility.

#### 1.2.7.2 Perfect insurance economy

In order to tell these two dimensions apart – precautionary savings and income volatility – I consider a second benchmark, that I label perfect insurance. In this perfect insurance model, I keep the worker-entrepreneur structure of the imperfect insurance model and incomplete financial markets, but I set unemployment benefits $B_t$ very close to the current real wage $W_t$ in the calibration.[7] Effectively, this high level of unemployment benefits eliminates the precautionary savings motive, but precludes the income pooling arising in the representative agent model. This allows me to break down the disagreement between complete and incomplete markets into two pieces. First, comparing the perfect insurance economy with the imperfect insurance model I will be able to pin down the implications of unemployment risk for the transmission of hiring subsidies. Second, confronting the representative agent model with the perfect insurance economy allows me to discern the consequences of the different income volatility previously discussed.

## 1.3 Calibration

I calibrate the model to the U.S. economy. One period of the model refers to one quarter. The values of parameters are collected in Table 1.3.1. These, in the incomplete markets economy with imperfect insurance, are chosen as follows. Regarding the labor market, I set the separation rate $\delta$ to 0.10, as in e.g. Gornemann *et al.* (2016). I set the matching efficiency $\chi$ to target an employment rate in steady state

7. A similar benchmark economy is used in Challe (2020).

**Table 1.3.1.** Calibrated parameters.

| Param. | Description | Imperfect Insurance | Perfect Insurance | Rep. Agent | Source/Target |
|---|---|---|---|---|---|
| $\eta$ | Elasticity of $M_t$ wrt $V_t$ | 0.50 | 0.50 | 0.50 | Standard value |
| $\delta$ | Separation rate | 0.10 | 0.10 | 0.10 | Gornemann *et al.* (2016) |
| $\varepsilon$ | Elasticity of subs. | 6.00 | 6.00 | 6.00 | Markup 20% |
| $\phi_\pi$ | Taylor rule | 1.50 | 1.50 | 1.50 | Standard value |
| b | Replacement rate | 0.90 | 0.99 | 0.90 | Cons. drop upon unempl. |
| $1/\sigma$ | Risk aversion | 1.50 | 1.50 | 1.50 | Ravn and Sterk (2017) |
| $\bar{\beta}$ | Discount factor | 0.98 | 0.99 | 0.99 | Interest rate s.s. 3% |
| $\alpha$ | Price stickiness | 0.80 | 0.80 | 0.80 | Mean price duration of 5$q$. |
| $\kappa_v$ | Vacancy posting cost | 0.06 | 0.06 | 0.06 | $q = 0.71$ |
| $\chi$ | Matching efficiency | 0.66 | 0.66 | 0.66 | $N = 0.94$ |
| $\gamma$ | Bargaining power of firm | 0.40 | 0.88 | 0.43 | Operating profits of 1% |
| $\xi$ | Home prod. entr. | 1.20 | 1.20 | 0.00 | Income share of top 20% |
| $\zeta$ | Wage rigidity | 0.54 | 0.55 | 0.55 | Elasticity of real wage |

*Notes:* The table shows the calibrated parameters. See the main text for a discussion of the calibration targets.

of 94%, implying $\chi = 0.66$. The elasticity of new matches with respect to unemployment $\eta$ is set to 0.5, in the ballpark of estimates of Petrongolo and Pissarides (2001). The bargaining power of firms $\gamma$ is set to target steady state operating profits of 1%, compare to Hagedorn and Manovskii (2008) and Shimer (2005). This implies $\gamma = 0.40$. I calibrate the vacancy posting cost $\kappa_v$ to target a vacancy filling rate in steady state of 71%, as in Den Haan *et al.* (2000). Regarding the New Keynesian block of the model, I set the probability of not readjusting prices $\alpha$ to 0.80, implying that on average firms readjust their prices every five quarters, similar to e.g. Gornemann *et al.* (2016). The elasticity of substitution across goods $\varepsilon$ is set to 6, implying a steady state markup of 20%, a common value in the literature. The response of nominal rates to inflation $\phi_\Pi$ is set to 1.5. As regards the household side, I set the relative risk aversion parameter $1/\sigma$ to 1.5 as in Ravn and Sterk (2017). I choose a value for the relative risk aversion parameter somewhat lower than that used in the heterogeneous agents literature (e.g. Bayer *et al.* (2019), Kaplan and Violante (2014)) in order to mitigate the impact of the absence of positive liquidity in my framework. The steady-state time discount factor $\bar{\beta}$ is chosen to match an annualized real interest rate of 3% in the steady state.

A crucial parameter that determines the strength of precautionary savings is the consumption drop upon unemployment, given by the gap between the real wage $W_t$ and unemployment benefits $B_t$. This matters along two dimensions. First, how large the income drop is at a given point in time. Second, how this income drop changes over the business cycle. I shut down the latter effect by assuming that the unemployment insurance scheme is defined by a constant replacement rate $b$ over the real wage. That is, the government provides unemployment benefits according to $B_t = bW_t$. This allows me to transparently isolate the change in precautionary savings arising only from the amount of slackness in the labor market. In Appendix 1.A, I explore the consequences of relaxing this assumption and show that the main results remain unaffected.

Chodorow-Reich and Karabarbounis (2016) find that consumption on non-durable goods and services declines by about 21% during an unemployment spell. On the other hand, Ganong and Noel (2019) report that the consumption drop on the onset of an unemployment spell is approximately 6%. I target an intermediate value and set $b = 0.90$, implying a consumption drop of 10% upon unemployment in the baseline calibration. [8]

I identify the group of entrepreneurs or firm-owners with the top 20% of the income distribution. I choose their home production level $\xi$ to match their income share $\lambda C_{F,t}/(\lambda C_{F,t} + N_t C_{e,t} + (1-N_t)C_{u,t})$. I target an income share of 61.4% (Rios-Rull and Kuhn (2016)), leading to $\xi = 1.20$.

Finally, I calibrate the parameter controlling wage rigidity $\zeta$ to match an elasticity of real wages with respect to productivity shocks and flexible prices of 0.45, following Hagedorn and Manovskii (2008). This delivers $\zeta = 0.54$.

In order to be as transparent as possible, I recalibrate the representative agent and perfect insurance models to ensure that they share the same steady state and wage cyclicality of the baseline imperfect insurance economy. In the perfect insurance model I set the replacement rate $b$ equal to 0.99 as to quantitatively shut down the effect of precautionary savings. This implies that the discount factor $\bar{\beta}$ increases to 0.992, as in the representative agent economy, in order to match the targeted steady state real rate. Given that the higher replacement rate implies a lower surplus of working, the bargaining power of firms increases to $\gamma = 0.88$. In the representative agent economy, with $b = 0.90$, I set $\gamma = 0.43$ to target the same operating profits as in the baseline imperfect insurance model. The wage rigidity parameter $\zeta$ slightly increases to 0.55 in the perfect insurance model and in the representative agent case.

## 1.4 Quantitative analysis

In order to clarify the transmission of hiring subsidies to employment, and how this is shaped by precautionary savings, I proceed in three steps. First, I show the impact

8. In Appendix 1.A a provide I sensitivity analysis with respect to this parameter. Results are robust unless that the consumption drop upon unemployment is substantially below the empirical estimates.

of subsidizing hiring with flexible prices. Second, I consider the case of sticky prices and an unconstrained central bank. Finally, I show the effects of a hiring stimulus in a liquidity trap.

Owing to the non-linearity introduced by the zero lower bound, standard solution methods are not well-suited for the liquidity trap analysis. As such, I follow McKay *et al.* (2016) and consider perfect-foresight shocks, solving the model non-linearly. Similar approaches are used in the literature (e.g. Christiano *et al.* (2011)). In order to enhance comparability between exercises, I use the same solution method even when I consider the flexible prices scenario and the sticky prices case away from the zero lower bound.

The shock that I consider is as follows. At time $t-1$ the economy is in the non-stochastic steady steady state, where hiring subsidies are zero. At time $t$ the government unexpectedly increases hiring subsidies $\tau_t^v$ to 10% on impact.[9] They decline exponentially with persistence of $\rho_\tau = 0.85$.[10] That is, at time $t+k$, the hiring subsidy is $\tau_{t+k}^v = \rho_\tau^{t+k}\tau_t^v$. I will consider the same path for hiring subsidies, in terms of size and persistence, in all exercises.

### 1.4.1 Flexible prices

Figure 1.4.1 shows the impulse responses to a hiring stimulus with flexible prices in the imperfect insurance economy and the two benchmark models, the perfect insurance model and the representative agent economy. The fall in hiring costs generated by the government induces firms to post more vacancies. As a consequence, aggregate employment increases, observe the first column of Figure 1.4.1. Since prices are flexible, the possible differences in consumption-savings decisions of households between the three economies do not feedback into output and hence the increase in employment is symmetric across all three models.

The second column of Figure 1.4.1 shows that the behavior of the natural interest rate – the real interest rate prevailing with flexible prices – notably differs across models. In the imperfect insurance economy, first row of Figure 1.4.1, the natural interest rate increases significantly. In sharp contrast, the natural interest rate persistently falls in the two benchmark economies, observe the last two rows of the second column in Figure 1.4.1. Yet, the magnitude of the drop of the natural interest rate is substantially larger under the representative agent model than in the perfect insurance economy.

9. The size of the initial increase is chosen such that figures in the analysis are visually informative. Results are unaffected by considering alternative magnitudes of the initial increase in hiring stimulus.

10. The persistence of the stimulus in line with the persistence of government spending shocks (e.g. Nakamura and Steinsson (2014)). Appendix 1.A provides a sensitive analysis with respect to this parameter.

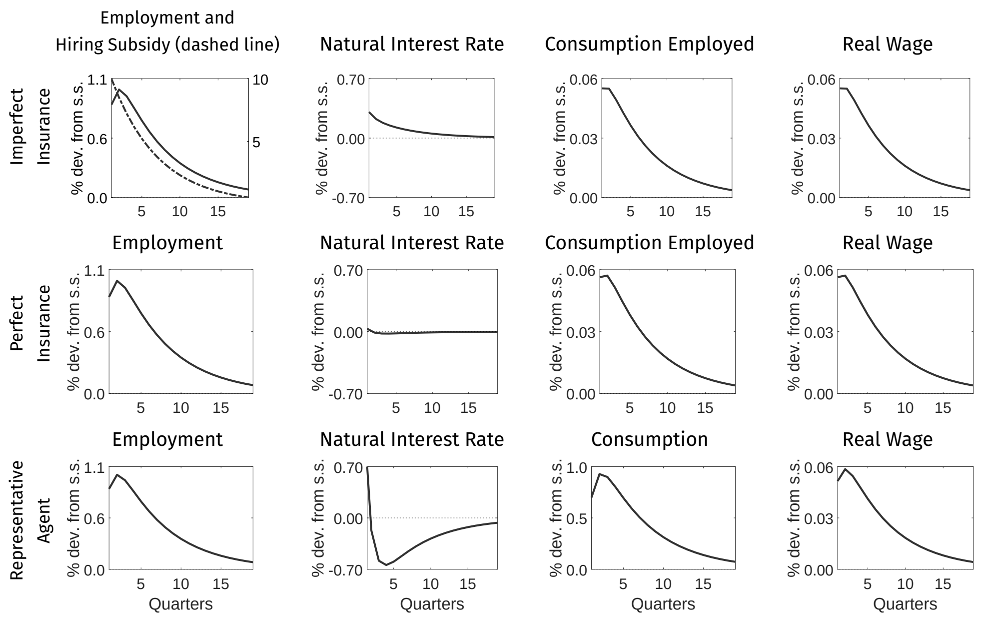


**Figure 1.4.1.** Effect of an Increase in Hiring Subsidies with Flexible Prices

*Notes:* Impulse responses to an increase in hiring subsidies with flexible prices. The path for the hiring subsidy is depicted in the first panel of the first row with a dashed line. The first row shows impulse responses in the imperfect insurance economy. The second row displays the results in the perfect insurance economy. The last row plots the impulse responses in the representative agent model. In the imperfect insurance and perfect insurance economies, "Consumption Employed" refers to the impulse response of the consumption of a single employed worker. The natural interest rate is the real interest rate prevailing with flexible prices and is reported in annualized level deviations.

As firms post more vacancies and labor market tightness increases, the outside option of the worker improves. Consequently, as shown in the last column of Figure 1.4.1, the real wage increases. Since the increase in employment, and hence in labor market tightness, is similar in the three economies, so it is the rise in the real wage.

In the imperfect insurance economy and the perfect insurance model, employed workers only consume the real wage in equilibrium. Accordingly, the consumption of a single worker increases in lockstep with the real wage in these economies, compare the third and fourth column in the first two rows in Figure 1.4.1. The increase in consumption of a single worker stands in sharp contrast with that of the representative agent, compare to the third panel of last row in Figure 1.4.1. The reason is that the representative agent internalizes in its budget constraint that more family members are working. Consequently, its consumption closely tracks aggregate employment, compare the first and third panel of the last row in Figure 1.4.1.

In sum, Figure 1.4.1 shows that although the response of aggregate employment with flexible prices does not depend on the details of the household side, the behavior of the natural interest rate crucially does. The natural interest rate, in turn, adjusts to ensure that the asset market clears without further adjustments in income.

As such, it constitutes a useful summary statistic to understand households' savings decisions in each economy. In order to build intuition and understand the large disagreement in the behavior of the natural interest rate found in Figure 1.4.1 it is instructive to log-linearize the Euler equation (1.2.23) with flexible prices:

$$\sigma \underbrace{\widehat{R}_t^n}_{\text{Natural Rate}} = \underbrace{\mathbb{E}_t\left(\widehat{c}_{e,t+1} - \widehat{c}_{e,t}\right)}_{\text{Consumption Growth}} + \underbrace{\sigma \Gamma \mathbb{E}_t \widehat{f}_{t+1}}_{\text{Precautionary Savings}} \tag{1.4.1}$$

with

$$\Gamma = \beta(1+\bar{r})f\delta(b^{-\frac{1}{\sigma}} - 1) \geq 0,$$

where letters with hats denote percentage deviations from steady-state values.[11] Equation (1.4.1) states that the natural interest rate is shaped by two forces.[12]

First, there is a *consumption growth channel*. Temporarily higher income – hence, in equilibrium, consumption –, implying that the first term on the right-hand side is negative, puts downward pressure on the natural interest rate. This force triggers intertemporal substitution, inducing households to increase savings to smooth consumption and leading to a drop in the real interest rate. Second, there is a *precautionary savings channel*, the main focus of this paper.[13] This channel states that higher future job-finding rates reduce unemployment risk, inducing households to cut back on precautionary savings, and hence raising the natural rate. The strength of this channel is governed by $\Gamma$. In particular, this channel disappears in the two benchmark economies where the consumption drop upon unemployment vanishes.

To understand how the previous two channels interact in equilibrium, suppose that the government temporarily raises hiring subsidies. As firms hire more, the labor market gets tighter, increasing real wages. Temporarily higher real wages induces households to increase savings, putting downward pressure on the natural interest rate. However, as the job-finding rate increases, workers expect to find jobs quickly, and hence unemployment risk falls. As a consequence, households reduce precautionary savings, bidding up the natural interest rate. In sum, after an increase in hiring subsidies, the consumption growth channel and the precautionary savings channel operate in opposite directions, and the net effect on the natural interest rate depends on relative strength of each of them.

As shown in Figure 1.4.1, the natural interest rate increases in the imperfect insurance economy. This implies that the precautionary savings channel dominates.

11. For expositional clarity I abstract here from a time-varying discount factor $\beta$.

12. Challe (2020) offers the same decomposition to show how the presence of precautionary savings affects the behavior of the natural interest rate in face of productivity and cost-push shocks.

13. It is worth emphasizing at this point that "precautionary savings" in this paper are understood as the increased desire of the household to hold savings in response to an increase in household income risk, driven by a drop in the job-finding rate. Note that this event has a first-order effect due to the presence of borrowing constraints and, therefore, would be present even if preferences exhibited no "prudence" (Kimball (1990)). See Challe and Ragot (2016) for a similar point.

Absent precautionary savings, as in the two benchmark economies, the consumption growth channel illustrated in equation (1.4.1) leads to a persistent fall in the natural interest rate.

The strength of the consumption growth channel, in turn, explains the quantitative difference in the fall of the natural interest rate between the two benchmark economies. The reason is as follows. The representative agent, owing to full risk-sharing that results from complete financial markets, internalizes in its budget constraint that more family members are working after the hiring stimulus. A single worker in the perfect insurance economy – as well as in the imperfect insurance model – does not. Owing to incomplete financial markets, she is constrained by her *own* current income – the real wage. As a consequence, the income of the representative agent rises significantly more than that of a single worker. Therefore, the desire to increase savings of the representative family is larger, the consumption growth channel stronger, and the fall of the natural interest rate deeper.[14]

The interaction between a weak consumption growth channel and a significant fall in unemployment risk explains the large disagreement in the behavior of the natural interest rate between the imperfect insurance economy and the representative agent model found in Figure 1.4.1. Of this gap, the importance of the precautionary savings channel is given by the difference between the perfect insurance and imperfect insurance economies – compare the second panel of the first two rows in Figure 1.4.1 – as both economies share the same consumption growth channel, compare the third panel of the first two rows. The remaining difference between the imperfect insurance model and the representative agent is accounted by the distinct consumption growth channel, which can be approximated as the difference between the representative agent economy and the perfect insurance model – compare the second panel of the last two rows in Figure 1.4.1 – since none of these two economies feature precautionary savings and they only differ in their income volatility.

### 1.4.2 Sticky prices

The different optimal saving choices of households did not feed back into employment and output with flexible prices. I introduce next sticky prices, such that aggregate demand affects equilibrium employment dynamics. I start by considering the effects of an increase in hiring subsidies with an unconstrained central bank. Figure 1.4.2 shows the results in the three economies. The first row shows the results in the imperfect insurance economy. The second row displays the impulse responses in the

14. Exercises provided in Appendix 1.A further illustrate this channel. In particular, I show that when real wages are perfectly flexible the consumption growth channel becomes stronger, dampening the precautionary savings channel, but the latter effect still dominates. Furthermore, I show that the weaker consumption growth channel in the incomplete markets economy is not a consequence of dividends being allocated to firm-owners, but rather a result of more family members working in the representative agent model.

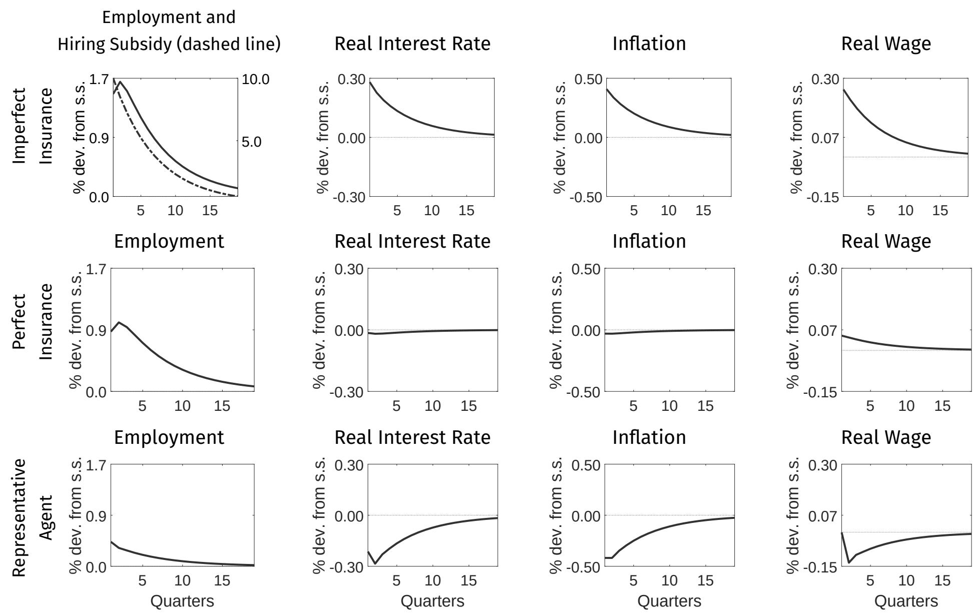


**Figure 1.4.2.** Effect of an Increase in Hiring Subsidies with Sticky Prices

*Notes:* Impulse responses to an increase in hiring subsidies with sticky prices and away from the zero lower bound. The path for the hiring subsidy is depicted in the first panel of the first row with a dashed line. The first row shows impulse responses in the imperfect insurance economy. The second row displays the results in the perfect insurance economy. The last row plots the impulse responses in the representative agent model. In the imperfect insurance and perfect insurance economies, "Consumption Employed" refers to the impulse response of the consumption of a single employed worker. The real interest rate and inflation are reported in annualized level deviations.

perfect insurance model, and the third row shows the results in the representative agent economy.

The increase in hiring subsidies reduces firms' marginal costs and stimulates aggregate supply. This channel, alone, would reduce inflation. The effects on aggregate demand, instead, are ambiguous, as discussed in the previous section. In the imperfect insurance economy, as shown previously, the precautionary savings channel dominates. Therefore, the hiring stimulus induces households to increase their demand for consumption goods. With sticky prices, the higher demand for goods generates inflationary pressures in the economy, observe the third panel of the first row in Figure 1.4.2. In response to higher inflation, the central bank raises the nominal interest rate, increasing the real rate, as shown in the second panel of the first row.

The behavior of inflation in the imperfect insurance economy stands in sharp contrast with the deflationary forces witnessed in the two benchmark models, observe the third panel of the last two rows in Figure 1.4.2. Absent the precautionary savings channel, the decline in firms' hiring costs reduce inflation. Furthermore, the consumption growth channel contains aggregate demand, reinforcing the deflation-

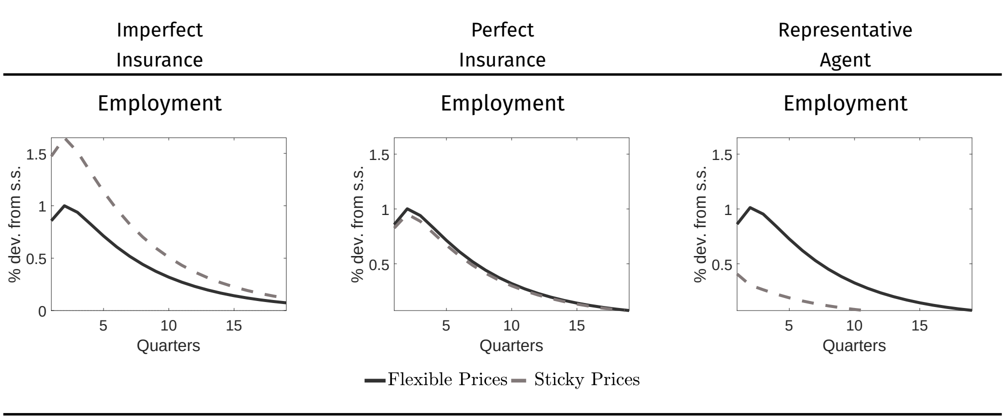


**Figure 1.4.3.** Flexible Prices vs. Sticky Prices

*Notes:* Black solid lines show the effects of increasing hiring subsidies when prices are flexible and gray dashed lines display the impulse responses to the same hiring subsidy shock when prices are sticky in the imperfect insurance economy (first panel), the perfect insurance model (second panel), and the representative agent economy (third panel).

ary pressures. According to the Taylor rule (1.2.20), the central bank cuts the nominal interest rate, inducing the real interest rate to fall, observe the second panel of the last two rows. In annualized terms, inflation drops about 0.42 percent in the representative agent economy, whereas it increases by roughly the same magnitude in the imperfect insurance model. In the perfect insurance framework, it barely falls by 0.03 percent. Similar to the previous section, the large quantitative difference between the imperfect insurance economy and the perfect insurance model underscores the relevance of the precautionary savings channel.

The different consumption response of households has now, with sticky prices, real effects on aggregate employment. The first column of Figure 1.4.2 shows that the employment response sharply differs across economies. More precisely, the drop in precautionary savings and increase in demand for consumption goods implies that employment in the imperfect insurance economy increases three times as much as it does in the representative agent model. The perfect insurance model lies between these two, as the precautionary savings channel is absent, but lacks the strong consumption growth channel present in the representative agent economy.

Figure 1.4.3 compares the responses with sticky prices, displayed with solid black lines, and flexible prices, shown with dashed gray lines. The first panel in Figure 1.4.3 shows that sticky prices amplify the hiring stimulus in the imperfect insurance economy. This is a consequence of the increase in the demand for consumption goods generated by the fall in unemployment risk. Absent the precautionary savings channel, the hiring stimulus is dampened with sticky prices, observe the second and third panels in Figure 1.4.3. Again, the stronger consumption growth channel triggered by the hiring stimulus explains the substantial dampening observed with a representative agent, relative to the perfect insurance model.

Yet, as we can observe in Figure 1.4.2, hiring subsidies succeed in bringing down unemployment rates in all three economies. Crucially, I have assumed that the central bank could respond to the dynamics of inflation. In particular, absent precautionary savings, the monetary authority lowers the nominal rate more than one for one with inflation, reducing the real rate and sustaining the demand for goods. In the imperfect insurance model, it raises the nominal rate, therefore setting back the higher consumption demand that follows the decline in unemployment risk. Next, I ask what happens when the central bank is constrained and cannot freely adjust the nominal interest rate.

### 1.4.3 Liquidity trap

Once that the transmission mechanism of hiring subsidies with flexible and sticky prices is clear, the effects at the zero lower bound will become straightforward. In order to generate a liquidity trap, I assume that the discount factor increases on impact from its steady state value $\bar{\beta}$ to $\beta_t = \bar{\beta} + 0.018$ and then reverts back to steady state with persistence 0.9.[15]

Figure 1.4.4 displays the results of the liquidity trap experiment. Solid black lines shows the impulse responses to the discount factor shock in isolation, absent any intervention from the fiscal authority. Dashed gray lines, instead, show the path for variables when, at the same times as the demand shock hits, the government provides hiring subsidies, as described in previous experiments. The first row shows the results in the imperfect insurance economy. The outcomes in the perfect insurance model are depicted in the second row. The third row captures the results in the representative agent economy.

Focusing first on the solid black lines, with no hiring stimulus, we observe that the discount factor shock leads to a large decline in employment, as shown in the first column of Figure 1.4.4. The discount factor shock induces households to be more patient, and therefore their current demand for consumption goods declines. As goods' demand falls, inflation drops and the central bank cuts the nominal interest rate until it hits the zero lower bound, observe the second and third column of Figure 1.4.4.

Comparing the three rows of the first column of Figure 1.4.4 we observe that the magnitude of the recession differs across the three economies. The zero lower bound prevents the central bank from providing enough accommodation. Hence, in order to ensure that the asset market clears, the current income of savers needs to decline. In the representative agent economy, this implies that employment must fall sufficiently. In the imperfect insurance and perfect insurance models, this requires

15. The size and persistence of the discount factor shock are chosen such that the zero lower bound binds for several periods. The implications of the duration of the zero lower bound are discussed further below.

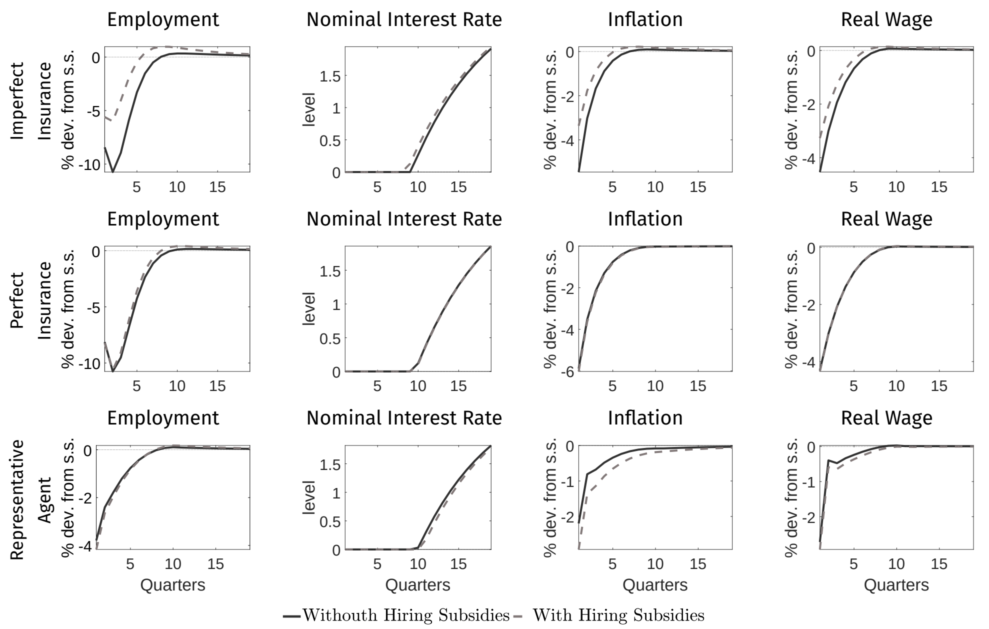


**Figure 1.4.4.** Liquidity Trap

*Notes:* Impulse responses to discount factor shock that makes the zero lower bound bind, as described in the main text, with and without hiring subsidies. Black solid lines show the effects of the discount factor shock absent any response from the fiscal authority. Gray dashed lines display the impulse responses when the discount factor shock is accompanied by the same increase in hiring subsidies as displayed in Figure 1.4.1 and Figure 1.4.2.

the income of employed workers – the savers in these models – to fall. That is, the real wage must decline enough. Since the real wage is sticky, this requires the labor market tightness, and hence employment, to fall markedly. This explains the large differences in the employment contraction observed across economies.

Can hiring subsidies curb the large employment losses depicted in Figure 1.4.4? Dashed gray lines in the first column provide the answer to this question. Visual inspection reveals a sharp conclusion. As long as precautionary savings are present, hiring subsidies stimulate employment in a liquidity trap, observe the first panel of the imperfect insurance economy in Figure 1.4.4. Absent uninsured unemployment risk, instead, the hiring stimulus is entirely crowded-out in equilibrium, see the first panel of the perfect insurance and representative agent economies in Figure 1.4.4.

In the imperfect insurance economy, hiring subsidies reduce unemployment risk which increases aggregate demand. As a consequence, inflation rises, compare dashed and solid lines of the third panel in the first row in Figure 1.4.4. With the nominal interest rate stuck at zero, the real interest rate – not shown – drops. A lower real rate stimulates consumption and hence employment rises, compare the solid black line and the dashed gray line in the first panel of the first column in Figure 1.4.4.

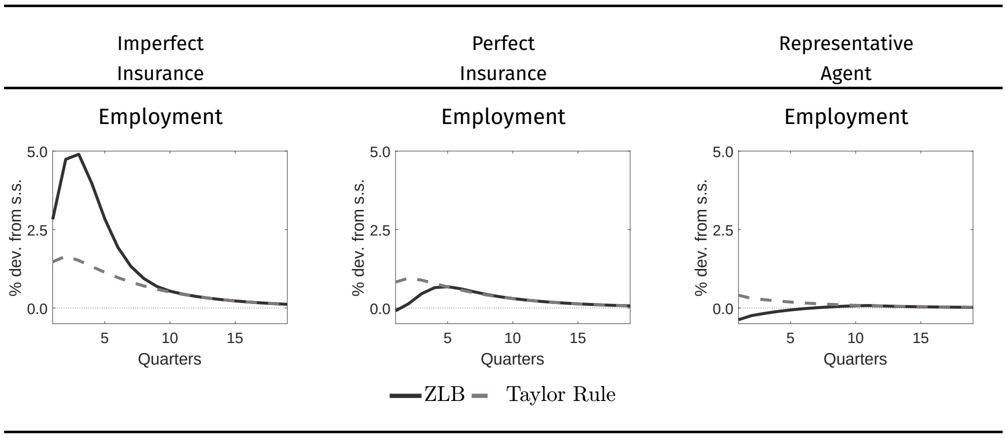


**Figure 1.4.5.** Zero Lower Bound vs. Taylor Rule

*Notes:* Effects of an increase in hiring subsidies, as depicted in Figures 1.4.1 and 1.4.2, at the zero lower bound (black solid lines) and away from the zero lower bound, under an operative Taylor rule (gray dashed lines) in the imperfect insurance economy (first panel), the perfect insurance model (second panel), and the representative agent economy (third panel). The black solid line is computed by taking the difference between the gray dashed lines and the black solid lines in Figure 1.4.4.

At the zero lower bound, deflationary pressures increase the real interest rate in the two benchmark economies, where precautionary savings are absent. As a consequence of a higher real interest rate, households demand less goods and employment contracts, compare solid and dashed lines of first panel in the representative agent row in Figure 1.4.4. The dynamics in the perfect insurance economy, that lacks the precautionary savings channel but has a weaker consumption growth channel, lie in between those of the representative family and the imperfect insurance model.

The previous results highlight that precautionary savings crucially shape the aggregate effects of the hiring stimulus in a liquidity trap. Figure 1.4.5 further illustrates this. Dashed gray lines show the effects of hiring subsidies when monetary policy is unconstrained and follows the Taylor rule (1.2.20). Solid black lines show, instead, the effects of the hiring stimulus in a liquidity trap, computed as the difference between dashed and solid lines in Figure 1.4.4.

The differences across models observed in Figure 1.4.5 are stark. In the presence of uninsured unemployment risk, hiring subsidies reduce unemployment substantially more in a liquidity trap than in normal times, observe the first panel in Figure 1.4.5. This is a consequence of the fall in the real interest rate at the zero lower bound, which amplifies the effects of hiring subsidies.

This amplification of the hiring stimulus stands in sharp contrast with the strong dampening observed in the perfect insurance and representative agent models, observe the second and third panels in Figure 1.4.5. In the liquidity trap, with the nominal interest rate stuck at zero, the real interest rate increases. As a result, consumption contracts and the employment stimulus is dampened. Indeed, in the representative agent economy, this channel is sufficiently strong to render hiring subsidies

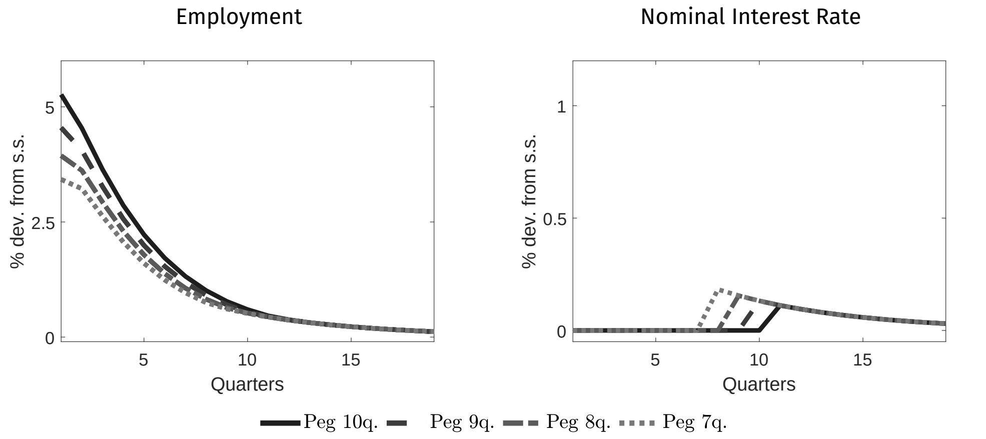


**Figure 1.4.6.** Duration of the ZLB

*Notes:* Effects of an increase in hiring subsidies, as displayed in Figures 1.4.1 and 1.4.2, under an interest rate peg in the imperfect insurance economy. The interest rate is assumed to remain its steady state level for 10, 9, 8, or 7 periods, as shown in the second panel. Thereafter, the nominal interest rate is set according to the Taylor rule (1.2.20).

contractionary in a liquidity trap, observe the third panel in Figure 1.4.5. This finding is in line with previous literature that has found that, in a complete markets framework, countercyclical supply side policies can be contractionary in a liquidity trap (Eggertsson (2011)).

In sum, the presence of precautionary savings renders hiring subsidies a powerful stabilizing tool in a liquidity trap. First, we have seen that with flexible prices the natural interest rate increases in the incomplete markets model. This is a consequence of the decline in precautionary savings induced by the fall in unemployment risk. Second, if prices are sticky, the fall in precautionary savings spurs aggregate demand for goods, inflation, and hence employment. At the zero lower bound, these inflationary pressures reduce the real interest rate, further stimulating consumption and amplifying the hiring stimulus. Absent precautionary savings, as in the representative agent model and the perfect insurance economy, hiring subsidies are deflationary. Consequently, the hiring stimulus is crowded-out in a liquidity trap.

### 1.4.4 Duration of the ZLB and implementation lags

#### 1.4.4.1 Duration of the ZLB

A common finding of the literature is that the equilibrium effects of a policy stimulus depends on the duration of the zero lower bound (e.g. Christiano *et al.* (2011)). This is relevant as fiscal measures tend to typically arrive with some delay. In order to address this issue transparently I assume that the economy is in steady state when the government increases hiring subsidies and the nominal interest rate is exogenously fixed at its steady state value for a certain number of periods. Figure

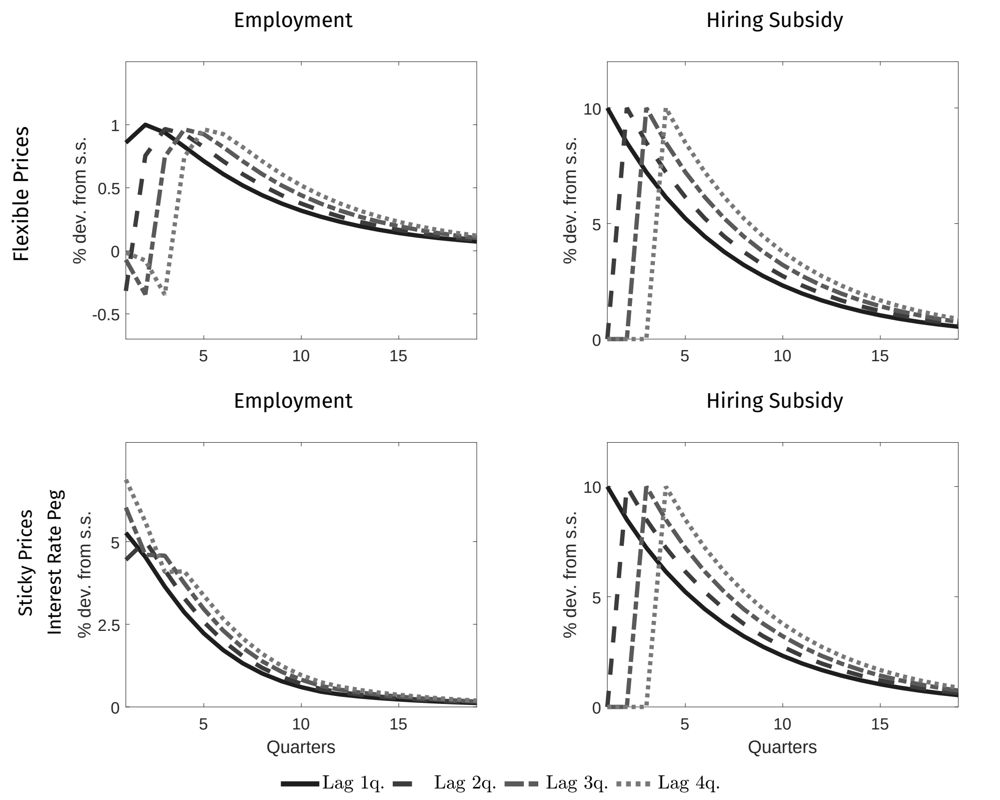


**Figure 1.4.7.** Implementation Lags

*Notes:* Effects of an increase in hiring subsidies, as shown in Figures 1.4.1 and 1.4.2, with different implementation lags in the imperfect insurance economy. The government announces at period 1 that it will increase hiring subsidies. Implementation takes place in period 1, 2, 3 or 4 as shown in the right column. The top row shows the effects in the case of flexible prices. The bottom row shows the effects with sticky prices and a nominal interest rate that is assumed to remain at its steady state level for 10 periods.

1.4.6 shows the effects of a hiring stimulus in the imperfect insurance economy when the nominal interest rate is assumed to be pegged for 10, 9, 8, and 7 periods. Thereafter, the central bank follows the Taylor rule (1.2.20).

As in can be observed in the left panel of Figure 1.4.6, the hiring stimulus has a bigger effect on employment the longer the nominal interest rate is pegged. The reason is that the larger the duration of the trap, for more periods the higher inflation generated by the hiring stimulus maps into lower real interest rates, further stimulating demand and hence output.

#### 1.4.4.2 Implementation lags

A related but different concern is that there might be a lag between the announcement of the stimulus and its implementation, due for example to the political process. In order to address this concern I assume, as before, that the economy is in steady state and the nominal interest rate is pegged for 10 periods. At period 1 the government announces that it will provide a hiring stimulus in the future. I consider the cases where implementation takes place in period 1 – i.e. no implementation lags –, in period 2, 3 or 4. Figure 1.4.7 displays the results of this experiment in the imperfect insurance economy. The first row collects the effects on employment when prices are flexible. The second row shows, instead, the effects with sticky prices and a nominal interest rate peg.

Focusing first on the case with flexible prices we observe that, when there is an implementation lag, employment actually falls until hiring subsidies are increased. The reason is that forward looking firms decide to postpone hiring as they expect lower vacancy posting costs in the near future.

This result sharply contrasts with the effects found with sticky prices and an interest rate peg, depicted in the second row of Figure 1.4.7. In this case, not only employment does not fall when there are implementation lags, but it actually may increase on impact more than when there are no implementation lags. The reason is that, in addition to firms, households are forward looking too. As consequence of the future stimulus, households expect higher future income and lower unemployment risk. Consequently, they reduce precautionary savings and increase demand for goods. With sticky prices, higher consumption demand induces firms to increase hiring and employment rises. Under an interest rate peg, the inflationary pressures reduce the real interest reate, further stimulating demand.

## 1.5 Conclusion

This paper has examined the ability of hiring subsidies to reduce unemployment in a liquidity trap. Towards this end, I have built a New Keynesian model with equilibrium unemployment, sticky real wages, and incomplete markets. A central finding of this paper is that precautionary savings crucially shape the aggregate effects of hiring subsidies at the zero lower bound. An increase in hiring subsidies induces firms to post more vacancies. This has two effects on aggregate demand. First, a tighter labor market bids up real wages, inducing households to increase savings to smooth consumption. Second, higher future job-finding rates reduce the need to self-insure, inducing households to cut precautionary savings and increase demand for goods. Quantitatively, I have found that the second channel dominates. As a consequence, hiring subsidies spur demand for goods and hence inflation, in spite of lower hiring costs. In a liquidity trap, higher inflation expectations reduce the real interest rate, further stimulating goods' demand and therefore amplifying the hiring stimulus.

I have found that, absent the precautionary savings channel, lower hiring costs and the desire to smooth consumption renders hiring subsidies deflationary in a representative agent economy. In a liquidity trap, this fall in inflation raises the real interest rate inducing consumption and employment to contract. The tractability of the model has allowed me to trace back the large disagreement between models to a second feature of incomplete markets: the consumption smoothing motive triggered by the hiring stimulus is substantially stronger with a representative agent. The reason is that the representative family, as a result of full risk-sharing, internalizes in its budget constraint that more family members are working after the hiring stimulus. A single worker in the incomplete markets economy does not, as she is constrained by her *own* current income – the real wage. Consequently, the hiring stimulus increases substantially more the current income of the representative household, triggering a stronger desire to increase savings and a consequent sharp fall in inflation.

In this paper, I have focused on hiring subsidies, a labor market policy tool that has been widely used during the economic downturns. However, a more general message from my paper is that stabilization policies that target the supply side of the economy are crucially shaped by household heterogeneity. To the extent that these policies can reduce idiosyncratic risk, while leaving the income of savers largely unaffected, they may stimulate aggregate demand for goods too. Most of the recent literature on heterogeneous agents and nominal rigidities has focused on the amplification and propagation of demand disturbances, and hence I consider this a fruitful avenue for future research.

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## Appendix 1.A Sensitivity analysis

Throughout the paper I have shown how the decline in unemployment risk brought about by the hiring stimulus prompts aggregate demand and inflation, rendering hiring subsidies a powerful tool in a liquidity trap. This is not the result of a particular combination of parameters, but rather a result of incomplete markets.

The strength of the mechanism, however, may vary as a result of particular assumptions. In particular, I have stressed that the main result of the paper, the increase in aggregate demand after hiring stimulus, is a consequence of two factors. Fist and foremost, households face unemployment risk against which they would like to self-insure. Second, the income of a worker, conditional on employment status, does not move much in response to the hiring stimulus, which weakens the consumption growth channel. I next evaluate the robustness of the main results of this paper to alternative assumptions and parameters affecting these channels.

### 1.A.1 Persistence of the stimulus

The channel presented in this paper depends on the fall in unemployment risk that follows the increase in hiring subsidies. As a consequence, it is influenced by how long households expect a tighter labor market, which, in turn, is affected by the persistence $\rho_\tau$ of the stimulus. In order to show and quantify the relevance of the persistence of the hiring subsidy I first assume that the economy is in steady state. The government increases hiring subsidies by 10% in the imperfect insurance economy, as in previous experiments. I consider different duration of the policy, as shown in the third panel of Figure 1.A.1, with lighter lines representing less persistent stimulus.

The first panel of Figure 1.A.1 shows the effects on employment when prices are flexible. Employment follows a similar path to hiring subsidies for each persistence level. It increases on impact by always the same amount, as the hiring subsidy does, but then declines more sharply as a consequence of the shorter duration of the stimulus. The second panel of Figure 1.A.1 shows the evolution of employment with sticky prices. As before, employment declines faster when the hiring subsidy is transitory. In contrast to what we have seen with flexible prices, this has a relevant effect on the impact response of employment. As employment returns back to steady state more rapidly, the decline in unemployment risk is muted. As such, the increase in demand for goods is dampened on impact, limiting the expansion on labor demand and hence employment.

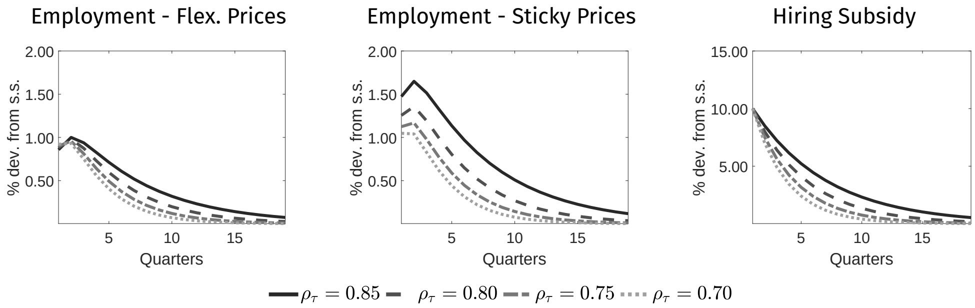


**Figure 1.A.1.** Persistence of the Stimulus

*Notes:* Effects of an increase in hiring subsidies, shown in the third panel, for different persistence of the shock in the imperfect insurance economy. The first panel shows the effects on employment with flexible prices. The second panel shows the effects on employment with sticky prices. The last panel shows the path for the hiring subsidy. In every case the hiring subsidy increases by 10 % on impact, lighter lines representing less persistent shocks, as captured in the legend.

### 1.A.2 Amount of insurance

A crucial quantity of the model is the income drop upon unemployment. This is controlled by the replacement rate, $b$, that I have set to 0.9 implying a consumption drop of 10%. Figure 1.A.2, top row, shows the path for the natural interest rate and inflation after the increase in hiring subsidies for different values of $b$. Lighter lines represent higher replacement rates. In all cases, I recalibrate the model to match the same steady state and wage cyclicality as in the baseline.

As the income drop upon unemployment falls, the need to self-insure declines. Consequently the precautionary savings channel becomes weaker, and the rise in the natural rate and inflation triggered by hiring subsidies becomes smaller. Yet, hiring subsidies only become deflationary once the income drop upon unemployment is lower than 3%, substantially below the empirical estimates (e.g. Chodorow-Reich and Karabarbounis (2016)).

A second form of idiosyncratic risk that I have abstracted from is a cyclical income drop upon unemployment. One may be concerned by the fact that if the increase in employment triggered by hiring subsidies raises real wages, the income fall upon a separation could become larger. Households, therefore, would like to self-insure against this procyclical source of risk, working against the decline in precautionary savings generated by higher future job-finding rates.

To investigate this issue, I drop the assumption of a constant replacement rate and I assume that the government provides a constant unemployment benefits *level* $B_t = B = bW$. The second row of Figure 1.A.2 shows the results for different levels of $b$. As before, in every simulation I recalibrate the model to maintain the same steady state and wage cyclicality as in the baseline.

The differences with respect to the baseline imperfect insurance economy are small; compare the two panels of the left column in Figure 1.A.2. The reason is

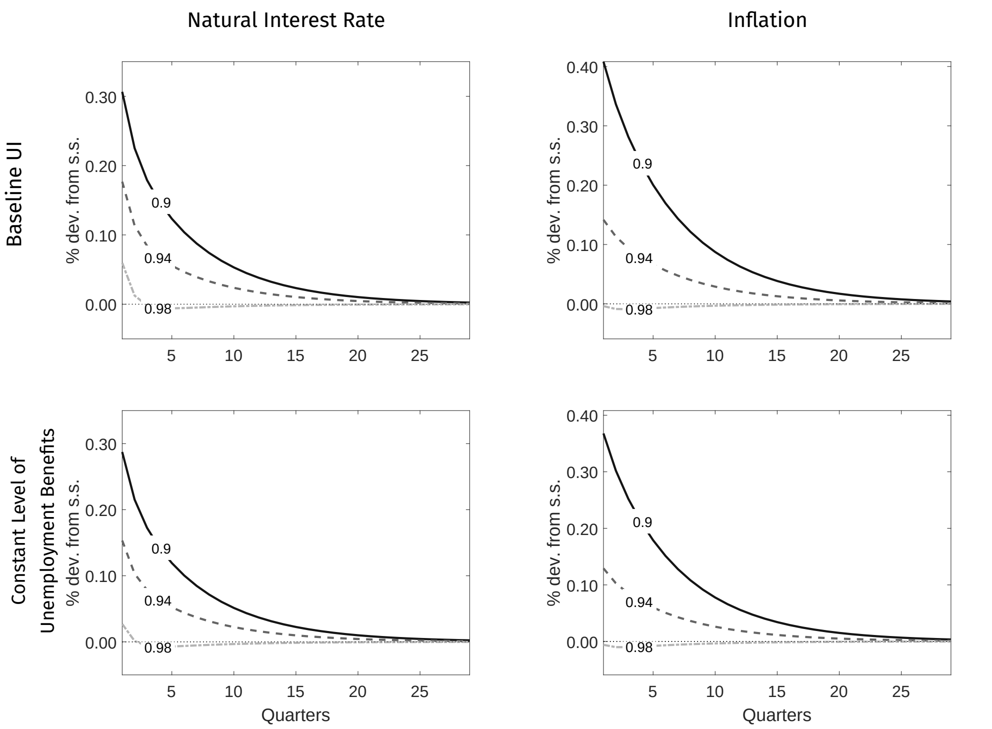


**Figure 1.A.2.** The Role of Insurance

*Notes:* Impulse responses of the natural interest rate (left column) and inflation (right column) to an increase in hiring subsidies, as shown in Figures 1.4.1 and 1.4.2, in the imperfect insurance economy. The top row shows the impulse responses for different values of $b$, the replacement rate, under the baseline unemployment insurance scheme $B_t = bW_t$. The bottom row shows the same but when the level of unemployment benefits is assumed to remain at its steady state value $B_t = B = bW$.

that even with a constant unemployment benefits level, since the real wage is sticky, the consumption drop upon unemployment remains roughly constant in response to higher hiring subsidies.

### 1.A.3 Income volatility

A second crucial part of the mechanism presented in this paper is that, conditional on employment status, the income of workers does not move much following an increase in hiring subsidies. This is the result of two features. First, the only income source of employed workers is the real wage. Second, the real wage is sticky.

**Flexible Real Wages**. I drop the latter assumption and assume that the prevailing real wage is the outcome of the Nash bargaining protocol (1.2.18), commonly viewed as a flexible wage benchmark. Figure 1.A.3, bottom row, shows the results under the Nash bargained wage, for different levels of the replacement rate $b$. For the baseline value of $b = 0.9$, the precautionary savings channel still dominates and

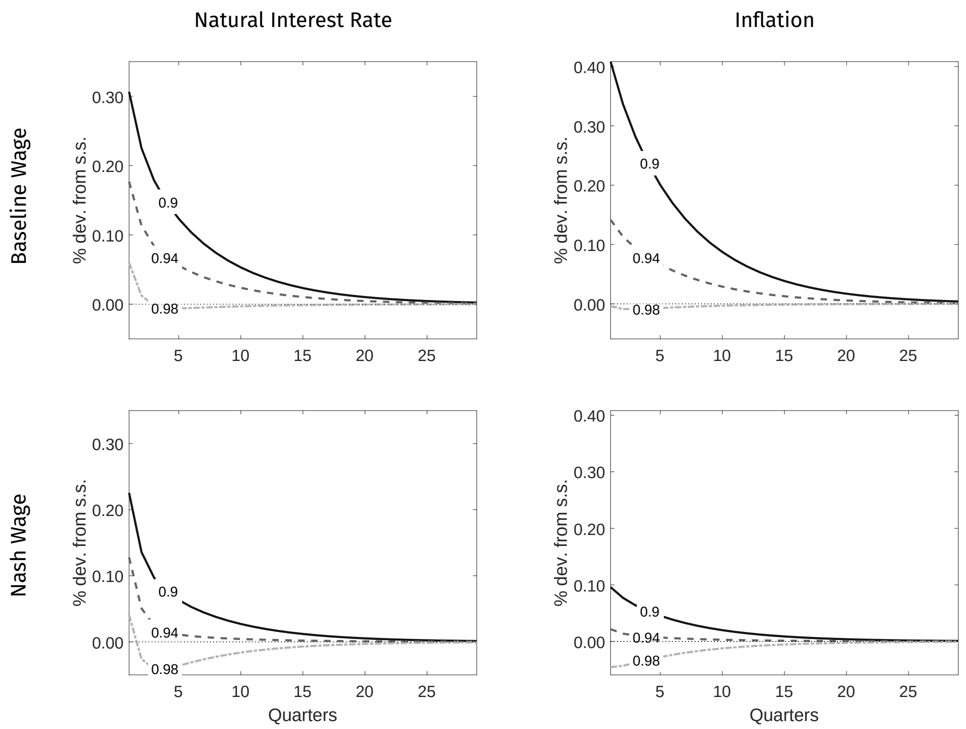


**Figure 1.A.3.** The Role of Wage Stickiness

*Notes:* Impulse responses of the natural interest rate (left column) and inflation (right column) to an increase in hiring subsidies, as shown in Figures 1.4.1 and 1.4.2, in the imperfect insurance economy. The top row shows the impulse responses for different values of $b$, the replacement rate, under the baseline unemployment insurance scheme $B_t = bW_t$ and the baseline elasticity of the real wage $\zeta = 0.54$. The bottom row shows the same variables as the top row when the prevailing real wage is given by the Nash bargained real wage, that is $\zeta = 0$.

hiring subsidies stimulate demand for goods, raising the natural rate and inflation. Yet, the increase is quantitatively muted and inflation raises on impact by about one fourth of what it does in the baseline, with a sticky wage.

**Other income sources**. A second concern is that, even if the real wage is sticky, other income sources could fluctuate. This is relevant, as I have illustrated by comparing the representative agent and perfect insurance economies. The income response of the representative family differs from that of a worker in two dimensions. First, it receives the dividends from the firms. Second, it internalizes the income gains from all workers in the economy. I have bypassed the former by assuming the existence of perfectly-insured entrepreneurs. The second one, however, is a result of income pooling with complete markets and, hence, goes hand in hand with the precautionary savings channel in the baseline imperfect insurance economy.

In order to tell these two dimensions apart I implement redistributive fiscal policies. First, I assume that the government entirely taxes before vacancy posting costs

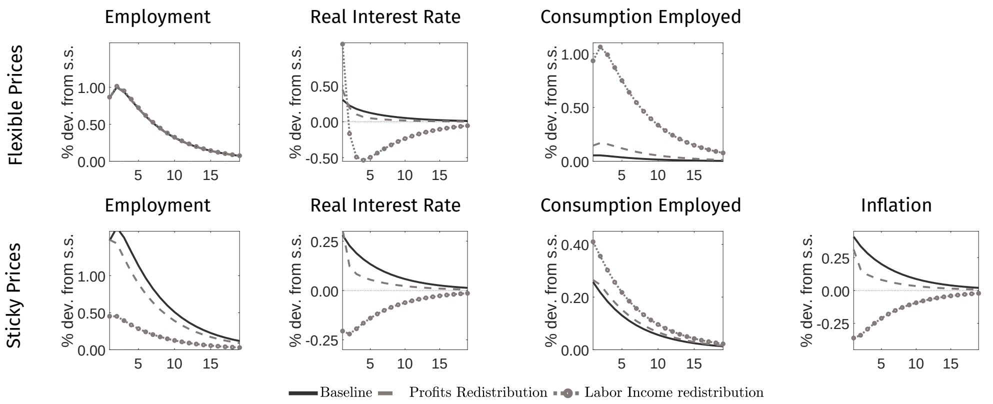


**Figure 1.A.4.** The Role of Other Income Sources

*Notes:* Effects of an increase in hiring subsidies, as shown in Figures 1.4.1 and 1.4.2, under different redistributive fiscal policies in the imperfect insurance economy. The top row shows the effects with flexible prices, and bottom row with sticky prices. See the main text for a descriptions of different cases considered.

dividends away from entrepreneurs, and rebates the revenue uniformly to workers in a lump-sum manner. That is, the equilibrium consumption of a worker is $C_{e,t} = W_t + \tilde{T}_t$, where $\tilde{T}_t = \Delta_t^{-1} N_t - N_t W_t$.

This effectively still leaves the income pooling channel out, while accounting for the distribution of dividends. To account for the income pooling effect, in a second scenario, I assume that the government provides every worker with a transfer $\tilde{T}_t = N_t W_t - W_t$ that is financed with lump-sum taxes on firm-owners. This implies that the equilibrium consumption of a worker is now given by $C_{e,t} = N_t W_t$. This is, then, "as if" an employed worker internalized the income gains of all other workers in the economy as it does the representative family, by means of a transfer in this case.

Figure 1.A.4 displays the effects of increasing hiring subsidies in the baseline imperfect insurance economy, with black lines, and the two redistribution scenarios, with gray lines. Dotted gray lines show the effect of raising hiring subsidies when the redistribution of labor income is implemented, and dashed gray lines the responses in the dividends redistribution scenario.

The main conclusions drawn from the baseline are robust to the redistribution of profits. With flexible prices, the precautionary savings channel dominates and the natural rate rises. Yet, it does by less as the income an employed worker markedly increases relative to the baseline, as consequence of higher dividends. With sticky prices, hiring subsidies remain inflationary and employment closely tracks the response in the baseline. The policy is mildly less expansionary since, as result of a stronger consumption growth channel, demand for goods rises somewhat less.

Results, however, resemble those obtained under a representative family when the income pooling transfer is implemented, depicted with dashed lines. Since now an employed worker, as the representative agent, internalizes the income gain from all workers in the economy, her income rises substantially. This implies that the consumption growth channel is markedly stronger, and hence dominates the precautionary savings channel. Consequently, the natural rate and inflation decline, muting the hiring stimulus considerably. Yet, this channel, that I have illustrated here by means of fiscal redistribution, is a consequence of complete markets, that gives raise to the representative agent representation. [16]

16. This is consistent with the available empirical evidence. Rogerson and Shimer (2011) show that the majority of cyclical fluctuations in aggregate hours comes from movements between employment and unemployment. Furthermore, Nakajima and Smirnyagin (2019) find that cyclical changes in household income risk are mainly explained by the amount of hours worked, possibly due to unemployment, and not wages. Moreover, Nakajima and Smirnyagin (2019) show that this result is robust to considering a second earner in the household.

# Chapter 2

# Unemployment Insurance, Precautionary Savings, and Fiscal Multipliers*

*Joint with Donghai Zhang*

## 2.1 Introduction

Over the last decade, the size of the government spending multiplier and the macroeconomic consequences of unemployment insurance (UI) benefits have been central elements in academic and policy discussions.[1] To a large extent, these debates have evolved in parallel. Yet, Figure 2.1.1 shows that, in the US, the two fiscal tools strongly co-move: the government markedly expands consumption and the duration of UI benefits during recessions. While the literature has made enormous progress in understanding each of these fiscal instruments in isolation, little is known about how they interact despite their empirical co-movement.

In this paper, we make progress towards filling this gap. We first provide new empirical evidence that the size of the government spending multiplier depends on the duration of UI benefits. Specifically, using regional-level US data, we document that the relative government spending multiplier is substantially lower when the duration of UI benefits is extended for reasons orthogonal to economic conditions. Moreover, we also document that not only UI extensions affect government spending multipliers, but also that increases in government spending lead to falls in the duration of UI benefits.

We next interpret our empirical findings through the New Keynesian small open economy of Galí and Monacelli (2005), which we extend by introducing heterogeneous households and equilibrium unemployment (Mortensen and Pissarides,

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1. See Ramey (2019) for a discussion of the literature on government spending multipliers, and Chodorow-Reich and Coglianese (2019) for a review of the stabilization consequences of UI benefits.

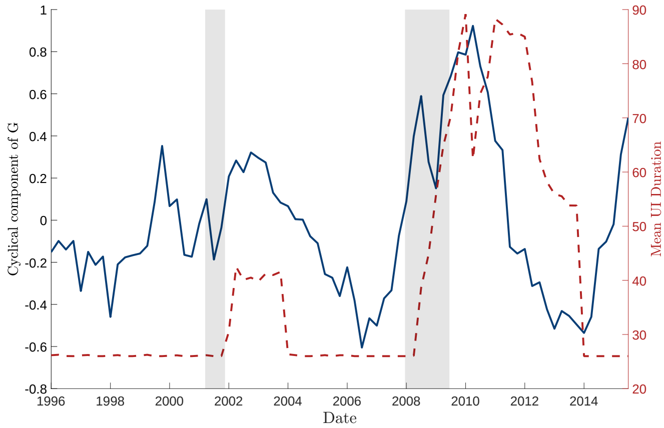


**Figure 2.1.1.** Government Consumption and UI duration

*Notes:* Cyclical component of real government consumption expenditures and investment (left axis, solid line) and average duration of UI benefits (right axis, discontinuous line). UI duration is the average duration of UI benefits across states, computed in Chodorow-Reich *et al.* (2018). The cyclical component of government consumption is the HP filtered cycle with smoothing parameter of 1600.

1994). The government provides households with unemployment benefits that expire stochastically. As in the US, when the unemployment rate is above some threshold, the duration of UI benefits is extended. We show that the model, as in the data, delivers substantially lower government spending multipliers when the duration of UI benefits is extended. We trace back the origin of this result to the non-linear response of the UI policy: an increase in government spending lowers unemployment, reducing the duration of UI benefits only to the extent that these have already been extended. As a result of lower insurance, households reduce consumption. Consequently, the size of the government spending multiplier is smaller.

More in detail, the empirical evidence that we provide arises as follows. We rely on two panel datasets a the level of US states. We first obtain regional-level government value added and GDP collected by Bernardini *et al.* (2020) from the Regional Economic Accounts of the BEA. The identification of government spending shocks follows from the conventional Blanchard and Perotti (2002) assumption that government spending is predetermined within the quarter. We then compute relative government spending multipliers by means of local projections (Jordà, 2005).[2] The government spending multipliers that we compute are state-dependent in that we estimate multipliers when UI benefits duration are at their baseline level, and when the duration of UI benefits is extended beyond its baseline level. Our state variable,

2. We incorporate time-fixed effects in our regressions. These absorb shocks and policy changes that hit all US states at the same time. This means that the government spending multipliers that we compute should be interpreted as the effect of a relative increase in government spending in one US region relative to another on the relative GDP (Nakamura and Steinsson, 2014).

the duration of UI benefits, varies over time and across regions. An important identification issue is that variations in UI benefits extensions are naturally correlated with (i) other economic states such as the business cycle and (ii) region-specific characteristics that may drive cross-sectional variation in unemployment rates.[3] As a result, the state-dependent government spending multipliers that a researcher uncovers using the raw variation in UI benefits extensions are confounded with existing evidence on sources of state-dependent multipliers other than the duration of UI benefits itself.[4]

We overcome the identification issue described above by using the exogenous extensions of UI benefits constructed in Chodorow-Reich *et al.* (2018). These authors identify extensions of UI benefits that are due to measurement error in the unemployment rate. Therefore, the extensions that we use to compute state-dependent multipliers are orthogonal to macroeconomic conditions and region-specific characteristics. This ensures that our state-dependent results are driven only by the duration of UI benefits and not by other unobservable macroeconomic covariates. We document that the duration of UI benefits strongly shapes the size of the government spending multiplier. When these are at their baseline level, the government spending multiplier is well above one. The size of the multiplier sharply falls below unity when UI benefits are extended, however.[5] Furthermore, we show that government spending affects the actual duration of UI benefits, too. Namely, to the extent that government spending raises output and reduces unemployment, we could expect a fall in the duration of UI benefits. This is precisely what we document in the data.

We rationalize our empirical findings in a New Keynesian small open economy model with household heterogeneity and search-and-matching frictions in the labor market. Financial markets are incomplete both domestically and internationally. Next to exogenous idiosyncratic productivity risk, households precautionary-save against unemployment spells. The fiscal authority affects the unemployment risk faced by households through both government spending and by running a UI system. On the one hand, with sticky prices, an increase in government spending raises aggregate demand, reducing the unemployment rate. On the other hand, unemployment benefits provide households with direct insurance against unemployment. We entertain a UI system that mimics the one present in the US. Namely, UI benefits have a limited duration, that we capture through stochastic expiration. Importantly, the UI policy is non-linear: the government only extends the duration of UI benefits beyond its steady-state level when the unemployment rate is higher than some

3. Examples of such region-specific characteristics are the degree of financial development or region-specific labor market frictions as the degree of wage rigidity.

4. For example, Auerbach and Gorodnichenko (2012) document that government spending multipliers are larger in recessions. We review this literature in more detail below.

5. Since UI extensions typically happen during recessions, we further show that these state-dependent multipliers are robust to controlling for the phase of the business cycle.

threshold. Finally, the monetary authority commits to a fixed exchange rate vis-à-vis the rest of the world economy. This allows us to interpret our small open economy as a region of a monetary union, in line with our empirical setting.

We calibrate the model to an average US region. We show that the model captures our empirical findings: the government spending multiplier is markedly lower when the duration of UI benefits is extended. Namely, we proceed as follows to study the interaction between government spending and UI. We first show that starting from the steady state, an increase in government spending raises aggregate demand and lowers unemployment. At this point, the fall in unemployment does not lead to an extension of UI benefits since these are at their baseline level. We next study the propagation of a three-month extension of UI benefits that lasts for two quarters. As in our empirical setting, this extension arises from measurement error in the unemployment rate. The increase in unemployment insurance leads households to reduce precautionary savings and increase consumption, resulting in a temporary fall of unemployment.[6] We next consider the previous two shocks together. As unemployment falls in response to the government spending shock, now the fiscal authority only extends the duration of UI benefits for a single quarter. The lower insurance provided by the government mutes the response of private consumption, leading to a lower government spending multiplier.

### Related literature

In studying how the duration of UI benefits affects government spending multipliers, we contribute to several strands of the literature. We first contribute to the literature estimating the size of the government spending multiplier and its determinants. Early studies include Ramey and Shapiro (1998) and Blanchard and Perotti (2002), from which we borrow our identification strategy. We also build on a more recent literature leveraging cross-sectional regional data to estimate relative government spending multipliers; see, for example, Nakamura and Steinsson (2014), Chodorow-Reich (2019), and Dupor *et al.* (2022). Several papers have investigated the state-dependent size of the multipliers. Auerbach and Gorodnichenko (2012) and Ramey and Zubairy (2018) estimate multipliers depending on the state of the economy using aggregate data, while Bernardini *et al.* (2020) rely on regional-level data. We also show that, although government spending multipliers tend to be larger during recessions, our main results are robust to controlling for the state of the business cycle. We complement other papers that provide state-dependent multipliers along other dimensions, such as the sign of the shock (Barnichon *et al.*, Forthcoming), and the demographic structure of the economy (Basso and Rachedi, 2021).

6. The quantitative response of unemployment to UI extensions in our model is consistent with the empirical evidence presented in Di Maggio and Kermani (2016) and Boone *et al.* (2021), and lies on average within the bounds reported in Chodorow-Reich *et al.* (2018).

The previous empirical research has been accompanied by a theoretical investigation of the determinants of government spending multipliers. Several papers study the interaction between government spending multipliers and monetary policy in a closed economy (Woodford, 2011; Christiano *et al.*, 2011) and with exchange rates (Corsetti *et al.*, 2013; Born *et al.*, 2021) in frameworks featuring a representative agent. Instead, we focus on the interaction between two major fiscal tools, government consumption and the duration of UI benefits, while holding the common response of the Federal Reserve constant. Michaillat (2014) and Albertini *et al.* (2021) build closed-economy models with search-and-matching frictions that deliver multipliers that are larger during recessions than during booms. Instead, our state-dependent multipliers hold even conditional on the phase of the business cycle, both theoretically and empirically.

Several papers have investigated the macroeconomic consequences of unemployment benefits. Prominent examples on the empirical front are Hagedorn *et al.* (2019) and Chodorow-Reich *et al.* (2018). Our identification of exogenous extensions of UI benefits, key for our empirical analysis, relies on the dataset constructed by the latter. We further show that the expansionary effects of UI benefits extensions lie within the estimates of Chodorow-Reich *et al.* (2018), Di Maggio and Kermani (2016), and Boone *et al.* (2021). We complement this literature by providing evidence that UI benefits also affect the propagation of aggregate shocks, government spending shocks.

Our paper is also related to the literature examining the theoretical consequences of unemployment benefits. In frameworks with flexible prices, Mitman and Rabinovich (2015), Jung and Kuester (2015), and Landais *et al.* (2018) study the optimal design of UI; and Nakajima (2012), Mitman and Rabinovich (2019), Krueger *et al.* (2016), and Krusell *et al.* (2010) its positive implications. Our paper, instead, highlights the demand consequences of UI extensions that come with redistribution and precautionary savings. We share such channel with Kekre (2021), McKay and Reis (2021), and Gorn and Trigari (2021). Relative to these papers, we empirically and theoretically analyze the interaction between government spending and the duration of UI benefits in a small open economy.

Finally, we contribute to an emerging literature that explores the consequences of household heterogeneity in open-economy models. de Ferra *et al.* (2020) explore how the composition of households' portfolios shapes the consequences of sudden stops. Auclert *et al.* (2021) study the propagation of exchange rate shocks with heterogeneous agents. Cugat (2019) and Guo *et al.* (2020) investigate the distributional consequences of external shocks. On the theoretical front, we complement this literature by extending the previous frameworks to incorporate search-and-matching frictions in the labor market.[7]

7. See Krusell *et al.* (2010), Ravn and Sterk (2017), Challe (2020), Gornemann *et al.* (2021) for models incorporating search-and-matching frictions and heterogeneous agents in a closed economy.

The remaining of the paper is structured as follows. Section 2.2 provides the empirical evidence. Section 3.3 outlines the model. In section 2.4 we calibrate the environment to the US economy. Section 2.5 provides the model results. A final section concludes.

## 2.2 Empirical evidence

In this section, we document empirically that the size of the government spending multiplier is crucially shaped by the duration of UI benefits. Namely, we compute relative open-economy government spending multipliers (Nakamura and Steinsson, 2014) using regional-level data for the US. We show that states that feature relative longer durations of UI benefits due to measurement error in the unemployment rate display smaller government spending multipliers. Moreover, we provide evidence that an expansion in government consumption induces a reduction in the duration of UI benefits. We first describe the data, then our empirical specification, and finally the main empirical results.

### 2.2.1 Data

We draw on two different sources of quarterly data at the US regional level.[8] The use of regional-level data is ideal for studying how the duration of UI benefits affects the size of government spending multipliers. First, as argued in Nakamura and Steinsson (2014), we can compute multipliers controlling for policy changes and shocks that affect all US regions at the same time. A prominent example is the response of the monetary authority, which is widely known to affect the size of the fiscal multiplier (Woodford, 2011; Christiano *et al.*, 2011). This helps us to isolate played by extensions of unemployment benefits. Second, the duration of UI benefits in the US is set at the regional level rather than at the national level. Therefore, having access to regional-level data provides us with rich cross-sectional variation in the duration of UI benefits.

We first rely on a dataset constructed in Bernardini *et al.* (2020) to obtain measures of regional-level GDP and its components. These authors draw from the Regional Economic Accounts of the Bureau of Economic Analysis to obtain a panel of regional-level real GDP and regional-level real government value added. The panel starts in the first quarter of 2005 and ends in the last quarter of 2015. We emphasize that our measure of government spending is government value added. This includes compensation of government employees and consumption of government capital. This measure has two advantages. First, it ensures that government spending takes

8. Throughout the text, in order to avoid confusion, we use the word region to refer to a state of the US. We use the term state to refer to the state of the economy in a region, as defined by the duration of UI benefits.

place in the region under consideration. Second, it does not include payments of UI benefits. In order to identify government spending shocks, we follow Blanchard and Perotti (2002) and assume that government spending is predetermined within the quarter.

We next need a regional-level measure of the duration of UI benefits. In the US, the baseline duration of UI benefits in most regions is 26 weeks. This duration of UI benefits is set irrespectively of the regional unemployment rate. During downturns, however, US regions can automatically extend the duration of UI benefits by an additional quarter when unemployment is above some predetermined threshold. Additionally, there have been discretionary measures in the different recessions that allowed US regions to extend UI benefits even beyond this additional quarter. Since not all US regions experience the same increase in the unemployment rate, it would seem natural to use the induced cross-sectional variation in the actual duration of UI benefits. However, as we argue below, this would fail to identify the actual state of the economy that matters for the size of the government spending multiplier. Instead, what we need is a measure of the duration of UI benefits that is orthogonal to other underlying macroeconomic forces and region-specific characteristics that jointly affect government spending multipliers and the duration of UI benefits.

The monthly data constructed in Chodorow-Reich *et al.* (2018) nicely fulfill our requirements. These authors identify variations in the duration of UI benefits that are driven by unemployment measurement error. Namely, Chodorow-Reich *et al.* (2018) rely on revisions of the unemployment rate to decompose the variation in the duration of UI benefits into two parts. The first part comes from differences in economic conditions. The second part arises from measurement error in the real-time data used to determine UI benefits extensions and is, therefore, orthogonal to economic conditions or region-specific characteristics.

We aggregate to quarterly frequency the monthly data constructed in Chodorow-Reich *et al.* (2018). The sample period starts in the first quarter of 1996 and ends in the third quarter of 2015. Since we combine these data with the quarterly regional-level data of Bernardini *et al.* (2020), our actual sample period runs from the first quarter of 2005 to the third quarter of 2015. Despite the short time period, the variation in our sample is rich due to its panel structure. For example, our sample contains 296 events of non-zero exogenous UI extensions due to measurement error, with a mean of about 0.40 months and a standard deviation of roughly 1.5 months. Furthermore, appendix 2.A shows that such exogenous variation in the duration of UI benefits is well spread over US regions.

### 2.2.2 Empirical specification

We compute relative government spending multipliers and the impulse responses induced by government spending shocks by means of local projection (Jordà, 2005). Local projections provide a flexible alternative to structural vector autoregressions, allowing for a direct estimation of impulse response functions without imposing dynamic restrictions. Furthermore, local projections can be easily extended to study state-dependent responses, rendering them well-suited for our analysis. Our starting point is the following linear panel regression:

$$X_{i,t+h} = \beta_h G_{i,t} + \gamma_h (L) Z_{i,t-1} + \alpha_{i,h} + \delta_{t,h} + \varepsilon_{i,t+h}, \quad h \geq 0. \tag{2.2.1}$$

Here, $X_{i,t+h}$ is the variable of interest in the region $i$ of the US, $G_{i,t}$ marks government spending, and $Z_{i,t-1}$ is a set of controls variables that always include four lags of government spending and regional-level GDP. $\alpha_{i,h}$ denotes region-fixed effects that allow us to control for regional-specific characteristics that are constant over time. $\delta_{t,h}$ are time-fixed effects that control for shocks and policy changes (such as the monetary stance) that hit the US as a whole at a particular point in time. Under the Blanchard and Perotti (2002) assumption that government spending is predetermined within the quarter, $\beta_h$ provides an estimate of the response of the variable $X$ at horizon $h$ to government spending shock at time $t$. Note that, since we include time-fixed effects, $\beta_h$ has the interpretation of a relative increase in government spending $G$ in region $i$ with respect to other regions on the relative variable of interest $X$. We follow Hall (2009) and transform the government spending variable and the output variable by taking the growth rate of the original variable and dividing by the lagged level of potential output. For example, our transformed government value added variable is $G_{i,t+h} = \frac{\tilde{G}_{i,t+h} - \tilde{G}_{i,t-1}}{\tilde{Y}^*_{i,t-1}}$, where $\tilde{G}$ and $\tilde{Y}^*$ mark government value added and potential output in levels.[9] This transformation allows us to interpret the estimates that we compute below directly as multipliers (Ramey and Zubairy, 2018).

We extend (2.2.1) to allow for government spending shocks to have different effects depending on the duration of UI benefits as follows:

$$\begin{aligned} X_{i,t+h} = {} & \beta_h G_{i,t} + \gamma_h (L) Z_{i,t-1} + \hat{T}_{i,t-1} \left( \beta_h^{UI} G_{i,t} + \gamma_h^{UI} (L) Z_{i,t-1} \right) \\ & + \alpha_{i,h} + \delta_{t,h} + \varepsilon_{i,t+h}, \quad h \geq 0, \end{aligned} \tag{2.2.2}$$

where $\hat{T}_{i,t-1}$ measures the additional extension of UI benefits in state $i$ due to measurement error in the unemployment rate. Above, $\beta_h^{UI}$ captures the additional the effect of $G$ on $X$ at horizon $h$ associated with a variation in UI benefits extensions due to measurement error.[10]

Equation (2.2.2) helps us to illustrate why using the exogenous variation in UI benefits duration identified in Chodorow-Reich *et al.* (2018) is key to define the economic state that shapes the effects of government spending. To this end, let $T^*_{i,t}$ be

9. Potential output is computed as the HP-filtered trend of GDP with smoothing parameter 1600.
10. The total effect of a time-$t$ government spending shock on $X$ at horizon $h$ is therefore given by $\beta_h + \beta_h^{UI}$.

the actual extension of the duration of UI benefits in region $i$. Next, let $f\left(U\left(S_{i,t};\Theta_i\right)\right)$ be some function of the unemployment rate $U\left(S_{i,t};\Theta_i\right)$. The unemployment rate itself is a function of some potentially non-observable macroeconomic covariates $S_{i,t}$ and region-specific characteristics $\Theta_i$. Then, we can write:

$$T^*_{i,t} \; = \; \hat{T}_{i,t} + f\left(U\left(S_{i,t};\Theta_i\right)\right). \tag{2.2.3}$$

In our empirical specification (2.2.2) we use $\hat{T}_{i,t}$ to define our state variable. Suppose instead that we had used $T^*_{i,t}$. In this case, our state indicator is endogenous to $U\left(S_{i,t};\Theta_{i,t}\right)$. Therefore, it could be that the state-dependent effects of government spending shocks that we uncover are driven by some underlying covariate $S_{i,t}$ or region-specific characteristic $\Theta_i$ that affects both the duration of UI benefits as well as the effects of government spending shocks.[11] Instead, using $\hat{T}_{i,t}$ to define our state indicator ensures that the results that we find are only shaped by the extensions of the duration of UI benefits. In other words, our empirical specification compares US regions that share the same $\{S_{i,t};\Theta_i\}$, but that differ in $T^*_{i,t}$ due to measurement error. [12]

The empirical specifications (2.2.1) and (2.2.2) allow us to trace the impulse responses of government spending shocks. We furthermore seek to compute the relative cumulative fiscal multipliers. To do so, we follow Ramey and Zubairy (2018) and consider the following IV-regression:

$$\begin{aligned}\sum_{h=0}^{H} Y_{i,t+h} \; &= \; \beta_h \sum_{h=0}^{H} G_{i,t+h} + \gamma_h\,(L)\,X_{i,t-1} + \hat{T}_{i,t-1}\left(\beta_h^{UI} \sum_{h=0}^{H} G_{i,t+h} + \gamma_h^{UI}\,(L)\,X_{i,t-1}\right) \\ &\quad + \alpha_{i,h} + \delta_{t,h} + \varepsilon_{i,t+h}, \quad h \; \geq \; 0,\end{aligned} \tag{2.2.4}$$

where we instrument the cumulative changes in government spending $\sum_{h=0}^{H} G_{i,t+h}$ with government spending at time $t$.

### 2.2.3 Empirical results

We present next our main empirical results. We first discuss the impulse responses to a government spending shock. We then show that the duration of UI benefits is a crucial determinant of the government spending multiplier. We finally provide evidence that our results are robust to further controlling for the state of the

11. A clear example of this could be the prevalence of downward nominal wage rigidity (DNWR) at the regional level. A relatively higher degree DNWR is well-known to amplify unemployment fluctuations, and hence potentially increase UI duration, and also to shape fiscal multipliers. See, for example, Barnichon *et al.* (Forthcoming) and Born *et al.* (2021).

12. Yet, further below, we show that our results are robust to controlling for the state of the business cycle.

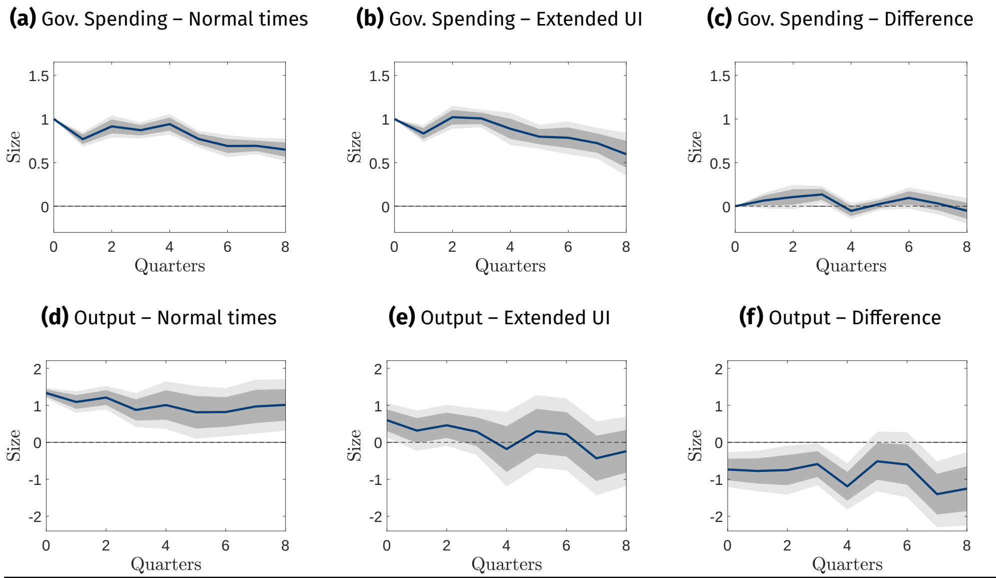


**Figure 2.2.1.** Impulse Responses to Government Spending Shock

*Notes:* Impulse responses to government spending shock of GDP (bottom panel) and government spending itself (top panel), estimated using regression (2.2.2). Shaded light (dark) areas provide 90% (68%) Driscoll and Kraay (1998) confidence bands.

business cycle.

**Impulse responses**. Figure 2.2.1 shows the impulse responses of government spending (top panel) and GDP (bottom panel) to a government spending shock, estimated using regression (2.2.2). The left column shows the responses during normal times, when UI benefits extensions are at their mean. The middle column shows, instead, the responses when UI duration is extended due to measurement error in the unemployment rate. In order to make results easily interpretable, throughout this section, we report the responses to a two standard deviation UI benefits extension. This is equivalent to a UI extension of three months, which is the automatic extension of UI benefits in the US. The right column displays the difference between normal times and states of extended duration of UI benefits. Shaded light (dark) areas provide 90% (68%) Driscoll and Kraay (1998) confidence bands, that correct for potential residual correlations across US regions and for serial correlation and heteroskedasticity over time.

The top panel shows that our results are not driven by different responses of government spending between periods of normal times (panel a) and states where the duration of UI benefits is extended due to measurement error in the unemployment rate (panel b). Indeed, as panel (c) shows, the difference in the response of government spending between both is not statistically significant.

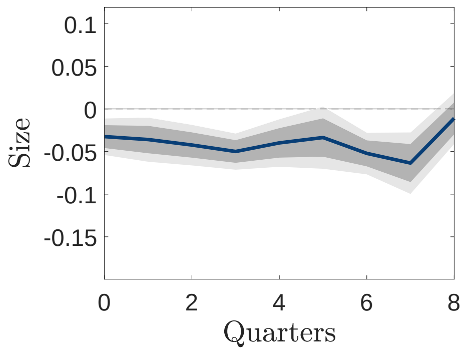


**Figure 2.2.2.** Impulse response of UI benefits extensions

*Notes:* Impulse response of the UI benefits extensions, computed using equation (2.2.1). Shaded light (dark) areas provide 90% (68%) Driscoll and Kraay (1998) confidence bands.

The bottom panel of Figure 2.2.1 shows, instead, that the response of economic activity to a government spending shock markedly differs depending on the duration of UI benefits. While GDP persistently rises more than one-to-one with government spending during normal times, the response is substantially dampened when UI benefits are extended. This is shown more formally in panel (f). There, it can be observed that extended UI benefits come with a significantly smaller response of GDP.

As emphasized previously, the duration of UI benefits in the US is endogenous to the business cycle and non-linear, increasing when the unemployment rate is high enough. Conversely, to the extent that an increase in government spending reduces unemployment, we could expect that the duration of UI benefits is shortened when this has been extended. This is precisely what Figure 2.2.2 shows. In that Figure, we plot the impulse response of the additional duration of UI benefits to a government spending shock. Consistent with the logic outlined before, UI benefits extensions are reduced following an increase in government spending. The fact that the UI policy is endogenous to economic activity, and hence to government spending, will play a pivotal role in the theory that we develop below.

**Government spending multipliers**. We next summarize the state-dependent responses of GDP by looking at relative cumulative government spending multipliers, computed as in regression (2.2.4).

We plot the estimated cumulative multipliers in Figure 2.2.3. Cumulative multipliers are well above one during normal times (panel a). While such multiplier is above the values reported in Ramey and Zubairy (2018), the relative government spending multiplier during normal times is in line with the estimates of Nakamura and Steinsson (2014). Consistent with the response of economic activity reported previously, the size of the government spending multiplier sharply falls below unity when the duration of UI benefits is extended (panel b). Panel (c) confirms that such

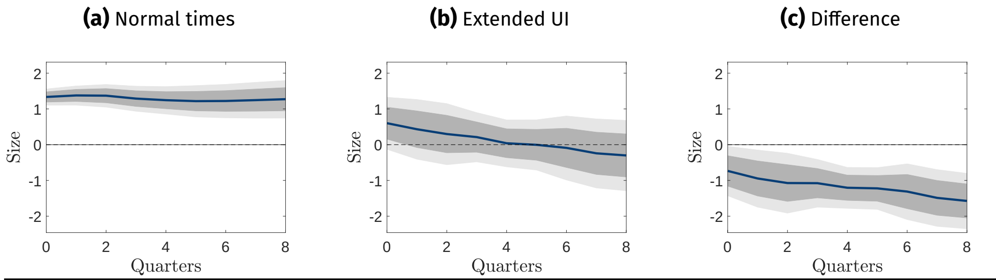


**Figure 2.2.3.** Government Spending Multipliers

*Notes:* Cumulative government spending multipliers, computed using regression (2.2.4). Shaded light (dark) areas provide 90% (68%) Driscoll and Kraay (1998) confidence bands.

difference is statistically significant, with a difference in the impact multiplier of around 0.5 dollars.

**Recessions vs. Extended UI.** A common finding in the literature is that government spending multipliers are typically larger during recessions (Auerbach and Gorodnichenko, 2012; Bernardini *et al.*, 2020). Our state variable, the extension of UI benefits due to measurement error, is meant to be orthogonal to economic conditions. Yet, there might be the concern that the unemployment measurement error that generates exogenous extensions of UI benefits is correlated with the size of the recession, times with large swings in the unemployment rate. In turn, this could imply that we are capturing the business-cycle effects on government spending multipliers, rather than the effects of extending UI benefits. We next show that this is not the case.

Towards this end, we extend equation (2.2.4) to include an indicator variable $\mathbb{I}_{i,t}^{REC}$ that takes value one if the US region $i$ is in a recession:[13]

$$\sum_{h=0}^{H} Y_{i,t+h} = \beta_h \sum_{h=0}^{H} G_{i,t+h} + \gamma_h (L) X_{i,t-1} + \hat{T}_{i,t-1} \left( \beta_h^{UI} \sum_{h=0}^{H} G_{i,t+h} + \gamma_h^{UI} (L) X_{i,t-1} \right) \tag{2.2.5}$$

$$+ \mathbb{I}_{i,t-1}^{REC} \left( \beta_h^{REC} \sum_{h=0}^{H} G_{i,t+h} + \gamma_h^{REC} (L) X_{i,t-1} \right) + \alpha_{i,h} + \delta_{t,h} + \varepsilon_{i,t+h}, \quad h \geq 0.$$

Above, $\beta_h^{REC}$ captures the additional effect of being in a recession on the government spending multiplier, while $\beta_h^{UI}$ measures the additional effect of a UI extension while controlling for the state of the business cycle.

13. We define a recession following Bernardini *et al.* (2020). Namely, a region $i$ is in a recession if it experiences at least two consecutive quarters of negative GDP growth.

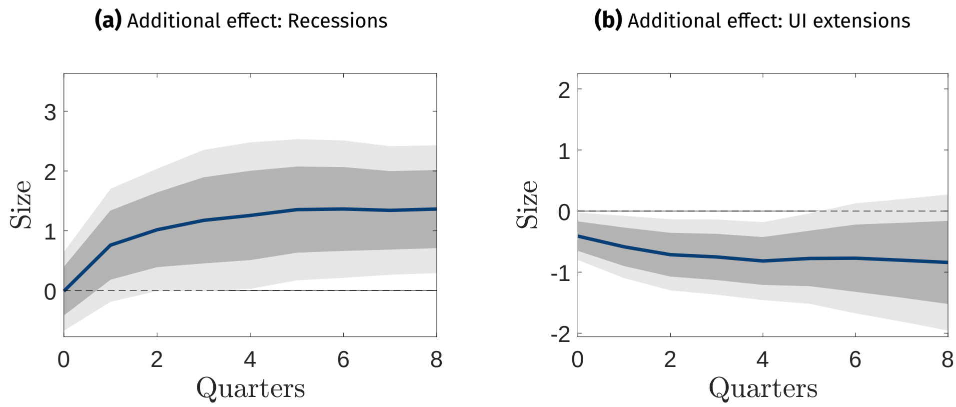


**Figure 2.2.4.** Gov. Spending Multiplier – Recessions vs. Extended UI

*Notes:* Additional effect on government spending multipliers of recessions (left panel) and of extended UI benefits due to measurement error (right panel), conditional on the business cycle. Shaded light (dark) areas provide 90% (68%) Driscoll and Kraay (1998) confidence bands.

Figure 2.2.4 plots in the left panel the additional effect of recessions on the government spending multiplier. The right panel shows the additional effect of extending UI benefits due to measurement error in the unemployment rate, conditional on the business cycle. Consistent with the previous findings in the literature, we find that recessions tend to increase government spending multipliers (panel a). While this is true, our finding that UI extensions significantly reduce government spending multipliers remains robust; observe the right panel.

## 2.3 Model

Our empirical evidence uncovers UI benefits extensions as a key determinant of the size of the government spending multiplier. We next interpret these findings through the lenses of a quantitative model where extensions of UI benefits play a non-negligible stabilization role. Towards this end, we extend the New Keynesian small-open-economy model of Galí and Monacelli (2005) to incorporate heterogeneous agents (Aiyagari, 1994; Huggett, 1993; Bewley, 1983) and a frictional labor market that gives rise to equilibrium unemployment as in Mortensen and Pissarides (1994). [14]

Our economy is composed of two regions, Home and Foreign. We model Home as a small open economy and Foreign as the rest of the economy. Since the Home

14. See also Auclert *et al.* (2021); Cugat (2019); de Ferra *et al.* (2020) for recent papers incorporating heterogeneous agents into a open-economy framework but without a frictional labor market, and Gornemann *et al.* (2021); Ravn and Sterk (2017); Challe (2020) for papers incorporating search-and-matching frictions in closed-economy models with heterogeneous agents.

region has a negligible size with respect to the whole economy, economy-wide variables are exogenous from the viewpoint of Home. In line with our empirical setting, we will assume that the monetary authority at Home adopts a fixed exchange rate with respect to Foreign. This allows us to interpret Home as a region of the US economy, in line with our empirical setting. Financial markets are incomplete both domestically and internationally, and households at Home can only save into a domestic and a foreign bond through assets issued by a representative mutual fund. As regards notation, we use the subscript H to denote Home variables and F for Foreign variables. We mark economy-wide variables with an asterisk.

### 2.3.1 Idiosyncratic states, labor market transitions, and UI eligibility

There is a continuum of infinitely-lived households of measure one indexed by $i$. We summarize the idiosyncratic states of a household by the vector $s = \{\beta, a, h, n, e\}$. We allow for permanent differences in households' discount factors $\beta \in \{\beta_1, \beta_2\}$, a modeling strategy commonly used in the literature to match the high degree of wealth inequality and the large marginal propensities to consume present in the data (Krusell and Smith, 1998; Carroll *et al.*, 2017). $a$ marks households' savings in assets issued by a representative mutual fund. Next to these, households differ in their idiosyncratic labor income productivity $h$, which follows an exogenous $AR(1)$ process in logs. A household can be either employed or unemployed, that we denote by $n \in \{1, 0\}$, respectively. If a household falls into unemployment, it can be either eligible or non-eligible to receive government-provided unemployment benefits, $e \in \{1, 0\}$. Therefore, a central feature of our model is that policy influences the idiosyncratic risk faced by households along two dimensions. First, the government can affect economic activity, for example through government spending, and therefore the employment status $n$ of households. Second, the UI system provides households with direct insurance against unemployment spells through both the level of unemployment benefits and their duration.

**Labor market**. Employment transitions are determined in a frictional labor market. At the end of period $t-1$ there is a a mass $N_{t-1}$ of employed households, and a mass $U_{t-1} = 1 - N_{t-1}$ of unemployed households. At the start of period $t$, an exogenous fraction $\delta$ of employed households separate from firms and instantaneously join the pool of unemployed households. Therefore, unemployment at the beginning of the period is given by $1 - (1-\delta)N_{t-1}$. Firms must open vacancies $V_t$ in order to be matched with a currently unemployed worker. New matches $M_t$ are formed according to the function:

$$M_t = \chi V_t^{\gamma} \left(1 - (1-\delta)N_{t-1}\right)^{1-\gamma} \tag{2.3.1}$$

where $\gamma \in (0, 1)$ is the elasticity of new matches with respect to vacancies and $\chi$ marks the matching efficiency.

We define labor-market tightness as the ratio of vacancies over unemployment $\theta := {}^{V_t}/(1-(1-\delta)N_{t-1})$. An unemployed household finds a job with probability $f_t := {}^{M_t}/(1-(1-\delta)N_{t-1})$, and a firm fills a vacancy with probability $q_t := {}^{M_t}/V_t$. Therefore, the law of motion for employment is given by:

$$N_t = (1-\delta)N_{t-1} + M_t \tag{2.3.2}$$

**UI eligibility**. Next to being either employed or unemployed, households can also be either eligible or non-eligible to receive unemployment benefits. We assume that the transition between eligibility states is stochastic and entirely determined by policy (Chodorow-Reich *et al.*, 2018; Mitman and Rabinovich, 2019). More precisely, consider a household that is unemployed and eligible to receive unemployment benefits at the end of the period $t-1$. Next period $t$, conditional on remaining unemployed, the household remains eligible with time-varying probability $(1-pe_t)$. With complementary probability, $pe_t$, the household loses eligibility for the remaining of the unemployment spell. Therefore, the expected duration of UI benefits is given by $pe_t^{-1}$. The stochastic expiration of unemployment benefits captures, in a parsimonious way, the limited duration of unemployment benefits present in the UI system of the US. Once that the non-eligible unemployed household finds a job, it regains eligibility probability with constant probability $pr$ for the rest of the employment spell. This assumption captures the fact that it takes several months of work for a recently hired worker to regain UI eligibility. We denote by $\{N_t^e, N_t^{ne}\}$ the mass of employed households that are respectively eligible and non-eligible at the end of the period. We define $\{U_t^e, U_t^{ne}\}$ analogously for unemployed households. The law of motion for each of these states is given by:

$$N_t^e = (1-\delta+\delta f_t)N_{t-1}^e + pr(1-\delta+\delta f_t)N_{t-1}^{ne} + f_t\left(U_{t-1}^e + prU_{t-1}^{ne}\right) \tag{2.3.3}$$
$$N_t^{ne} = (1-pr)(1-\delta+\delta f_t)N_{t-1}^{ne} + (1-pr)f_t U_{t-1}^{ne} \tag{2.3.4}$$
$$U_t^e = (1-f_t)(1-pe_t)\left(U_{t-1}^e + \delta N_{t-1}^e\right) \tag{2.3.5}$$
$$U_t^{ne} = (1-f_t)\left(U_{t-1}^{ne} + \delta N_{t-1}^{ne}\right) + (1-f_t)pe_t\left(U_{t-1}^e + \delta N_{t-1}^e\right) \tag{2.3.6}$$

### 2.3.2 Households' problem

**Domestic households**. Households have time-separable preferences with time discount factor $\beta \in \{\beta_1, \beta_2\}$. They derive utility from consuming domestically-produced goods, $c_{Ht}$, and a basket of foreign goods, $c_{Ft}$, according to the felicity function $u(c)$:

$$u(c) = \frac{c^{1-\sigma}}{1-\sigma}, \tag{2.3.7}$$

where $\sigma \geq 0$ marks the inverse of the intertemporal elasticity of substitution and $c$ is the composite consumption index:

$$c := \left[ (1-\alpha)^{1/\eta} c_H^{\frac{\eta-1}{\eta}} + \alpha^{1/\eta} c_F^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}. \tag{2.3.8}$$

Here, $\eta > 0$ marks the elasticity of substitution between Home and Foreign goods, and $\alpha \in [0, 1]$ measures the degree of home bias. The consumption of home goods $c_H$ and foreign goods $c_F$ are themselves consumption indexes over differentiated goods $j$:

$$c_H := \left( \int_0^1 c_{jH}^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}} ; \quad c_F := \left( \int_0^1 c_{jF}^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}}, \tag{2.3.9}$$

where $\varepsilon > 0$ denotes the elasticity of substitution between varieties.

A household characterized by its idiosyncratic state vector $s$ at time $t$, chooses consumption and next-period savings $a_t$ to solve:

$$V_t(s) = \max_{c_{Ht}, c_{Ft}, a_t} u\left(c_{Ht}, c_{Ft}\right) + \beta \mathbb{E}_t V_{t+1}\left(s'\right) \tag{2.3.10}$$

$$\text{s.t.} \quad \frac{P_{Ht}}{P_t} c_{Ht} + \frac{P_{Ft}}{P_t} c_{Ft} + a_t = \left(1-\tau_t\right) h_t \left(d_t + \mathbb{I}_{n=1} w_t + \mathbb{I}_{(n=0,e=1)} b_t + \mathbb{I}_{(n=0,e=0)} \tilde{b}_t\right) + (1 + r_t^a) a_{t-1}, \quad a_t \geq 0.$$

Above, $P_{Ht} := \left( \int_0^1 P_{jHt}^{1-\varepsilon} dj \right)^{\frac{1}{1-\varepsilon}}$ marks the price index of domestic goods, where $P_{jHt}$ denotes the price of variety $j$. Analogously, $P_{Ft} := \left( \int_0^1 P_{jFt}^{1-\varepsilon} dj \right)^{\frac{1}{1-\varepsilon}}$ is the price of foreign goods in units of the domestic currency. $P_t$ is the consumer price index, given by:

$$P := \left[ (1-\alpha) P_H^{1-\eta} + \alpha P_F^{1-\eta} \right]^{\frac{1}{1-\eta}}. \tag{2.3.11}$$

The ex-post real return on households' holdings of mutual fund's assets $a_{t-1}$ is given by $r_t^a$. As in McKay and Reis (2021), we assume that firm dividends $d_t$ are rebated lump-sum to households according to their idiosyncratic productivity $h_t$. Next to firms' dividends, the income of a household depends on the joint idiosyncratic state over employment and eligibility status $(n, e)$. A currently employed household, $n = 1$, earns the real wage $w_t$ regardless of its eligibility status $e$. A household that is unemployed and eligible, $(n, e) = (0, 1)$, receives unemployment benefits $b_t$ from the government. An unemployed household that has exhausted its unemployment benefits, $(n, e) = (0, 0)$, receives transfers from the government $\tilde{b}_t \leq b_t$. These capture safety-net transfers provided by the government such as food stamps. All sources of income are subject to a tax rate $\tau_t$.

The demand for each differentiated good $j$ from a household with idiosyncratic state $s$ at time $t$ is given by:

$$c_{jHt}(s) = \left(\frac{P_{jHt}}{P_{Ht}}\right)^{-\varepsilon} c_{Ft}(s); \quad c_{jFt}(s) = \left(\frac{P_{jFt}}{P_{Ft}}\right)^{-\varepsilon} c_{Ht}(s). \tag{2.3.12}$$

Finally, households optimally divide their consumption expenditures between Home and Foreign goods according to:

$$c_{Ht}(s) = (1-\alpha)\left(\frac{P_{Ht}}{P_t}\right)^{-\eta} c_t(s); \quad c_{Ft}(s) = \alpha\left(\frac{P_{Ft}}{P_t}\right)^{-\eta} c_t(s). \tag{2.3.13}$$

We denote by $\mu_t$ the time-$t$ type distribution over idiosyncratic states $s \in \mathscr{S}$. Therefore, $C_{Ht} = \int_{\mathscr{S}} c_{Ht}(s)d\mu_t$ and $C_{Ft} = \int_{\mathscr{S}} c_{Ft}(s)d\mu_t$ are, respectively, aggregate domestic private consumption of Home and imported goods. Aggregate private domestic consumption is given by $C_t = \int_{\mathscr{S}} c_t(s)d\mu_t$.

**Foreign households** We assume that demand from Foreign households for variety $j$ of domestically-produced goods is given by:

$$C^*_{jHt} = \left(\frac{P^*_{jHt}}{P^*_{Ht}}\right)^{-\varepsilon} C^*_{Ht}, \tag{2.3.14}$$

where $P^*_{Ht}$ is the price of home goods denominated in unit of Foreign currency and $C^*_{Ht}$ marks aggregate foreign demand for Home goods. The latter is assumed to be given by:

$$C^*_{Ht} = \alpha\left(\frac{P^*_{Ht}}{P^*_t}\right)^{-\eta} C^*_t, \tag{2.3.15}$$

where $P^*_t$ is the economy-wide price index and $C^*_t$ denotes aggregate Foreign consumption.

We assume that the law of one price holds at all times, meaning that $P_{Ht} = \mathscr{E}_t P^*_{Ht}$ and $P_{Ft} = \mathscr{E}_t P^*_{Ft}$. Here, $\mathscr{E}_t$ marks the nominal exchange rate defined as units of domestic currency per unit of foreign currency. That is, an increase in $\mathscr{E}_t$ marks a depreciation of the domestic currency. For future reference, we define the real exchange rate $Q_t$ as:

$$Q_t := \frac{\mathscr{E}_t P^*_t}{P_t}, \tag{2.3.16}$$

and the terms of trade $S_t$ as the price of imports $P_{Ft}$ over the price of exports $P_{Ht}$:

$$S_t := \frac{P_{Ft}}{P_{Ht}}. \tag{2.3.17}$$

### 2.3.3 Mutual fund

A representative risk-neutral fund issues one-period real bonds $A_t$ to households to finance purchases of risk-free domestic government bonds $B_{Ht}$ and foreign bonds $B_{Ft}$:[15]

$$A_t \;=\; B_{Ht} + Q_t B_{Ft} \tag{2.3.18}$$

The ex-post return $r_t^a$ is given by the beginning-of-period flow constraint of the mutual fund:

$$(1 + r_t^a)A_{t-1} \;=\; (1 + r_t)B_{H,t-1} + (1 + r_t^*)Q_t B_{F.t-1}. \tag{2.3.19}$$

Here $r_t$ marks the ex-post real return on domestic government bonds $B_{Ht}$. This is linked to the nominal interest rate set by the monetary authority $i_t$ through the standard Fisher equation:

$$1 + r_t \;:=\; \frac{1 + i_{t-1}}{1 + \pi_t}, \tag{2.3.20}$$

where $1 + \pi_t := P_t/P_{t-1}$ marks the gross consumer price inflation. Analogously, $1 + r_t^*$ denotes the real gross return on foreign bonds, denoted in units of the foreign currency. Similarly, $r_t^*$ is linked to the nominal interest rate $i_t^*$ on foreign bonds through $r_t^* = \frac{1+i_t^*}{1+\pi_t^*}$, where $1 + \pi_t^* := P_t^*/P_{t-1}^*$.

The first-order conditions of the mutual fund's problem deliver the non-arbitrage condition between domestic and foreign bonds, the real uncovered-interest-parity condition:

$$\mathbb{E}_t \frac{1 + i_t}{1 + \pi_{t+1}} \;=\; \mathbb{E}_t \frac{1 + i_t^*}{1 + \pi_{t+1}^*} \frac{Q_{t+1}}{Q_t}, \tag{2.3.21}$$

and the non-arbitrage condition between the return received on government bonds and the return paid on liabilities:

$$\mathbb{E}_t 1 + r_{t+1}^a \;=\; \mathbb{E}_t 1 + r_{t+1} \tag{2.3.22}$$

### 2.3.4 Firms

The supply side of the economy has two layers of production. Producers of labor goods produce homogeneous goods using labor hired in a frictional labor market as a production input. A unit mass of producers of differentiated goods indexed by $j$ differentiate labor goods and set prices subject to adjustment costs à la Rotemberg (1982).

15. We follow Auclert *et al.* (2021) in modeling the mutual fund. The mutual fund assumption is a common modeling strategy in the literature that features multiple assets and heterogeneous agents; see, for example, Gornemann *et al.* (2021) and Kaplan *et al.* (2018).

#### 2.3.4.1 Producers of labor goods

Producers of labor goods are composed of a single worker and use a linear technology to produce homogeneous labor goods. We denote by $J_t^L$ the value of a firm with a worker, given by:

$$J_t^L = Z_t \frac{MC_t}{P_t} - \frac{W_t}{P_t} + \mathbb{E}_t \frac{1}{1 + r^a}(1 - \delta) J_{t+1}^L, \tag{2.3.23}$$

where $MC_t$ is the price of labor goods, and $W_t$ is the nominal wage. $Z_t$ marks aggregate productivity. This is assumed to follow an $AR(1)$ process in log-deviations from its steady-state value $Z$:

$$\log\left(\frac{Z_t}{Z}\right) = \rho_z \log\left(\frac{Z_{t-1}}{Z}\right) + \varepsilon_t^z, \quad \rho_z \in (0, 1), \quad \varepsilon^z \sim \mathcal{N}(0, 1) \tag{2.3.24}$$

In order to produce, firms must hire a worker. Hiring a worker involves posting vacancies at cost $\kappa_v$ per vacancy. Since there is free entry, in equilibrium, firms post vacancies until the expected gains from not doing so are zero:

$$\kappa_v = q_t J_t^L \tag{2.3.25}$$

The presence of matching frictions in the labor market means that there are multiple wages that are bilaterally efficient (Hall, 2005). We resolve this indeterminacy by assuming the following rule for the real wage $w_t$:

$$\log(w_t/w) = \phi^w \left[ log\left(Z_t \frac{MC_t}{P_t}\right) - log\left(Z \frac{MC}{P}\right)\right], \tag{2.3.26}$$

where variables without a time subscript mark steady-state values. $\phi^w \in [0, 1]$ measures the degree of real wage rigidity, thereby potentially amplifying aggregate fluctuations. For similar rules see, for example, Blanchard and Gali (2010) and Gornemann *et al.* (2021).

Aggregate nominal profits of labor good firms gross of vacancy-posting costs are given by:

$$D_t^L = N_t Z_t MC_t - W_t N_t \tag{2.3.27}$$

#### 2.3.4.2 Producers of differentiated goods

Differentiated goods producers operate under monopolistic competition and set prices subject to quadratic adjustment costs. A firm $j$ purchases $X_{jt}$ homogeneous goods from labor good producers at price $MC_t$ and transform them into differentiated goods using a linear technology $Y_{jt} = X_{jt}$. A typical producer of differentiated goods $j$ solves:

$$\max_{\{P_{jHt+k}\}_{k=0}^{\infty}} \mathbb{E}_t \sum_{k=0}^{\infty} \left(1 + r^a\right)^{-k} \left[ \left(P_{jHt+k} - MC_{t+k}\right) Y_{jt+k}^D - \frac{\kappa_p}{2\varepsilon} \log\left(\frac{P_{jHt+k}}{P_{jHt+k-1}}\right)^2 P_{Ht+k} Y_{t+k}^D \right],$$

$$\text{subject to} \quad Y_{jt}^D = \left(\frac{P_{jHt}}{P_{Ht}}\right)^{-\varepsilon} \left(C_{Ht} + C_{Ht}^* + G_t\right). \quad (2.3.28)$$

Above, $Y_{jt}^D$ marks aggregate demand for variety $j$ and $Y_t^D = C_{Ht} + C_{Ht}^* + G_t$ denotes aggregate demand for domestically-produced goods. Here, $G_t$ is government consumption of Home goods. The first-order condition of the above problem yields the conventional non-linear Phillips Curve:

$$\log(1 + \pi_{H,t}) = \kappa_p \left(\frac{MC_t}{P_{Ht}} - \frac{\varepsilon - 1}{\varepsilon}\right) + \mathbb{E}_t \frac{1}{1 + r^a} \log(1 + \pi_{H,t+1}) \frac{Y_{t+1}^D}{Y_t^D}, \quad (2.3.29)$$

where $1 + \pi_{Ht} := P_{Ht}/P_{Ht-1}$ denotes gross domestic inflation. Aggregate nominal profits from producers of differentiated goods gross of price-adjustment costs are given by:

$$D_t^P = P_{Ht} Y_t - MC_t, \quad (2.3.30)$$

where $Y_t = \int_0^1 Y_{jt} dj$ is aggregate production of differentiated goods. We assume that both vacancy-posting and price-adjustment costs are virtual. Therefore total nominal profits rebated to households $D_t$ are given by:[16]

$$D_t = D_t^L + D_t^P. \quad (2.3.31)$$

16. The assumption that adjustment costs are virtual – and therefore do not enter into the aggregate resource constraint – ensures that the non-linear results that we obtain are not due to the non-linearities induced by adjustment costs. See, for example, Eggertsson and Singh (2019) or Hagedorn *et al.* (2019) for similar assumptions.

### 2.3.5 Government

The government is comprised of a monetary authority and a fiscal authority. Consistent with our empirical setting, we assume that the monetary authority sets the domestic nominal interest rate to credibly fix the nominal exchange rate:

$$\mathscr{E}_t = \mathscr{E}. \tag{2.3.32}$$

The fiscal authority is subject to the following budget constraint:

$$\frac{P_{Ht}}{P_t}G_t + (1+r_t)B_{H,t-1} + b_t U_t^e + \tilde{b}_t U_t^{ne} = B_{H,t} + \tau_t\left(w_t N_t + b_t U_t^e + \tilde{b}_t U_t^{ne} + d_t\right). \tag{2.3.33}$$

Above, $G_t$ marks government consumption of domestic goods. We assume that it follows a $AR(1)$ process in log-deviations from its steady-state value $G$:

$$\log\left(\frac{G_t}{G}\right) = \rho_G \log\left(\frac{G_{t-1}}{G}\right) + \varepsilon_t^G, \quad \rho_G \in (0,1), \quad \varepsilon_t^G \sim \mathscr{N}(0,1). \tag{2.3.34}$$

Next to expenditures on consumption of domestic goods, the government runs a UI system. This is defined by both the unemployment benefits provided to eligible households $b_t$, and the probabilities of losing and regaining eligibility $\{pe_t, pr\}$. As regards the level of unemployment benefits, we assume that it is defined by a constant replacement rate $b$ over the prevailing real wage:[17]

$$b_t = bw_t. \tag{2.3.35}$$

A central feature of the UI system in the United States is that the duration of UI benefits is highly non-linear and state-dependent. Namely, as highlighted in the empirical section, US regions can automatically extend the duration of UI benefits during times of high unemployment. At the same time, during times of low unemployment, the duration of UI benefits is not reduced but rather kept at its baseline level. We capture these features by assuming that the average duration of UI benefits in our model, $pe_t^{-1}$, is set as follows:

$$\frac{1}{pe_t} = \begin{cases} \frac{1}{pe} & \text{if} \quad U_t + \varphi_t \leq \tilde{U}, \\ \frac{1}{pe} + \lambda_t & \text{else.} \end{cases} \tag{2.3.36}$$

Above, $pe^{-1}$ marks the steady-state average duration of UI benefits. The average duration of UI benefits is endogenous to the business cycle. Namely, the government

17. The functional form that we entertain for unemployment benefits captures, in a parsimonious form, that unemployment benefits in the US are typically indexed to past earning.

increases the average duration of UI benefits by $\lambda_t \geq 0$ whenever the measured unemployment rate $(U_t + \varphi_t)$ is above some pre-defined threshold $\tilde{U} \in (U, 1)$. Consistent with our empirical setting, we assume that the government measures the unemployment rate in real time with error $\varphi_t$. We allow this to follow an $AR(1)$ process in levels:

$$\varphi_t = \rho_\varphi \varphi_{t-1} + \varepsilon_t^\varphi, \quad \rho_\varphi \in (0,1), \quad \varepsilon^\varphi \sim \mathcal{N}(0,1). \tag{2.3.37}$$

The shocks $\varepsilon^\varphi$ to the measured unemployment rate $u_t + \varphi_t$ are the model counterpart of our empirical shocks that can trigger an exogenous increase in the duration of UI benefits.

Next to the UI system, the government provides safety-net transfers $\tilde{b}_t$ to the unemployed households that are not entitled to receive unemployment benefits. In this case, we also assume that safety-net transfers are characterized by a constant replacement rate $\tilde{b}$:

$$\tilde{b}_t = \tilde{b} w_t, \quad \tilde{b} \leq b. \tag{2.3.38}$$

Finally, as our baseline, we assume that the government adjusts the tax rate $\tau_t$ to balance the budget every period, leaving the supply of government debt constant at its steady-state level $B_H$:

$$B_{Ht} = B_H \tag{2.3.39}$$

### 2.3.6 Equilibrium

A *competitive equilibrium* is a set of households' policy functions $\{c_{Ht}(s), c_{Ft}(s), c_t(s), a_t(s)\}$, aggregates $\{C_t, C_{Ht}, C_{Ft}, Y_t, Y_t, N_t\}$, prices $\{P_{Ht}, P_{Ft}, P_t, d_t, \mathcal{E}, Q_t, r_t^a, i_t, w_t, mc_t\}$, and distributions $\{\mu_t\}$ such that given aggregate shocks households optimize, firms optimize, the government budget constraint holds, the market for labor services clears $Y_t = Z_t N_t$, the labor market clears $N_t = \int_S n d\mu_t$, and the market for domestic goods clears:

$$Y_t = C_{H,t} + C_{H,t}^* + G_t. \tag{2.3.40}$$

Since we are primarily interested in the joint interaction between government spending and the generosity of unemployment insurance in the domestic economy, we abstract from shocks happening abroad. Given that Home is atomistic with respect to the whole economy, economy-wide variables are constant and equal to their steady-state values. Namely, $P_t^* = P^*$, $C_t^* = C^*$, $i_t^* = i^*$. Furthermore, we focus on a symmetric steady state where all domestic savings are invested in domestic government bonds $A = B_H$.

## 2.4 Calibration and solution method

We calibrate the model to a representative region of the US. One period in the model is one quarter. The calibrated parameters are summarized in Table 3.4.1.

**Household preferences**. We set the coefficient of relative risk aversion $\sigma$ to a standard value of 2. We jointly calibrate the discount factors $\{\beta_1, \beta_2\}$ to hit an annualized real interest rate at the steady state of 4% per annum and a quarterly aggregate marginal propensity to consume of 0.20, a common value in the literature (Parker *et al.*, 2013). The elasticity of substitution between intermediated goods $\varepsilon$ is set to 7. Next, we follow Nakamura and Steinsson (2014) and set $\eta$ equal to 2, and the share of imported goods $\alpha$ equal to 0.3. The parametrization of the idiosyncratic productivity process follows the estimates provided in Bayer *et al.* (2019).

**Firms**. We follow Hagedorn and Manovskii (2008) to set the parameter governing the stickiness of the real wage $\phi^w$ to 0.45. The vacancy-posting cost $\kappa_v$ is set equal to 4.5% of the quarterly real wage, in line with Silva and Toledo (2009). We set the steady-state real wage $w$ to target a vacancy-filling rate of 0.71, as in Den Haan *et al.* (2000). The calibrated slope of the Phillips Curve $\kappa_p$ would imply an average price duration of 5 quarters in a Calvo setting. We pick the steady-state value of productivity $Z$ to normalize aggregate domestic private consumption to unity.

**Labor market**. The separation rate $\delta$ is set to 0.10, a common value in the literature; see, for example, Shimer (2005). The elasticity of new matches with respect to vacancies $\gamma$ is set equal to 0.5, within the range estimated in Petrongolo and Pissarides (2001). The matching efficiency $\chi$ is calibrated to target a steady-state employment rate of 0.94.

**Government**. We set $B_H$ to target an annual debt-to-GDP ratio of 0.60. The tax rate is set to target a ratio of government consumption to GDP of 0.20. The replacement rate of UI $b$ is equal to 0.4, a conventional value in the literature; see, for example, Shimer (2005). We rely on the estimates of Nakajima (2012) to set the replacement rate of the safety-net transfers $\tilde{b}$ to 0.2. We set the baseline probability of losing UI eligibility while unemployed, $pe$, to target an average baseline duration of UI benefits of two quarters, the most common duration of UI benefits in most US regions. Following Mitman and Rabinovich (2019) we set the probability of regaining UI while employed equal to 0.5. This implies that, on average, it takes two quarters for an employed household to regain UI eligibility. We set the automatic extension of UI benefits $\lambda$ equal to $0.5pe^{-1}$. This means that when the unemployment rate is sufficiently high, unemployed households get, on average, an additional quarter of UI benefits. This is in line with the UI policy present in the US. Finally, we set

**Table 2.4.1.** Calibrated parameters.

| Parameter | Description | Value | Target / Source |
|---|---|---|---|
| Households | | | |
| $1/\sigma$ | IES | 0.5 | Standard value |
| $\beta_1$ | Discount factor high | 0.98 | $r = 0.04/4$ |
| $\beta_2$ | Discount factor low | 0.88 | MPC = 0.20 |
| $\rho_h$ | Persistence $h$ | 0.98 | Bayer *et al.* (2019) |
| $\sigma_h$ | Std. innovations to $h$ | 0.12 | Bayer *et al.* (2019) |
| $\varepsilon$ | Elast. subs. intermediate goods | 7 | Standard value |
| $\eta$ | Elast. subs. H and F goods | 2 | Nakamura and Steinsson (2014) |
| $\alpha$ | Share imported goods | 0.3 | Nakamura and Steinsson (2014) |
| Firms | | | |
| $\kappa_v$ | Vacancy posting cost | 0.05 | 4.5% of quarterly wage |
| $w$ | St-st. real wage | 1.13 | $q = 1$ |
| $\phi^w$ | Wage rigidity | 0.45 | Hagedorn and Manovskii (2008) |
| $Z$ | St-st. productivity | 1.33 | $C = 1$ |
| $\kappa_p$ | Slope NKPC | 0.05 | Mean price duration of 5 q. |
| Labor market | | | |
| $\delta$ | Separation rate | 0.10 | Standard value |
| $\chi$ | Matching efficiency | 0.66 | $N = 0.94$ |
| $\gamma$ | Curvature matching function | 0.5 | Petrongolo and Pissarides (2001) |
| Government | | | |
| $\tau$ | Steady-state tax rate | 0.24 | $G/Y = 0.20$ |
| $B_H$ | Steady-state gov. debt | 3 | $B_H/4Y = 0.60$ |
| $b$ | Replacement rate UI | 0.4 | Standard value |
| $\tilde{b}$ | Replacement rate safety-net | 0.2 | Nakajima (2012) |
| $pe$ | Prob. loosing eligibility | 0.5 | Avg. duration UI of 2 q. |
| $pr$ | Prop. regaining eligibility | 0.5 | 2 q. to regain eligibility |
| $\tilde{U}$ | UI extension threshold | 6.5% | Chodorow-Reich *et al.* (2018) |
| $\lambda$ | Increase in UI duration | $0.5pe^{-1}$ | Chodorow-Reich *et al.* (2018) |

*Notes:* Variables without time subscripts indicate steady-state values. The main text provides further details.

the unemployment threshold for the extension of UI benefits equal to 6.5%, as in Chodorow-Reich *et al.* (2018) and Mitman and Rabinovich (2019).

**Solution method**. Our empirical analysis uncovers strong non-linear interactions between government spending multipliers and the duration of UI benefits. Our model is potentially non-linear, too. A prominent example of this is the state-dependent policy rule for the duration of unemployment benefits. As to account for this, we compute the non-linear perfect-foresight responses of the economy to aggregate shocks. In particular, we use a shooting algorithm. When updating our guess, we employ the version of Newton's method developed in McKay *et al.* (2016).

## 2.5 Results

We next interpret our empirical findings on the interaction between government spending multipliers and the duration of UI benefits through the lenses of the model. Towards this end, we proceed in several steps. We first analyze the propagation of an increase in government spending at the steady state, with a baseline duration of UI benefits. Second, we discuss the propagation of an unemployment measurement error shock $\varphi_t$ that raises the duration of UI benefits. Finally, we combine the previous two steps to analyze how an extended duration of UI benefits shapes government spending multipliers. Although, for ease of exposition, in this section we focus on shocks around the steady state, in appendix 2.B we show that our results remain unchanged conditional on a TFP-driven recession.

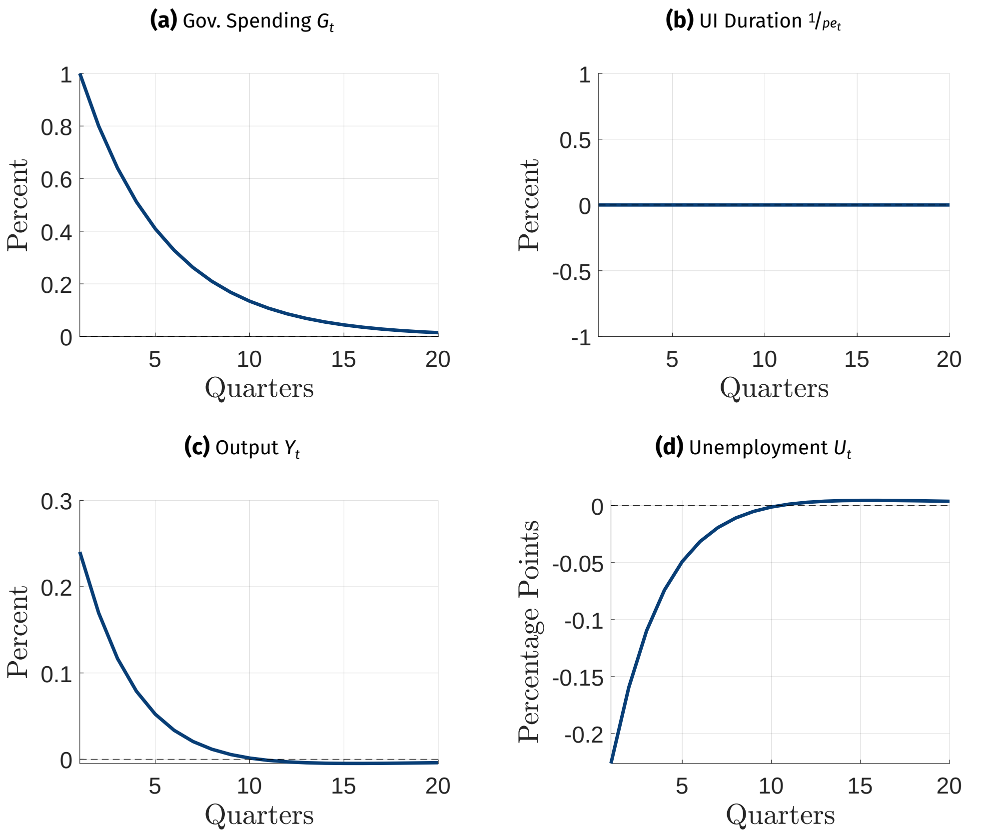


**Figure 2.5.1.** Propagation of a G shock with baseline UI

*Notes:* Impulse responses to a 1% government spending shock starting from the steady state.

### 2.5.1 Propagation of a G shock with baseline UI

Figure 2.5.1 shows the aggregate consequences of a 1% exogenous increase in government spending starting from the steady state. We set the persistence of government spending $\rho_G$ to 0.8.[18] Recall that at this point the duration of UI benefits is at its baseline, $pe_t^{-1} = pe^{-1}$. The path for government spending is displayed in panel (a). Due to the presence of nominal rigidities, the increase in government spending comes with an increase in aggregate output and a fall in the unemployment rate; see panels (c) and (d). Importantly, note that in this case the increase in government spending does not command an extension of the duration of UI benefits; observe panel (b). This is a consequence of the non-linear systematic response of UI benefits to unemployment; see equation 2.3.36.

### 2.5.2 Propagation of a UI shock

Figure 2.5.2 shows the consequences of a shock to unemployment measurement error $\varphi_t$. We pick the size of the initial shock and its persistence $\rho_\varphi$ such that it leads to an increase in the duration of UI benefits during 2 quarters; see panel (b).[19] The increase in the expected duration of unemployment benefits improves insurance against unemployment spells. As a result, households cut back on precautionary savings and increase demand for consumption goods. With sticky prices, the increase in aggregate demand leads to a temporary boom in aggregate output and a fall in the unemployment rate while the increase in UI benefits persists; observe panels (c) and (d).

The aggregate response to the extension of UI benefits implied by our model is reasonable. For example, our model delivers a UI impact multiplier of around 1.7, below the empirical value of 1.9 found in Di Maggio and Kermani (2016) and within the range of multipliers considered in Chodorow-Reich and Coglianese (2019).[20] Furthermore, the average decline of unemployment during the first two quarters (while the extension of UI benefits is active) is −0.06 percentage points, within the range of estimates found in Chodorow-Reich *et al.* (2018) and in line with the estimates of Boone *et al.* (2021). The maximal response of unemployment in Figure 2.5.2 is −0.15 percentage points, somewhat larger than the lower bound of −0.09 percentage points reported in Chodorow-Reich *et al.* (2018).

18. This is a common value in the literature; see, for example, Christiano *et al.* (2016). We have found that, although $\rho_G$ matters for the level of government spending multipliers, it has little impact on the difference between multipliers during periods of baseline and extended duration of UI benefits.

19. This mimics the typical UI error in the data, as reported in Chodorow-Reich *et al.* (2018). More precisely, the typical extension of UI benefits created by unemployment measurement error leads to a three-month extension in the duration of UI benefits with a half-life of roughly one quarter.

20. We compute the UI multiplier as the change in aggregate output divided by the equilibrium change in total UI payments made by the government to households.

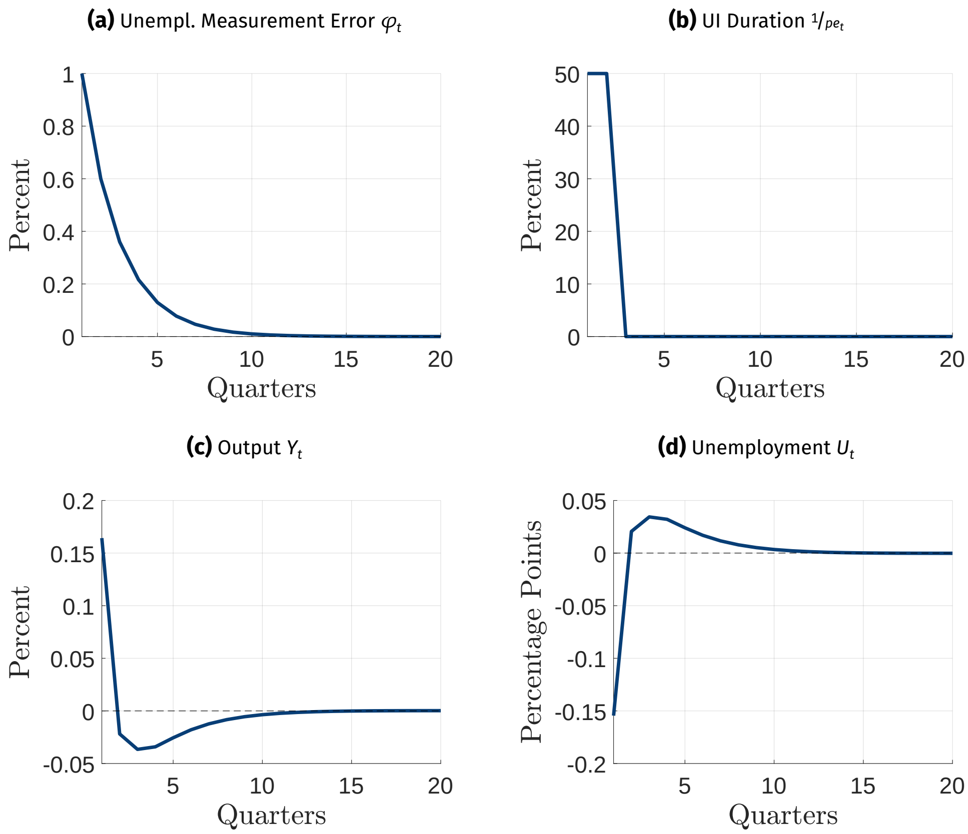


**Figure 2.5.2.** Propagation of a UI shock

*Notes:* Impulse responses to an increase in the duration of UI benefits (middle panel) driven by a unemployment measurement error shock (left panel).

We also note that, despite that the extension of UI benefits leads an initial expansion, unemployment slightly raises thereafter. This is explained as follows. The initial expansion brought about by the extension of UI benefits comes with an increase in the price level and domestic inflation (not shown). However, in our small open economy, a fixed exchange rate anchors expectations of the long-rung price level (cf. Corsetti *et al.* 2013; Nakamura and Steinsson 2014). As a result, since the price level of Foreign does not move, subsequent periods of mild deflation and lower output (hence, employment) ensure that the domestic price level return to its steady-state value.

### 2.5.3 Propagation of a G shock with extended UI

As a final step, we look to the aggregate consequences of an increase in government consumption at a time when UI benefits are extended due to measurement error. More precisely, we proceed as follows. Starting from the steady state, we simultaneously perturb the economy with a $G$ shock and a $\varphi$ shock, as displayed in panels (a) of Figures 2.5.1 and 2.5.2 respectively. Let $\{\tilde{X}\}_t$ be the path of variable $X$ generated by the two shocks. Let $\{\hat{X}\}_t$ be the path for $X$ generated by only the $\varphi$ shock, as shown in Figure 2.5.2. Then the marginal effect on $X$ of an increase in government spending $G$ during times of extended UI benefits is given by $X_t = \tilde{X}_t - \hat{X}_t$. Figure 2.5.3 plots the results for $X_t \in \{G_t, pe_t^{-1}, Y_t\}$.

The increase in government spending leads to a boom in output; see panel (c). The expansion in output comes with a fall in the unemployment rate (panel d). Crucially, and contrary to what we observed in Figure 2.5.1, the fall in the unemployment rate now comes with a tightening of the duration of UI benefits. As it can be observed in panel (b), the duration of UI benefits contracts in the second quarter. What this means is that, owing to expansion induced by the increase in government spending, UI benefits are only extended by one quarter instead of two (recall panel (b) in Figure 2.5.2). The endogenous tightening of UI benefits means that, now, output expands relatively less than in Figure 2.5.1.

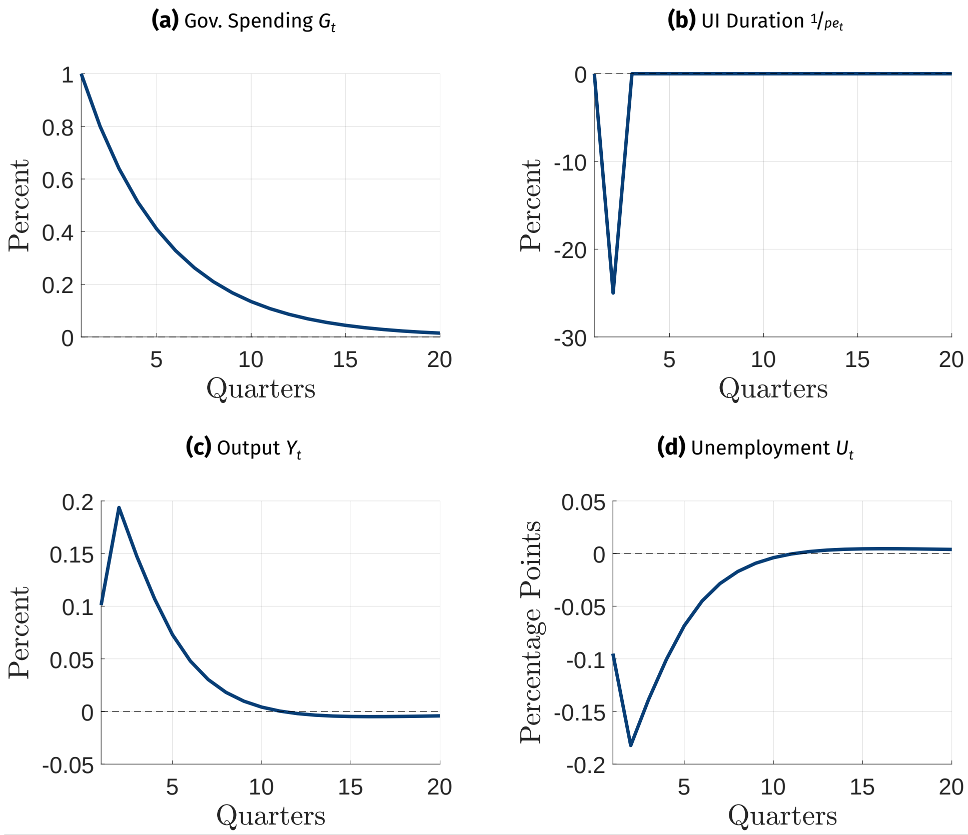


**Figure 2.5.3.** Propagation of a G shock with extended UI

*Notes:* Marginal effect of a government spending shock when duration of UI benefits has been extended due to a unemployment measurement error shock.

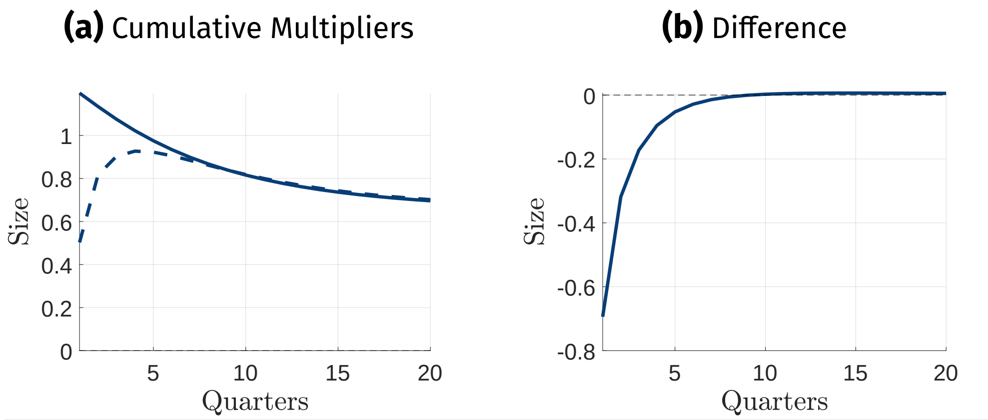


**Figure 2.5.4.** Cumulative Multipliers

*Notes:* Cumulative multipliers as defined in (2.5.1). Left panel: multiplier with baseline (solid) and extended (dashed) duration of UI benefits. Right panel: difference.

### 2.5.4 Government spending multipliers

We gauge the interaction between the duration UI benefits and the stimulative effects of government spending through looking at cumulative government spending multipliers, as in our empirical section. We define the cumulative government spending multiplier at time $T$ as follows:[21]

$$\frac{\sum_{t=0}^{T}\left(Y_t - Y\right)}{\sum_{t=0}^{T}\left(G_t - G\right)} \tag{2.5.1}$$

The left panel of Figure 2.5.4 plots the cumulative multipliers associated with a baseline duration of UI benefits (solid line) and with an extended duration of UI benefits (dashed line). The right panel shows the difference between both. Additionally, Table 2.5.1 collects the cumulative multipliers for $T \in \{1, 2, 3, 4\}$.

Government spending multipliers during normal times lie well within the range of available empirical estimates. The impact multiplier is almost 1.2, falling to about 1 after the first year. In line with our empirical findings, multipliers are significantly lower during periods of extended UI benefits. The size of the impact multiplier falls by about 0.70 and is meaningfully lower throughout the first two years, observe the right panel of Figure 2.5.4.

21. Note than in equation (2.5.1) we do not discount cumulative multipliers, which is consistent with our empirical section. Results remain unchanged if we discount cumulative multipliers.

**Table 2.5.1.** Cumulative Multipliers

| Quarter | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Baseline UI | 1.19 | 1.13 | 1.07 | 1.02 |
| Extended UI | 0.50 | 0.81 | 0.90 | 0.92 |

*Notes:* Cumulative multipliers as defined in (2.5.1) for $T \in \{1, 2, 3, 4\}$. Top row: baseline duration of UI benefits. Bottom row: extended duration of UI benefits.

### 2.5.5 Transmission channels

We next explore in more detail the transmission mechanism that gives rise to lower government spending multipliers when the duration of UI benefits is extended. We first show that the different response of output is driven by domestic private consumption. We then explore the transmission channels that explain the different responses of households' consumption.

We first start by combining the market clearing equation (2.3.40) with the demand for exports (2.3.15) and with the demand for home goods from domestic agents $C_{Ht} = (1-\alpha)\left(\frac{P_{Ht}}{P_t}\right)^{-\eta} C_t$:

$$Y_t \;=\; (1-\alpha)\left(\frac{P_{Ht}}{P_t}\right)^{-\eta} C_t + \alpha\left(\frac{P^*_{Ht}}{P^*_t}\right)^{-\lambda} C^* + G_t. \tag{2.5.2}$$

Next, we make use of the law of one price, the definition of the terms of trade (2.3.17), and the consumer price index (2.3.11) to find that:

$$Y_t \;=\; (1-\alpha)\left(1-\alpha+\alpha S_t^{1-\eta}\right)^{\frac{\eta}{1-\eta}} C_t + \alpha S_t^{\eta} C^* + G_t. \tag{2.5.3}$$

It is easy to see from equation (2.5.3) that an increase in government spending influences output through (i) affecting private domestic consumption $C_t$ (ii) changes in the terms of trade $S_t$. To the extent that the government raises aggregate demand, it will lead to an increase in the price of domestically produced goods $P_{Ht}$, and hence to an appreciation of the terms of trade – that is, a decrease in $S_t$. Consequently, households will switch consumption expenditures away from domestic goods and towards foreign goods, reducing domestic output.

Figure 2.5.5 decomposes the overall response of aggregate output to the government spending shock for a baseline duration of UI (left panel) and for the extended duration of UI benefits (right panel). By construction, the contribution of the exogenous increase in government spending is the same in both cases, observe the lines marked with circles. Next to this, one can observe by comparing the dotted lines that the contribution of the terms of trade is roughly the same in both cases. It is, instead, a smaller response of private consumption – indeed, a crowding out – what drives the smaller response of aggregate output; observe the dashed lines.

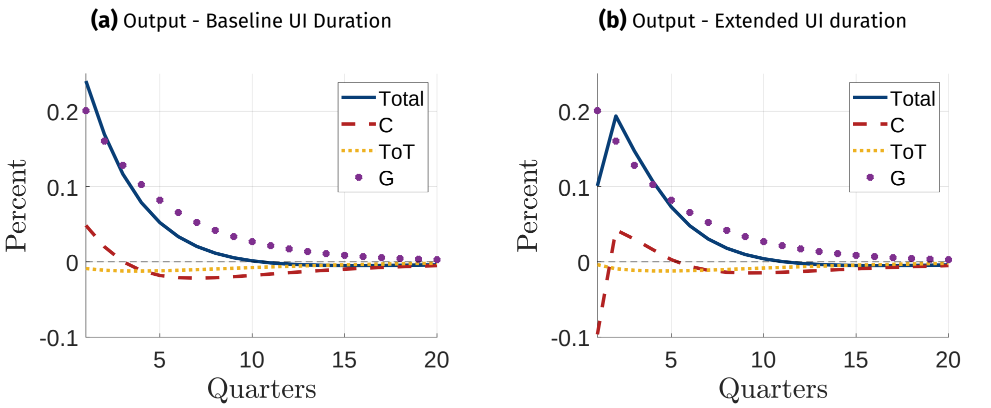


**Figure 2.5.5.** Transmission Channels – Output

*Notes:* Decomposition of the output response to a government spending shock when the duration of UI benefits is at its baseline level (left panel) and UI benefits have been extended due to a measurement error shock (right panel).

What drives the different responses of $C_t$? To answer this question, we follow Kaplan *et al.* (2018) and write aggregate consumption as a function of the sequences of household policy functions induced by $\{1+\pi_t, w_t, d_t, \tau_t, pe_t, f_t\}_{t\geq 0}$:[22]

$$C_t(\{1+\pi_t, w_t, \tau_t, pe_t, f_t\}_{t\geq 0}) = \int_{\mathscr{S}} c(s; \{1+\pi_t, w_t, d_t, \tau_t, pe_t, f_t\}_{t\geq 0}) d\mu_t. \quad (2.5.4)$$

Totally differentiating (2.5.4) decomposes the response of aggregate consumption at period $t$ into the parts explained by the path for inflation $1+\pi_t$, the job-finding rate $f_t$, the (inverse of) the expected duration of UI benefits $pe_t$, the tax rate $\tau_t$, the real wage $w_t$, and firms' aggregate dividends $d_t$.

Figure 2.5.6 shows the decomposition of the response of aggregate consumption to an increase in government spending when the duration of UI benefits is at the baseline level (left panel) and when the duration of UI benefits is extended (right panel). For ease of exposition, we combine the joint effect of wages, taxes, and firms' dividends into an income channel, displayed with diamonds.[23]

Comparing both panels of Figure 2.5.6 it is easy to see that the contribution of the job-finding rate (red dashed lines), income (marked with diamonds), and inflation (marked with circles) to the response of aggregate consumption is similar

22. Note that we do not make explicit the dependence of households' policy functions on the domestic policy rate $i_t$ since this remains constant over time to ensure that the nominal exchange rate $\mathscr{E}$ remains fixed. However, note that inflation $1+\pi_t$ does affect the real interest rate.

23. In appendix 2.C we report the contribution of the path for wages, taxes, and dividends separately. There, we show that the income channel that we plot in Figure 2.5.6 is primarily driven by the tax rate rather than by changes in wages or dividends.

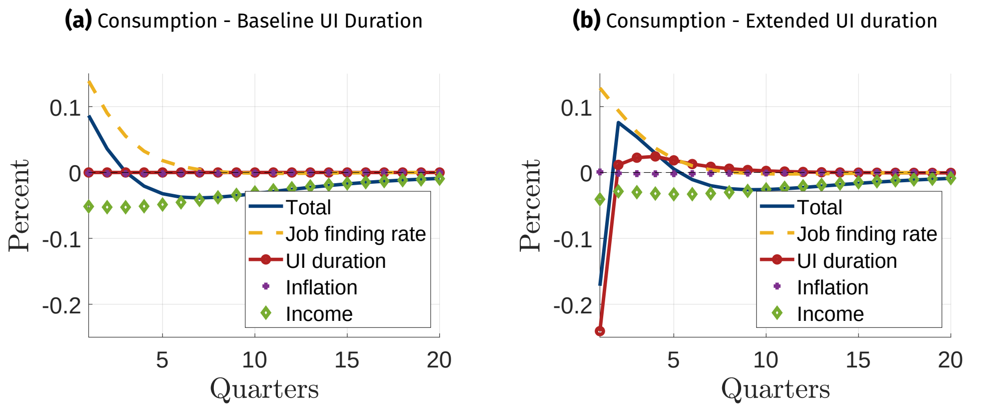


**Figure 2.5.6.** Transmission Channels – Consumption

*Notes:* Decomposition of the consumption domestic response to a government spending shock when the duration of UI benefits is at its baseline level (left panel) and UI benefits have been extended due to a measurement error shock (right panel).

in both cases. Namely, the increase in the job-finding rate would lead to an increase in private consumption, but this is to a large extent offset by the increase in taxes (and hence lower after-tax income) required to pay for the increase in government expenditures.

The response of the duration of UI benefits is key; observe continuous lines with circles. When UI benefits are at the baseline level, the expansion induced by the increase in government spending does not come with a shortening of the duration of UI benefits. Therefore, the contribution of this channel is zero in this case; see the left panel. On the contrary, when UI benefits have already been extended, the fiscal stimulus reduces unemployment, leading the government to also shorten the duration of UI benefits. The expectation of a shorter duration of UI benefits leads households to cut back consumption already in the present, crowding out private consumption (observe the continuous lines with circles in the right panel). Therefore, it is the systematic non-linear response of UI policy that explains state-dependent multipliers. As government spending reduces unemployment, UI tightens, crowding-out private consumption and reducing the government spending multiplier.

## 2.6 Conclusion

In this paper, we uncover a new determinant of the size of the government spending multiplier: the duration of UI benefits. We first provide new empirical evidence that local government consumption multipliers are lower when the duration of UI benefits is extended. In order to achieve this finding, we combine regional-level data for the US with variation in UI benefit extensions that are orthogonal to economic conditions and region-specific characteristics. We then interpret these findings through a small-open-economy model with heterogeneous households and equilibrium unemployment. The model attributes the origin of the state-dependent multiplier to the non-linear response of UI policy: an increase in government spending reduces unemployment, leading to a reduction in the duration of UI benefits only when these have already been extended. As we show, the response of UI policy is consistent with the data.

The welfare consequences of each of these fiscal policy tools have been widely discussed in the literature. Although we have restricted to a positive analysis, our findings suggest that the optimal design of UI policy and countercyclical government spending may need to be considered jointly. This is a relevant and interesting question that would be interesting to pursue in future research.

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## Appendix 2.A Empirical appendix

A potential concern with our empirical strategy is that we do not have enough exogenous variation in the duration of UI benefits to identify state-dependent government spending multipliers. However, as indicated in the main text, our sample contains

296 events of non-zero exogenous UI extensions due to measurement error, with a mean of about 0.40 months and a standard deviation of roughly 1.5 months.

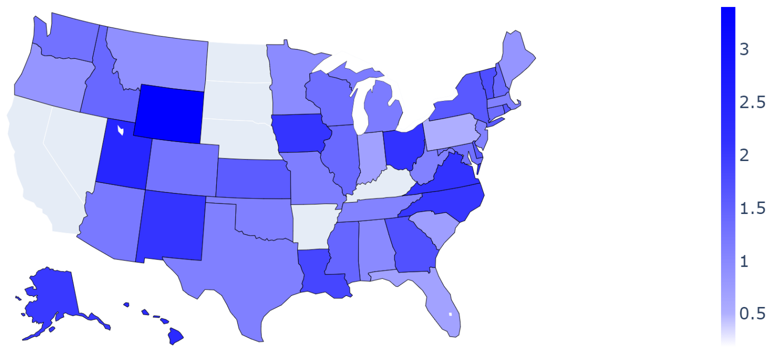


**Figure 2.A.1.** Standard deviation of $\hat{T}_{i,t}$

*Notes:* Standard deviation of UI extensions due to measurement error, $\hat{T}_{i,t}$, conditional on $\hat{T}_{i,t} \neq 0$ per US state. Darker colors indicate a larger standard deviation. States in white indicate that no data is available. Original data on $\hat{T}_{i,t}$ extracted from Chodorow-Reich *et al.* (2018).

Figure 2.A.1 shows that the variation mentioned above is well spread across US regions. It plots the standard deviation of UI extensions due to measurement error, $\hat{T}_{i,t}$, conditional on $\hat{T}_{i,t} \neq 0$ per US state. Darker colors indicate larger standard deviations. White-colored regions mark missing data. As it can be observed, exogenous UI extensions are not concentrated in a few US regions but are rather common to the whole US territory.

## Appendix 2.B Fiscal multipliers conditional on recessions

In section 2.5 we showed the responses and government spending multipliers implied by our model starting from the steady state. However, in the data most of the UI extensions due to measurement error occur when the unemployment rate is close enough to the UI trigger threshold, meaning that unemployment is above its mean. In this appendix we show that our results are unchanged when we mimic by more closely the empirical scenario, by first inducing a recession in our model economy.

More precisely, starting from the steady state, we first hit our economy with a −0.3% productivity shock. We pick the size of the shock such that the resulting recession is large but not enough to lead to an increase in the duration of UI benefits, absent measurement error. Additionally, we assume that the persistence of productivity $\rho_Z$ is equal to 0.95, a common value in the literature. Figure 2.B.1 displays the impulse response functions to the productivity shock, which can be observed in the left panel. As intended, the drop in output (right panel), is not enough to trigger an increase in the duration of UI benefits (middle panel).

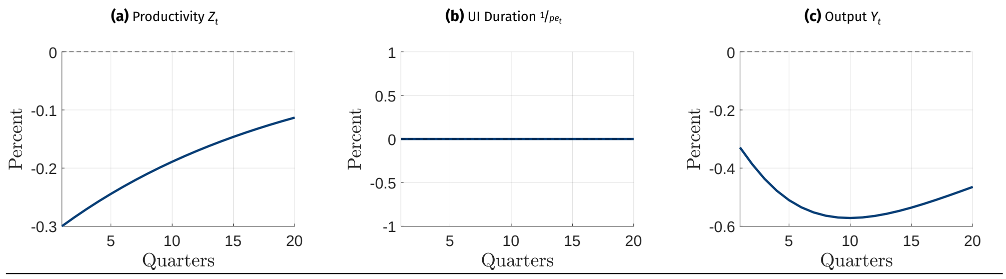


**Figure 2.B.1.** Propagation of a productivity shock

*Notes:* Impulse responses to a productivity shock starting from the steady state.

We next compute government spending multipliers depending on the duration of UI benefits, conditional on a recession. First, we compute the the cumulative government spending multiplier absent an UI extension. Towards this end, we simultaneously add a government spending shock to the negative productivity shock displayed in Figure 2.B.1. Second, we compute the cumulative spending multipliers when UI benefits are extended by additionally hitting the economy with a shock to unemployment measurement error $\varphi_t$.[24]

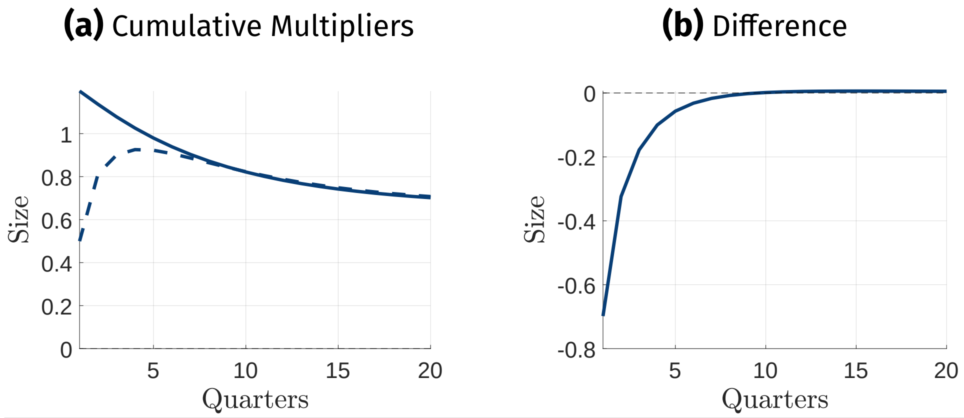


**Figure 2.B.2.** Cumulative Multipliers

*Notes:* Cumulative multipliers, as defined in (2.5.1), conditional on a recession. Left panel: multiplier with baseline (solid) and extended (dashed) duration of UI benefits. Right panel: difference.

24. Here we adapt the size of the measurement error shock such that UI benefits are extended by 3 additional months during two quarters, as in the main text; see Figure 2.5.2.

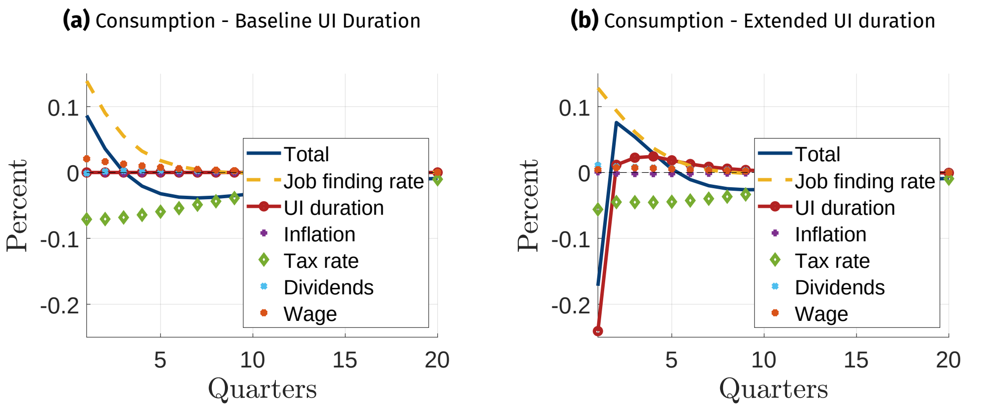


**Figure 2.C.1.** Transmission Channels – Consumption

*Notes:* Decomposition of domestic consumption response to a government spending shock when the duration of UI benefits is at its baseline level (left panel) and when UI benefits have been extended due to a measurement error shocks (right panel).

Figure 2.B.2 displays cumulative government spending multipliers when the duration of UI benefits is at its baseline level and when it is extended due to measurement error (left panel) and the difference (right panel), conditional on the recession. Results remain unchanged relative to our exercises in the main text; compare to Figure 2.5.4. In particular, government spending multipliers are substantially smaller when the UI benefits are extended, falling about 0.60 on impact and remaining lower throughout the first year.

## Appendix 2.C Decomposition of consumption response

In section 2.5 we provided a decomposition of the overall response of consumption to an increase in government spending. For ease of exposition, we compacted there the overall contribution of changes in real wages, dividends, and the tax rate into a single income channel. Figure 2.C.1 unpacks the contribution of each of these sources of income to total response of consumption. The increase in taxes required to finance higher government expenditures drives down income and hence consumption, observe lines marked with diamonds. Since the real wage is sticky it moves little and hence its contribution to the overall response of consumption is rather small, see lines marked with circles. Finally, the contribution of the change in firms' dividends is small too. The reason is that aggregate firms' dividends move little in our model. This is so because although the dividends of intermediate good producers fall in response to the increase in government spending – a common feature of New Keynesian models with sticky prices –, the dividends of labor good producers rise, leaving aggregate dividends roughly unaffected.

# Chapter 3

# Precautionary Savings and Financial Frictions[⋆]

## 3.1 Introduction

A long tradition in monetary macroeconomics, going back at least to Tobin (1969), views the liquidity characteristics of assets and portfolio choices of agents as central to business cycle fluctuations.[1] In this view, the state of the banking system not only matters because the banking system provides *credit* to *firms*, but also because it issues *demand deposits* and engages in liquidity transformation. Doing this, the banking system provides a liquid store of value to *households*. The current paper seeks to probe into the importance of banking frictions in this household-centric view of intermediation, both empirically and in a model environment that explicitly accounts for households' needs of a liquid store of value.

First, I empirically assess the transmission of a shock that induces households to rebalance their portfolios towards more liquid assets: a shock to households' uncertainty about their own labor income.[2] I find that the resilience of an economy

⋆ I would like to thank Keith Kuester and Christian Bayer for their invaluable support and guidance. I would like to thank participants at the EEA Virtual Congress 2021, the RTG-2281 Summer School 2021, the UCL-Bonn Macro Workshop, the YEP Seminar, the Konstanz Seminar on Monetary Theory and Policy, the Bonn-Boston-Cambrige-Columbia-UCL 2021 Workshop and the ECONtribute Rhineland Workshop for valuable feedback. I am grateful to my discussants R. Anton Braun and Matthew Knowles for insightful comments and suggestions. I would like to also thank Thomas Hintermaier, Donghai Zhang, Pavel Brendler, Moritz Kuhn, Joachim Jungherr, Zeno Enders, and Josef Schroth for useful comments. Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy - EXC 2126/1– 390838866. Earlier financial support by the Deutsche Forschungsgemeinschaft through RTG-2281 "The macroeconomics of inequality" is gratefully acknowledged.

1. Further classic references are Brunner and Meltzer (1972, 1976) and Friedman (1978).

2. Wide swings in household uncertainty have been documented in Storesletten *et al.* (2004) and Bayer *et al.* (2019). What makes a shock to household income risk particularly useful for the question at hand is that it is measurable in a model-independent way and affects the household level first and foremost.

to swings in the desired composition of household portfolios crucially depends on the state of the banking sector. A rise in labor-income uncertainty is substantially more recessionary if financial conditions are tight. In addition, only when financial conditions are loose, banks respond to higher income uncertainty by issuing more demand deposits.

This suggests a more general mechanism: suppose that households seek to rebalance their portfolios toward demand deposits and away from outright capital investment. Unconstrained banks can meet this demand, and in the process, provide funding to investment projects that now lack the funding from households. Constrained banks, instead, cannot increase deposit supply. Thus, households' demand for deposits itself has to fall back to a lower level. Excess demand for deposits is mirrored by a lack of demand for goods. If the aggregate supply of goods is demand-determined, output and household incomes fall, reducing the demand for liquid savings until the market for deposits clears.

I study this channel, second, in a formal business-cycle model (a "HANK" model, Kaplan *et al.* 2018). In its core, the model follows Bayer *et al.* (2019): households face idiosyncratic income risk; they can invest into illiquid capital, and they can purchase a liquid store of value. Into this setting, I introduce banks. The modeling follows Gertler and Karadi (2011), but with an emphasis on banks' ability to provide a liquid store of value: They issue demand deposits. Restrictions on bank leverage can limit the ability of banks to increase the supply of liquid assets. This gives rise to the paper's novel mechanism. Calibrating the environment to the US, I first document that the model replicates the gist of the empirical findings. Through a policy experiment, I show that liquidity provision (the household view) is essential for this: the muted creation of liquid deposits accounts for half of the deeper recession when financial conditions are tight.

More in detail, the empirical evidence arises as follows. I rely on a series of shocks to household income risk that Bayer *et al.* (2019) identify from the U.S. Survey on Income and Program Participation data, following the methodology of Storesletten *et al.* (2004). The series is designed such that the shocks measure an exogenous impulse that, for a while, raises the spread of shocks to the persistent part of household income going forward, for all households in the economy. I then study the response of GDP aggregates, bank credit, and deposits to these shocks by means of local projections (Jordà, 2005). The projections are state-dependent in that I estimate separate responses for times when financial conditions are tight and when they are loose. Following Adrian *et al.* (2019), I rely on the National Financial Conditions Index constructed by the Federal Reserve Bank of Chicago to determine the state of the financial sector.[3] I first document that, empirically, in response to an

3. An advantage of the National Financial Conditions Index over other measures is that it offers a wide coverage of the financial sector. It includes commercial banks, the main suppliers of households' deposits.

increase in household income uncertainty, deposits markedly rise in loose financial conditions. Instead, when financial conditions are tight, deposits do not rise. If anything, they fall. What is more, the effect of the shock on aggregate activity is benign when financial conditions are loose. Instead, when they are tight, a recession ensues: aggregate consumption persistently falls. Output drops more, too, since investment contracts sharply along with bank credit. The empirical results, thus, are suggestive of the state of the banking system being fundamental in shaping how shocks to household risk (and the ensuing shift in the desired portfolio composition) transmit to economic activity.[4]

Next, in order to understand the drivers of these empirical findings, I build a quantitative New Keynesian model with heterogeneous households, a portfolio choice between liquid and illiquid assets (Kaplan *et al.*, 2018; Bayer *et al.*, 2019), and banks (Gertler and Karadi, 2011). Households can save in high-return illiquid claims on capital or low-return liquid bank deposits. The illiquidity of capital stems from the assumption that these assets can only be traded with a certain probability each period. Therefore, liquid bank deposits are better suited to smooth consumption. Only banks can issue such deposits to households. Banks themselves are subject to a leverage constraint. When this binds, net worth of banks restricts lending to firms. At the same time, and this is the focus of the current paper, it also restricts the funding side of banks, namely, the creation of liquid deposits. Thus, the aggregate amount of liquid household savings in the economy, bank deposits, is endogenous to banking frictions. This is a distinctive feature of the current paper. I calibrate this model to the U.S. economy. Households face the same income risk process that underpinned the estimated shocks that I used in the empirical study.

I then look at the transmission of a shock to household income uncertainty. Upon the shock, households reduce their demand for consumption goods and increase their demand for savings. What is more, they seek to rebalance their portfolios from illiquid claims on capital to liquid bank deposits. I look at two scenarios: one in which the leverage constraint never binds, the other when banks' leverage constraint always binds. When the banks are unconstrained, if income risk rises the model sees an expansion in deposit creation. Indeed, the economy as a whole is able to provide the desired increase in household savings: investment rises since banks extend the funding to firms that households no longer seek to provide. As a result, while consumption falls, the effect of the income-uncertainty shock on output is mild. In stark contrast, when the leverage constraint binds, the shock leads to a sharp contraction in output. Constrained banks cannot meet households' increased demand for liquid savings, and deposits only rise somewhat. With sticky prices, the real interest rate does not fall fast enough to clear the deposit market. Thus, the excess demand for deposits comes with a lower demand for consumption goods. As the supply of goods is demand-determined, household income falls, leading to an even larger contrac-

4. The reader may raise questions of the endogeneity of financial conditions themselves. I show that my results are robust to, among others, controlling for the state of the business cycle.

tion in consumption. Next to this, since banks cannot provide further loans to firms, not only does consumption contract, but aggregate investment and asset prices fall sharply as well. Falling household income and falling asset prices weaken households' demand for liquid savings, restoring the equilibrium. Both lower consumption and lower investment amplify the recession.

The current paper assigns a dual role for banks: they intermediate funds between households and firms, and they supply a liquid store of value to households. I analyze the different roles of the bank through two counterfactuals. First, I exogenously fix the supply of deposits and compare this to the response of the economy with a binding leverage constraint. Fixing the supply of deposits, on impact, consumption and output fall by 40 percent more. What is more, the larger contraction of consumption is not explained by a deeper fall in investment: it falls just as much in both cases. This suggests that the limited supply of deposits is central for the larger contraction in consumption.

A second counterfactual quantifies the role of liquidity provision through looking at unconventional monetary policy. In the scenario of a binding leverage constraint, the monetary authority purchases assets from banks. In doing so, it relaxes their leverage constraint. This stimulates bank lending and investment. The effect on the supply of deposits depends on how the policy is financed, however. I consider two financing schemes. In a first one, the central bank purchases banks' assets in exchange for reserves. This is just a swap of assets, from one asset counting towards the leverage constraint against another not counting. Hence, new lending is financed by issuing deposits. This raises the supply of liquid assets. In the second financing scheme, central bank asset purchases are financed through lump-sum taxes on banks' shareholders. In this case, banks finance new loans with the funds obtained from selling assets to the central bank. Now, the monetary intervention has no direct effect on the supply of liquid assets. A reserves-financed policy stimulates lending, raises the supply of liquid assets, and entirely eliminates the amplification arising from a binding leverage constraint. A tax-financed policy stimulates investment, too. However, it barely expands the supply of deposits. Without liquidity provision, the effectiveness of the policy is cut in half for output and consumption. Therefore, a muted creation of liquid assets can explain half of the amplification when the leverage constraint binds. This shows that banking frictions not only matter because they constrain lending, but also because they restrict the supply of liquid assets to households.

The model also has implications for inequality. I document that, in the model, the distributional consequences of a shift in the desired liquidity of household portfolios are shaped by the state of the financial system, too. Upon a rise in household income risk, wealth inequality rises in tight financial conditions, whereas it falls when conditions are loose. This is surprising since the desired shift in the portfolio allocation sharply reduces the price of capital in tight financial conditions. This tends to hurt wealth-rich households more, who – as in the data – have more illiquid portfolios. At the same time, the sharp fall in incomes means that it is the wealth-poor who – in spite of the increase in risk – reduce their savings and end up holding fewer deposits and less wealth. In contrast, when banks are unconstrained, meaning that the recession is mild, the wealth-poor exhibit the strongest build-up of precautionary savings, compressing the wealth distribution.

### Related literature

In studying the role of banks' liquidity provision to the household sector I contribute to several strands of the literature. First, my work relates to a strand of literature that views portfolio choice, and supply and demand of assets with different liquidity characteristics as key to studying business cycle fluctuations. That a shift in the desired liquidity of household portfolios can be recessionary has been documented in Den Haan *et al.* (2017) and Bayer *et al.* (2019). My contribution is twofold. I provide empirical evidence that the state of the financial system affects the transmission of such shocks. And I explicitly model the supply of liquid assets to the household sector as being provided by banks. This gives a novel perspective on the importance of the funding of banks.[5]

Second, my paper relates to the literature that studies the macroeconomic consequences of financial frictions. I share with Bernanke *et al.* (1999), Kiyotaki and Moore (1997), and, in particular, Gertler and Karadi (2011) the central idea that financial frictions can amplify aggregate shocks. My modeling builds on this literature. What I add is a shift of emphasis: from the asset side of banks (loans to firms) to the role of the funding side (creating liquid assets for households). The focus on liquidity transformation relates my paper to Brunnermeier and Sannikov (2016). Where I focus on households and labor-income uncertainty, they model idiosyncratic investment risk. The focus on liquidity provision and financial frictions relates my work to Kiyotaki and Moore (2019) and Del Negro *et al.* (2017). Liquid savings in my model are endogenously created, and affected by banking frictions. Finally, I share with Diamond and Dybvig (1983) the view that banks perform liquidity transformation. I abstract from bank runs. I focus, instead, on the aggregate equilibrium consequences of limited liquidity provision to households.

Third, my paper relates to a literature that looks at uncertainty as a driver of the business cycle. For the firm sector, the literature has discussed real options channels (Bloom, 2009) and financial frictions (Gilchrist and Zakrajšek, 2012; Gilchrist *et al.*, 2014). Basu and Bundick (2017) also show that rigid prices can amplify shocks to aggregate risk even in complete-market settings. In my paper, aggregate uncertainty remains constant. The recession arises from an exogenous shift in idiosyncratic risk. I see this shift as a primitive, different from other work in the HANK literature, for example, Challe (2020), Den Haan *et al.* (2017), Gornemann *et al.* (2021), McKay and Reis (2021), and Ravn and Sterk (2017). That is, I abstract from uncertainty

5. Other papers investigating the propagation of idiosyncratic income risk directly abstract from aggregate savings, e.g. Ravn and Sterk (2017), Challe (2020). Or, like Gornemann *et al.* (2021), they model aggregate savings in a one-asset model where all capital is liquid.

feedback loops. This is in line with evidence presented by Bayer *et al.* (2020) that the uncertainty of persistent income changes appears to be an exogenous driver of portfolio choices and the business cycle.

Several other exciting papers have recently incorporated financial frictions into models with heterogeneous households. In all of these, to my knowledge, the focus differs from my work. Fernández-Villaverde *et al.* (2019), using a global solution method, study the non-linear interaction between the wealth distribution and leverage over the business cycle in a one-asset model with heterogeneous agents. They show that this gives rise to aggregate risk. Lee *et al.* (2020) build a one-asset New Keynesian model with heterogeneous agents and financial intermediaries. They focus on the consequences of a countercyclical spread on consumer loans. Instead, I emphasize the role of the supply of a liquid vehicle for household saving. Bigio and Sannikov (2021) build a heterogeneous agents economy with financial frictions in the interbank market. I explore the link between deposit creation for households and shocks to idiosyncratic risk on the household side. Closely related, too, is Lee (2021) who studies the distributional effect of quantitative easing in a two-asset HANK model with banks and equilibrium unemployment. What I add to this work, is a focus on banks as the main providers of liquidity to households, presenting empirical evidence that appears to support the importance of the channel that I study.

Finally, this paper also contributes to an active empirical literature that explores the state-dependent effects of aggregate shocks and policies. The literature has investigated the state-dependent effects of fiscal policy (e.g. Ramey and Zubairy 2018; Auerbach and Gorodnichenko 2012) and monetary policy (Tenreyro and Thwaites, 2016), for example. To the best of my knowledge, my paper is the first to document how changes in household income uncertainty depend on financial conditions.

The remainder of the paper is organized as follows. Section 3.2 provides the empirical evidence. Section 3.3 lays out the model environment. Section 3.4 discusses the numerical implementation and calibration. Section 3.5 provides the model-based results. It discusses the transmission of a shock to income risk and the role of liquidity creation, policy counterfactuals, and inequality consequences. A final section concludes. The appendix provides additional results and robustness checks.

## 3.2 Empirical evidence

The banking sector, through deposits, is the main provider of liquid assets to households. The current paper emphasizes that banking frictions not only hamper credit supply to firms but also impair liquidity provision to households. In order to see the empirical relevance of this mechanism most clearly, this section documents the transmission of a shock that affects households' demand for liquid assets. Namely, I document how an increase in idiosyncratic labor income risk affects banks' deposit creation and aggregate activity, and how that effect in turn depends on the state of the financial sector. I first describe the data, then the baseline empirical specification, and finally, the main empirical results.

### 3.2.1 Data

Times of increased idiosyncratic income risk should be times of high demand for liquid assets. Labor income being the main source of income for working-age households, I focus on labor income risk.

I rely on the measure of household income risk shocks identified in Bayer *et al.* (2019); and available from 1983 until 2013. These authors extend the procedure of Storesletten *et al.* (2004) to estimate a time series of shocks to the variance of the persistent component of after-tax household labor income. In particular, they first specify an income process consisting of a transitory component, a household-fixed, a deterministic and a persistent component with time-varying variance. Then, they estimate this income process using panel data from the U.S. Survey of Income and Program Participation (SIPP). Changes in the dispersion of residual income across cohorts over time allow them to estimate a time series for the variance of the persistent component of income (income risk) and a time series of the shocks to this variance (income risk shocks). Figure 3.A.1 in appendix 3.A.1 displays the estimated time series of household income uncertainty and the shocks to household income uncertainty.

Therefore, my measure of shocks to household income risk consists of the innovations to the variance of the persistent component of household income. Thus, I focus on swings in uncertainty about long-term household income, rather than on uncertainty about short-term household income fluctuations. This means that these shocks are less likely to be contaminated by aggregate fluctuations that only induce changes in household income at business cycle frequency. This point receives further empirical support by the results of Bayer *et al.* (2020). These authors, extending the procedure of Bayer *et al.* (2019), allow idiosyncratic household income uncertainty to respond endogenously to fluctuations in aggregate output in an estimated quantitative heterogeneous agents model. They find the estimated feedback of aggregate activity to idiosyncratic household income risk to be negligible. Still, in the next subsection, I present further robustness checks addressing potential concerns regarding the exogeneity of shocks.

Following Adrian *et al.* (2019), I use the National Financial Conditions Index (NFCI) constructed by the Federal Reserve Bank of Chicago to measure the state of the financial system.[6] The NFCI provides a weekly estimate of financial conditions of the U.S. in money markets, debt and equity markets, and the traditional and shadow banking systems. The index is a weighted average of several measures of

6. An advantage of the NFCI over other measures is that it offers a wide coverage of the financial sector, including commercial banks that are the main suppliers of households' deposits.

financial activity, grouped into a leverage subindex, a risk subindex, and a credit subindex. Although the NFCI starts in 1971, I only use the sample period between 1983 and 2013, the period for which the household income risk shocks are available. I aggregate these weekly estimates to quarterly frequency by averaging over the quarter. I define financial conditions to be tight when the NFCI takes value above its average over the sample period and to be loose otherwise. Figure 3.A.2 in appendix 3.A.1 provides the resulting time series for the quarterly NFCI.

The rest of the aggregate data used in the analysis consist of quarterly U.S. time series from 1983 to 2016, retrieved from FRED, Federal Reserve Bank of St. Louis. In particular, my measure of households' liquid savings consists of total currency and deposits held by the household sector.[7] As of credit, I employ total bank credit from all commercial banks.[8] I use the log of real aggregate output, consumption, investment, and the unemployment rate to assess the effects of income risk on aggregate activity. Finally, I employ the 3-Month Treasury Bill as a measure of the nominal interest rate. See appendix 3.A.1 for further details.

### 3.2.2 Empirical response to household income risk shocks

I compute the responses of macroeconomic aggregates to household income risk shocks by means of state-dependent local projections (Jordà, 2005). Local projections provide a flexible alternative to structural vector autoregressions, allowing for a direct estimation of impulse response functions without imposing dynamic restrictions. Furthermore, local projections can be easily extended to study state-dependent responses, rendering them well-suited for my analysis. More precisely, I distinguish between two states, tight financial conditions ("*FT*") and loose financial conditions ("*FNT*"). I entertain the following state-dependent specification,

$$\begin{aligned} y_{t+l} =& \mathbb{I}_{t-1}^{FT}\left[\alpha_{FT,l} + \phi_{FT,l}(L)\mathbf{x}_t + \beta_{FT,l}\frac{\varepsilon_t^s}{\sigma_s}\right] \\ &+ (1-\mathbb{I}_{t-1}^{FT})\left[\alpha_{FNT,l} + \phi_{FNT,l}(L)\mathbf{x}_t + \beta_{FNT,l}\frac{\varepsilon_t^s}{\sigma_s}\right] + \gamma_l \text{trend}_t + \nu_{t+l}\ , l \geq 0, \end{aligned} \tag{3.2.1}$$

where $y_{t+l}$ is the variable of interest, $\mathbf{x}_t$ is a set of controls, $\phi_{FT,l}(L)$ and $\phi_{FNT,l}(L)$ are lag operators and $\varepsilon_t^s$ is the household income-risk shock normalized by its standard deviation $\sigma_s$. $trend_t$ is a linear trend and $\alpha_{FT,l}$ and $\alpha_{FNT,l}$ are constant terms.

7. The original source of this data series is the Flow of Funds (FoF). Therefore, the household sector, which is computed as a residual in the FoF, includes nonprofit organizations serving households as well.

8. In the model presented later, credit will be only provided to firms. In the US, small firms are the most reliant on bank credit, that may finance themselves through the personal collateral of the firm-owner (e.g., Abdulsaleh and Worthington 2013; Petersen and Rajan 1994). This makes it difficult to distinguish in the data between a loan to a firm and a loan to a household that is used for firm investment.

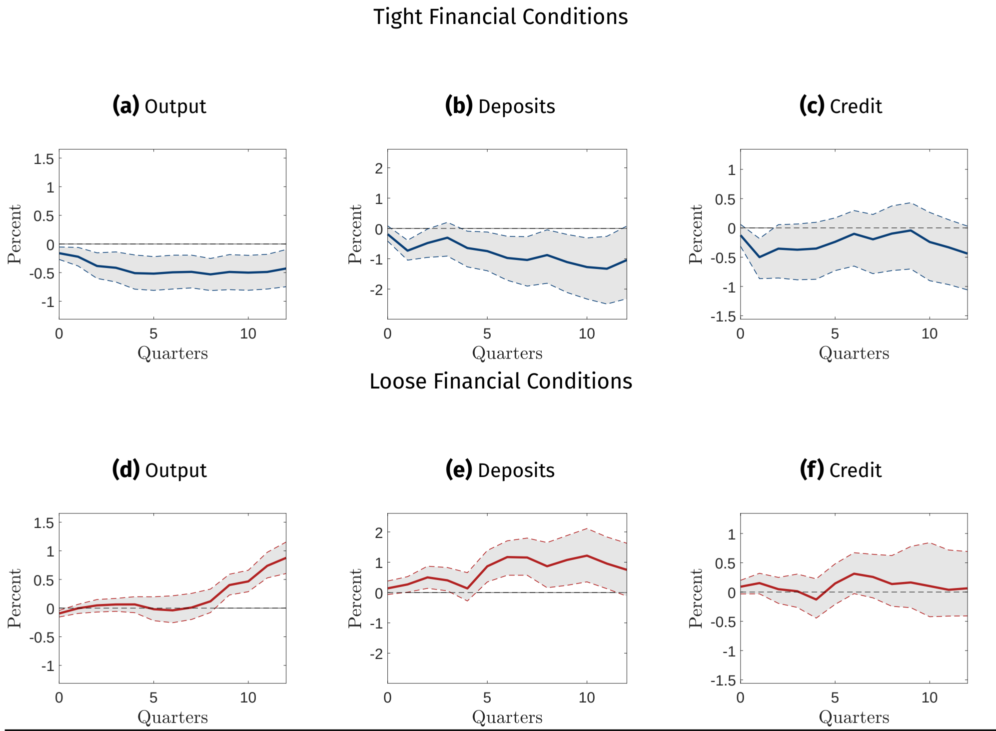


**Figure 3.2.1.** Empirical Response to an Increase in Income Risk

*Notes:* Estimated responses to one standard-deviation shock to household income risk, as identified in Bayer *et al.* (2019). The top panel shows the empirical responses when financial conditions are tight as measured by the National Financial Condition Index (NFCI). The bottom panel shows the responses when financial conditions are loose. Block bootstrapped 66% confidence bounds are shown in gray areas delimited by dashed lines. Appendix 3.A.2 reports the response of further variables in Figure 3.A.3 and the difference in the response between times of tight and loose financial conditions in Figure 3.A.4.

The variable $\mathbb{I}^{FT}_{t-1}$ is an indicator variable that takes value one if financial conditions are tight at $t-1$, as measured by the NFCI, before the shock hits. The coefficient $\beta_{FT,l}$ gives the response of the variable of interest $y_{t+l}$, at horizon $l$, to the household income-risk shock that occurs at time $t$ when the state of the economy is characterized by tight financial conditions. Similarly, $\beta_{FNT,l}$ provides the response of $y_{t+l}$ at horizon $l$ when financial conditions are loose. The controls include one lag of household income uncertainty, the 3-Month Treasury Bill, the unemployment rate, the log of real output, and the lagged value of the variable of interest $y$.

Figure 3.2.1 shows the empirical response of output, deposits, and credit to a one standard-deviation shock to household income risk. The top panel shows the response of these variables when financial conditions are tight. The bottom panel shows the response during periods of loose financial conditions. Block bootstrapped 66% confidence bounds are shown in gray areas delimited by dashed lines. Appendix 3.A.2 reports the response of further variables (consumption, investment, and unemployment) in Figure 3.A.3 and the difference in the response between times of tight and loose financial conditions in Figure 3.A.4.

Theory suggests that a shock to households' income risk induces them to reduce demand for goods as to build a buffer of precautionary savings. In particular, households may seek to accumulate more liquid savings as to self-insure against heightened income risk. Figure 3.2.1 shows that the effects on aggregate activity of such shock markedly depend on the state of the financial system, however. During times of tight financial conditions, the shock leads to a recession. Output persistently falls by around 0.5% (panel a). In contrast, the contractionary effects of the shock are muted if financial conditions are tight. In this case, output barely falls and tends to increase after two years (panel d). Figure 3.A.3 in the appendix further shows that aggregate consumption and investment display a similar state-dependent response. They fall notably if financial conditions are tight, while the response is muted during periods of benign financial conditions.

What is more, the aggregate response of liquid deposits to an increase in income uncertainty is notably shaped by the health of the financial sector, too. Loose financial conditions come with an ample expansion of liquid savings. In response to an income risk shock, liquid deposits persistently increase to around 1% (panel e). In marked contrast, and despite the increase in income risk, this expansion of liquid savings is absent during periods of tight financial conditions. Instead, deposits tend to fall (panel b). On the asset side of the financial system, credit falls during periods of tight financial conditions (panel c), while the response is muted if financial conditions are benign (panel f).

In sum, Figure 3.2.1 shows that the effects of a shock that induces households to increase their demand for liquid savings, an increase in income risk, crucially depend on the state of the financial sector. During periods of benign financial conditions, the creation of liquid savings by the financial system, in form of deposits, is ample, and the consequences on aggregate activity mild. On the contrary, the shock triggers a pronounced recession if financial conditions are tight, and the creation of liquid deposits is markedly muted. These empirical results, thus, are suggestive of the state of the banking system being fundamental in shaping how shocks to household income risk transmit to economic activity.

Appendix 3.A.3 provides a series of robustness checks. As can be observed in the time series for the NFCI in Figure 3.A.2, times of tight financial conditions sometimes coincide with economic slumps, the last financial crisis being a salient example of this. This may raise the concern that the state-dependent responses shown in Figure 3.2.1 are due to differences between expansions and recessions, and not to financial conditions. To address this issue, in appendix 3.A.3.1, I extend my baseline specification (3.2.1) to control for the state of the business cycle, using the unemployment rate to determine expansions and recessions. Figure 3.A.5 shows that results remain largely unchanged.

Second, the National Financial Conditions Index contains financial indicators for risk, credit, and leverage. However, in my model, financial conditions will be tightly linked to leverage in the financial sector. In appendix 3.A.3.2 I use the leverage subindex of the NFCI as an indicator variable for financial conditions instead. I obtain similar results under this alternative specification, as shown in Figure 3.A.7.

An important assumption in the baseline regression (3.2.1) is that the estimated shocks to household income risk identified in Bayer *et al.* (2019) are purely exogenous and orthogonal to other structural shocks $\nu_{t+l}$ in the economy. My baseline specification (3.2.1) can be understood as ordering income risk first in a Cholesky identified SVAR. As a robustness check, in appendix 3.A.3.3 I take the opposite assumption and entertain a specification where only uncertainty itself responds contemporaneously to the income risk shock. Figure 3.A.10 in the appendix shows that results remain robust.

## 3.3 Model

The empirical evidence presented in the previous section suggests that the state of the financial system is central for the aggregate consequences of a shock that shifts households' demand for liquid assets: a household income risk shock. I seek to explore next the channels behind these findings. Towards this end, I build a two-asset New Keynesian model with heterogeneous households (Kaplan *et al.*, 2018; Bayer *et al.*, 2019) and financial intermediaries that engage in liquidity transformation, subject to a potentially binding leverage constraint (Gertler and Karadi, 2011). While the literature typically focuses on the banks' role in financing firms, this paper focuses on their role in creating liquid savings for households.

More precisely, the model economy is composed of a household sector, a production sector, financial intermediaries, and a government. The production sector is comprised of a final good producer, capital goods producers, resellers that set prices subject to adjustment costs à la Rotemberg (1982), and intermediate good producers that use labor and capital as production inputs. Financial intermediaries use deposits issued to households and their own net worth to purchase financial claims on physical capital subject to a leverage constraint. Households consume, supply labor, and face time-varying idiosyncratic income risk, described in detail below. In order to self-insure, households can save in two assets: liquid bank deposits and financial claims on physical capital, that can only be traded infrequently.

Financial claims on physical capital are modeled following Gertler and Karadi (2011). In particular, non-financial firms in this economy will use labor and capital as production inputs. I assume that the entirety of firms' capital has to be financed through loans. These loans take the form of state-contingent claims on the earnings generated by capital. Therefore, they can be thought of as equity of the non-financial firm. Financial claims (or equity) can be purchased by both the household sector and financial intermediaries.

### 3.3.1 Households

The household sector builds on Bayer *et al.* (2019). I use small case letters to denote individual variables and capital letters to denote aggregate variables. There is a unit mass of ex-ante identical infinitely-lived households indexed by $i \in [0, 1]$. A household can be a worker or an entrepreneur. Both types of households consume and participate in asset markets, but only workers supply labor. Entrepreneurs, instead, receive a non-tradable share of aggregate profits.[9] Households randomly transition between being one of the two types.

#### 3.3.1.1 Idiosyncratic productivity and labor supply

Workers face time-varying idiosyncratic labor productivity $h_{i,t}$. As in Bayer *et al.* (2019), labor productivity follows a *AR* (1) process in logs with time-varying variance and a constant transition probability between the worker and the entrepreneur state:

$$\tilde{h}_{i,t} = \begin{cases} \exp\left(\rho_h \log \tilde{h}_{i,t-1} + \varepsilon^h_{i,t}\right), & \text{with probability } 1-\zeta \text{ if } h_{i,t-1} \neq 0, \\ 1, & \text{with probability } \iota \text{ if } h_{i,t-1} = 0, \\ 0, & \text{else,} \end{cases} \tag{3.3.1}$$

with individual productivity $h_{i,t} = \frac{\tilde{h}_{i,t}}{\int_0^1 \tilde{h}_{i,t} di}$, such that average worker productivity remains constant. The shocks $\varepsilon^h_{i,t}$ to labor productivity are normally distributed with time-varying variance given by

$$\sigma^2_{h,t} = \bar{\sigma}^2_h \exp\left(s_t\right), \quad \bar{\sigma}_h > 0, \tag{3.3.2}$$

$$s_{t+1} = \rho_s s_t + \varepsilon^s_t, \quad |\rho_s| < 1, \tag{3.3.3}$$

$$\varepsilon^s_t \sim \mathcal{N}\left(-\frac{\sigma^2_s}{2(1+\rho_s)}, \sigma^2_s\right), \quad \sigma_s > 0. \tag{3.3.4}$$

In words, a household that is a worker, $h \neq 0$, remains a worker next period with probability $1-\zeta$. With complementary probability, $\zeta$, the household becomes an entrepreneur next period and has zero labor productivity, $h = 0$, but is compensated with a share of aggregate profits. A household that is currently an entrepreneur with

9. The introduction of an entrepreneur state is useful for two reasons. First, it solves the problem of the allocation of profits without distorting factor returns and without the computational complexity of introducing a third tradable asset. Second, the entrepreneurial state, as a high-income state, is a useful modeling device to match the wealth distribution, following the idea of Castaneda *et al.* (1998).

zero productivity in the labor market returns to the workforce next period with median productivity with probability $\iota$.

Households maximize the discounted sum of utility over consumption and leisure. In particular, they have time-separable Greenwood–Hercowitz–Huffman (GHH) preferences over consumption $c_{i,t}$ and leisure with time-discount factor $\beta$,

$$\mathbb{E}_0 \max_{\{c_{i,t}, n_{i,t}\}} \sum_{t=0}^{\infty} \beta^t u(c_{i,t} - G(n_{i,t}; h_{i,t})), \tag{3.3.5}$$

where $n_{i,t}$ denotes hours worked.[10] The felicity function $u$ is of the constant-relative-risk-aversion (CRRA) type with risk aversion parameter $\xi > 0$,

$$u(x_{i,t}) = \frac{1}{1-\xi} x_{i,t}^{1-\xi}, \tag{3.3.6}$$

where $x_{i,t} = c_{i,t} - G(n_{i,t}; h_{i,t})$ is a composite good of consumption and leisure, with $G(n_{i,t}; h_{i,t})$ measuring the disutility from working. In the following, I assume $G(n_{i,t}; h_{i,t}) = h_{i,t} n_{i,t}^{1+\gamma} / 1+\gamma$, with $\gamma > 0$.

The labor income of a household $h_{i,t} n_{i,t} w_t$ is the product of the wage rate $w_t$, hours worked $n_{i,t}$, and idiosyncratic productivity $h_{i,t}$. Given a tax rate $\tau$, the labor supply first order condition is,

$$h_{i,t} n_{i,t}^{\gamma} = (1-\tau) w_t h_{i,t}, \tag{3.3.7}$$

so that all households supply the same amount of hours, $n_{i,t} = N(w_t)$. Consequently, the total amount of effective hours worked $\int h_{i,t} n_{i,t} di$ is also equal to $N(w_t)$ since $\int h_{i,t} di = 1$.

#### 3.3.1.2 Consumption and saving decisions

Financial markets are incomplete, and households can only use two assets to self-insure. They can hold liquid deposits, $d_{i,t}$, issued by financial intermediaries, with real gross return $R_t$. As described previously, households can also purchase financial claims on physical capital, $k^h_{i,t}$, at price $q_t$. The dividends generated by these claims will be, in equilibrium, equal to the net returns on physical capital, denoted by $r^k_t$. While households can access their savings in deposits every period, financial claims are illiquid. More specifically, following Luetticke (2021), I assume that in any given period only a random fraction $\nu \in (0, 1)$ of households is allowed to trade these

10. The assumption of GHH preferences together with the functional form assumed for $G(n_{i,t}; h_{i,t})$ simplifies the numerical analysis substantially, since it will imply that all households work the same number of hours.

assets. Households that are allowed to participate in the market for claims on capital face the following budget and non-borrowing constraints:

$$\begin{aligned} c_{i,t} + q_t k^h_{i,t+1} + d_{i,t+1} &= (q_t + r^k_t) k^h_{i,t} + R_t d_{i,t} + (1-\tau)(w_t n_{i,t} h_{i,t} + \mathbb{1}_{h_{i,t}=0} \Xi_t), \\ k^h_{i,t+1} &\geq 0, \quad d_{i,t+1} \geq 0, \end{aligned} \tag{3.3.8}$$

where $\mathbb{1}_{h_{i,t}=0}$ is an indicator function that takes value one if the household is an entrepreneur and $\Xi_t$ marks aggregate profits. Further note that households are not allowed to hold negative amounts of any of the two assets.[11] The real interest rate paid on deposits in period $t$ is linked to the nominal interest rate $1+i_t$, set by the central bank in $t-1$, and inflation, $1+\pi_t$, through the Fisher equation:

$$R_t = \frac{1+i_t}{1+\pi_t}. \tag{3.3.9}$$

The fraction $1-\nu$ of households that cannot trade the illiquid asset at period $t$ can access its liquid deposits and receive the dividends generated by their claims on physical capital. The budget constraint of these households simplifies to:

$$\begin{aligned} c_{i,t} + d_{i,t+1} &= r^k_t k^h_{i,t} + R_t d_{i,t} + (1-\tau)(w_t n_{i,t} h_{i,t} + \mathbb{1}_{h_{i,t}=0} \Xi_t), \\ d_{i,t+1} &\geq 0. \end{aligned} \tag{3.3.10}$$

The optimal consumption and saving choices of a household depend on its idiosyncratic states $(d, k^h, h)$. As a consequence, aggregate prices will be a function of the joint distribution $\Theta_t$ over these idiosyncratic states at period $t$. This renders $\Theta_t$ a state variable of the household problem that will fluctuate in response to aggregate shocks. The programming problem of a household is characterized by the following two Bellman equations, for the case of households who cannot and can adjust their holdings of capital claims:

$$\begin{aligned} V^n_t(d, k^h, h) = &\max_{d'_n} u\left[x\left(d, d'_n, k^h, k^h, h\right)\right] + \beta \mathbb{E}_t\left[\nu V^a_{t+1}\left(d'_n, k^h, h'\right)\right. \\ &\left. + (1-\nu) V^n_{t+1}\left(d'_n, k^h, h'\right)\right], \end{aligned} \tag{3.3.11}$$

$$\begin{aligned} V^a_t(d, k^h, h) = &\max_{d'_a, k^{h'}} u\left[x\left(d, d'_a, k^h, k^{h'}, h\right)\right] + \beta \mathbb{E}_t\left[\nu V^a_{t+1}\left(d'_a, k^{h'}, h'\right)\right. \\ &\left. + (1-\nu) V^n_{t+1}\left(d'_a, k^{h'}, h'\right)\right], \end{aligned} \tag{3.3.12}$$

where time subscripts summarize the dependence on aggregate states, including the joint distribution $\Theta_t$. I denote by $d^*_{a,t}$ and $d^*_{n,t}$ the optimal savings policy in liquid deposits for adjusters and non-adjusters, respectively. Accordingly, $k^{h*}_{a,t}$ denotes

11. For a model that allows for consumer loans see Lee *et al.* (2020).

the optimal savings policy for claims on capital for adjusters, and $k^{h*}_{n,t} = k$ for non-adjusters. These policies depend on the current idiosyncratic and aggregate states of the economy – including the joint distribution $\Theta_t(d, k^h, h)$ – as well as on current and future prices, summarized through expected continuation values $\left\{V^n_{t+1}, V^a_{t+1}\right\}$. Therefore, the aggregate amount of capital claims purchased by the household sector, $K^h_{t+1}$, is given by:

$$K^h_{t+1} \;=\; \mathbb{E}_t\left[\,\nu k^{h*}_{a,t} + (1-\nu)k^{h*}_{n,t}\right] \tag{3.3.13}$$

### 3.3.2 Financial intermediaries

Financial intermediaries are the main providers of liquid savings to households. Thus, banks play a central role in this economy: they perform liquidity transformation, supplying the liquid deposits that households demand to self-insure against swings in labor income uncertainty. Through the balance sheet of banks, the supply of these assets will depend on the lending capacity of the financial sector. The financial system is modeled following Gertler and Karadi (2011), but with an emphasis on banks' ability to provide a liquid store of value.

#### 3.3.2.1 Bank problem

There is a continuum of ex-ante identical financial intermediaries (or banks) of measure one. I use small-case letters to denote individual bank variables. Financial intermediaries use short-term deposits issued to households, $d_t$, and their own net worth, $e_t$, to finance their purchases of financial claims on capital, $k^b_t$. Due to financial market frictions described in detail below, banks may be constrained in the amount of assets that they can purchase.

The objective of the bank is to maximize the expected discounted profits from intermediating funds. At the beginning of the period a measure $(1-\sigma)/\sigma$ of banks enters the industry, where $\sigma \in (0, 1)$. All banks are then hit by an idiosyncratic random shock, indicating whether the bank should close down. With probability $1-\sigma$ the bank is forced to exit and pay back all its accumulated net worth, $e_t$, to its shareholders – the entrepreneurs – as dividends. With complementary probability the bank continues to operate. New entrants start with equity $\omega_t$, that they receive from shareholders. By means of entry, the measure of operating banks always equals 1.[12]

Banks perform liquidity transformation. In particular, and contrary to households, financial intermediaries can trade financial claims on capital every period. I

12. This device is commonly used in the literature to ensure that banks do not accumulate enough net worth to render the leverage constraint described below irrelevant.

assume, however, that they face a linear utility cost $\varsigma$ for each financial claim that they trade. [13] Therefore, the franchise value of a surviving bank $V_t^b$ is given by:

$$V_t^b \;=\; \mathbb{E}_t \Lambda_{t,t+1}\left[(1-\sigma)e_{t+1} + \sigma V_{t+1}^b\right] - \varsigma q_t k_{t+1}^b, \tag{3.3.14}$$

where $\Lambda_{t,t+1}$ is the discount factor of a bank, and $e_{t+1}$ is the net worth that an exiting bank pays as dividends. I assume that $\Lambda_{t,t+1} = 1/R_{t+1}$. [14] At each period $t$ the bank faces the following balance sheet constraint:

$$q_t k_{t+1}^b \;=\; e_t + d_{t+1}. \tag{3.3.15}$$

The left-hand side of (3.3.15) gives the volume of loans that the bank provides to firms, $k_{t+1}^b$ being the claims on physical capital purchased by the bank at time $t$. The right-hand side shows that loans have to be financed through net worth or by issuing deposits to the household sector. The net worth of a bank born in period $t$ is simply given by its start-up transfer $e_t = \omega_t$. Due to frictions left unmodeled, banks cannot issue new outside equity. They accumulate net worth through retained earnings. Hence, the net worth of a surviving bank in period $t+1$ is given by the market value of the assets intermediated in the previous period, $q_{t+1}k_{t+1}^b$, plus the dividends they receive on them, $r_{t+1}^k k_{t+1}^b$, net of the funding costs from deposits, $R_{t+1}d_{t+1}$:

$$e_{t+1} \;=\; (q_{t+1} + r_{t+1}^k)k_{t+1}^b - R_{t+1}d_{t+1}. \tag{3.3.16}$$

Banks further face a leverage constraint that constrains its franchise value, $V_t^b$, to not be lower than a fraction $\theta$ of the market value of its holdings of capital claims, $q_t k_{t+1}^b$:

$$\theta q_t k_{t+1}^b \;\leq\; V_t^b. \tag{3.3.17}$$

The leverage constraint (3.3.17) sets an upper bound on the amount of credit that banks can offer. What is more, through its balance sheet (3.3.15), the leverage constraint also influences the amount of liquid deposits that the financial system can supply to households. Therefore, as explained in more detail below, financial frictions not only impair lending, but also limit the expansion of the funding side of banks' balance sheets.

The above constraint can be motivated by the following moral hazard problem. Suppose that each period a bank can decide to divert a fraction $\theta$ of its holdings of capital claims. If it decides to divert assets, depositors force the bank to declare bankruptcy, and hence the financial intermediary loses its franchise value $V_t^b$. Under this setup, households will only be willing to lend to banks when these do not have

13. This utility cost can be motivated as a monitoring or origination cost for each loan that the bank provides. In my baseline calibration, this cost will be set to zero. However, it will be useful to make sure that all the experiments that I consider share the same steady state.

14. I have entertained different specifications for the discount factor $\Lambda_{t,t+1}$. Results remain robust.

incentives to declare bankruptcy, effectively implying that the franchise value of the bank cannot be lower than the amount of assets that can be diverted.

To derive a solution for the bank problem it useful to use equations (3.3.15) and (3.3.16) to derive the evolution of net worth of a continuing bank:

$$\begin{aligned} e_{t+1} &= [(R^k_{t+1} - R_{t+1})\psi_t + R_{t+1}]e_t, \\ \psi_t &= \frac{q_t k^b_{t+1}}{e_t}, \\ R^k_{t+1} &= \frac{q_{t+1} + r^k_{t+1}}{q_t}, \end{aligned} \tag{3.3.18}$$

where $\psi_t$ denotes the leverage ratio and $R^k_{t+1}$ the gross return on claims on capital holdings. Using (3.3.18) we can write the franchise value of the bank (3.3.14) as:

$$V^b_t = (\mu^b_t \psi_t + \eta^b_t)e_t, \tag{3.3.19}$$

where

$$\mu^b_t = \mathbb{E}_t[\Lambda^b_{t,t+1}(R^k_{t+1} - R_{t+1}) - \varsigma], \tag{3.3.20}$$

$$\eta^b_t = \mathbb{E}_t \Lambda^b_{t,t+1} R_{t+1}, \tag{3.3.21}$$

$$\Lambda^b_{t,t+1} = \Lambda_{t,t+1}(1 - \sigma + \sigma\varphi^b_{t+1}), \tag{3.3.22}$$

$$\varphi^b_t \equiv \frac{V^b_t}{e_t}. \tag{3.3.23}$$

The variable $\mu^b_t$ is the expected discounted excess return on banks' assets relative to deposits, net of intermediation utility costs $\varsigma$, and $\eta^b_t$ is the expected discounted cost of a unit of deposits. Intuitively, the marginal value of an extra unit of net worth to the bank, $\varphi^b_t$, will be higher when spreads or the return on deposits is high. In this situation, an additional unit of net worth would allow the bank to increase loans taking advantage of higher returns without relying on deposits.

Under the previous notation, the problem of a bank is to choose leverage, $\psi_t$, to solve:

$$\varphi^b_t = \max_{\psi_t}(\mu^b_t \psi_t + \eta^b_t), \tag{3.3.24}$$

subject to the leverage constraint

$$\theta\psi_t \leq \mu^b_t \psi_t + \eta^b_t. \tag{3.3.25}$$

Note that since the bank problem, (3.3.24) and (3.3.25), is linear in leverage, all banks, in equilibrium, will choose the same leverage ratio $\psi_t$. Consequently, financial intermediaries can be aggregated into a single representative bank. Summing across individual banks, we have that the aggregate value of capital claims held by the financial sector, $q_t K^b_{t+1}$, is related to aggregate net worth, $E_t$, according to,

$$q_t K^b_{t+1} \;=\; \psi_t E_t. \tag{3.3.26}$$

The evolution of aggregate net worth $E_t$ is given by the sum of retaining earnings from surviving banks plus the start-up funds of new born banks, $\omega_t$. I assume that start-up funds are given by a constant fraction of the current value of assets intermediated in the previous period $\omega_t = \frac{\bar{\omega}}{1-\sigma} q_t K^b_t$.[15] As a result, the evolution of aggregate net worth of banks is given by:

$$E_{t+1} \;=\; \sigma[(R^k_{t+1} - R_{t+1})\psi_t + R_{t+1}]E_t + \bar{\omega} q_{t+1} K^b_{t+1}. \tag{3.3.27}$$

#### 3.3.2.2 Solution to the bank problem and mechanisms

This paper focuses on how financial frictions on banks impair liquidity provision, and how this affects aggregate activity. This section provides intuition for why this is the case. Towards this end, I start by characterizing the solution to the bank problem. The solution to the bank problem, (3.3.24) and (3.3.25), is characterized by the following first-order condition and the complementary slackness condition:

$$\mathbb{E}_t \Lambda^b_{t,t+1}(R^k_{t+1} - R_{t+1}) \;=\; \varsigma + \lambda_t \theta, \tag{3.3.28}$$

$$\lambda_t(\theta\psi_t - \mu^b_t \psi_t - \eta^b_t) \;=\; 0, \tag{3.3.29}$$

where $\lambda_t$ denotes the lagrange multiplier on the leverage constraint (3.3.25).

The economy can be in two different regimes. A first one, where the financial system is unconstrained, is characterized by a non-binding leverage constraint ($\lambda_t = 0$); and a second one, where the leverage constraint is binding ($\lambda_t > 0$) and the financial system is impaired. In the former case, banks are on their Euler equation (3.3.28), implying that the expected excess return on capital claims over deposits will be constant up to first order, leading to an elastic supply of liquid deposits from the financial sector.

A constrained financial system, $\lambda_t > 0$, makes the supply of bank deposits less elastic. More precisely, we can impose a binding leverage constraint (3.3.17), and combine it with the balance sheet of a bank (3.3.15) and equation (3.3.23), to obtain the supply of liquid deposits from the financial system:

$$d_{t+1} \;=\; \frac{\mathbb{E}_t \Lambda^b_{t,t+1} R^k_{t+1} - \theta - \varsigma}{\theta - \mathbb{E}_t[\Lambda^b_{t,t+1}(R^k_{t+1} - R_{t+1}) - \varsigma]} e_t. \tag{3.3.30}$$

15. This formulation of the start-up transfer, $\omega_t$, is common in the literature, see Gertler and Karadi (2011) or Bocola (2016).

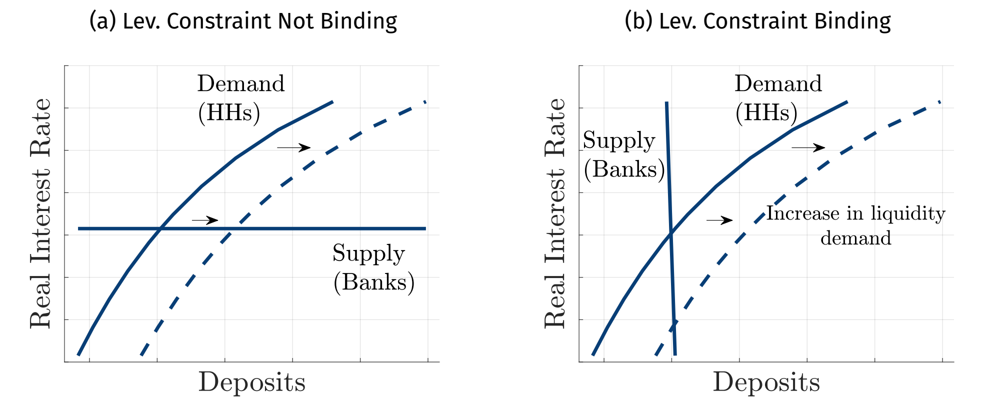


**Figure 3.3.1.** Demand and Supply for Liquid Deposits

*Notes:* Equilibrium in the deposit market. Right panel: the downward-slopping curve represents the supply of liquid deposits from banks when the leverage constraint binds, equation (3.3.30), after aggregating across banks. Left panel: the horizontal line represents the supply of liquid deposits from banks when the leverage constraint does not bind, equation (3.3.28) with $\lambda_t = 0$. In both panels the upward-slopping solid curve represents households' demand for liquid deposits. The dashed upward-slopping curve in both panels represents an increase in households' demand for liquid deposits.

When the financial system is constrained, according to (3.3.30), an increase in the supply of liquid deposits must come with either a fall in the expected real interest rate, $R_{t+1}$, or an increase in the expected return on capital claims, $R^k_{t+1}$. A fall in the interest rate on deposits, or an increase in the return on capital, increases banks' margins. As a consequence, net worth and the franchise value of the bank increase. This relaxes the leverage constraint (3.3.25), allowing the bank to increase lending and, in the process, issue deposits to households, performing liquidity transformation.

The central observation of this paper is that financial frictions are crucial to determine equilibrium households' liquid savings. In order to show this more clearly, Figure 3.3.1 displays the equilibrium in the deposit market schematically. The left panel shows the case when the leverage constraint does not bind. The right panel the case when it binds. Each panel shows the demand and supply of deposits on the horizontal axis and the real interest rate on the vertical axis.

Focus first on the case in which the leverage constraint is not binding (panel a). In this situation, banks are only constrained by their balance sheet. Hence, they can freely issue more deposits to lever up and increase lending. This means that banks' supply of liquid assets is fairly elastic. Suppose that the demand for deposits rises, shifting the demand schedule to the right, see the dashed line in panel (a). Such an increase could, for example, be caused by an increase in idiosyncratic income risk. An unconstrained financial system is able to meet this increase in demand for deposits. Thus, there is an ample creation of liquid savings in equilibrium with small movements in the interest rate.

If the financial system is impaired (panel b), the supply of deposits is downward-slopping and inelastic: banks can only issue more deposits if the real interest rate falls sufficiently to reduce funding costs, increase net worth, and hence relax the leverage constraint (3.3.17). In this scenario, the financial system is not able to meet the increase in households' demand for liquid savings (dashed line, panel b). Instead, the interest rate on deposits falls markedly. A lower real interest rate reduces households' demand for liquid savings, restoring equilibrium. Therefore, the creation of liquid savings is muted with a constrained financial system: financial frictions impair the provision of liquid assets from the banking sector to households.

As we shall see in the quantitative results in section 3.5, the limited expansion in the supply of liquid deposits feeds back into aggregate activity. With sticky prices, the adjustment in the real interest rate observed in panel (b) will be sluggish. In such a situation, the excess demand of liquid savings will be mirrored by a lack of demand for consumption goods. With the aggregate supply of goods being demand-determined, aggregate activity and household income will fall, amplifying the contraction in consumption and output.

### 3.3.3 Final good producer

Final good producers are perfectly competitive and use differentiated goods as inputs. The final good can be used for both consumption and investment. The problem of the representative final good producer is:

$$\max_{Y_t, y_{j,t} \in [0,1]} P_t Y_t - \int_0^1 p_{j,t} y_{j,t} dj \tag{3.3.31}$$

$$\text{s.t.} \quad Y_t = \left( \int_0^1 y_{j,t}^{\frac{\eta-1}{\eta}} dj \right)^{\frac{\eta}{\eta-1}},$$

where $y_{j,t}$ is the quantity of the differentiated good $j$ demanded. The first-order conditions of the final good producer deliver the following demand for differentiated goods:

$$y_{j,t} = \left( \frac{p_{j,t}}{P_t} \right)^{-\eta} Y_t. \tag{3.3.32}$$

The zero-profit condition implies that the price of the final good is given by $P_t = \left( \int_0^1 p_{j,t}^{1-\eta} dj \right)^{\frac{1}{1-\eta}}$.

### 3.3.4 Intermediate goods producers

Intermediate goods are produced with a constant returns to scale production function, using labor, hired in a competitive market, and capital as inputs:

$$Y_t = A_t N_t^{\alpha} K_t^{(1-\alpha)}, \tag{3.3.33}$$

where $A_t$ is total factor productivity (TFP). It follows a first-order autoregressive process in logs:

$$logA_t \;=\; \rho_A logA_{t-1} + \varepsilon_t^A, \quad \varepsilon_t^A \;\sim\; \mathcal{N}(0, \sigma_A^2). \tag{3.3.34}$$

Let $MC_t$ be the relative price at which the intermediate good is sold to resellers. The first-order condition with respect to labor implies,

$$w_t \;=\; \alpha A_t MC_t \left(\frac{K_t}{N_t}\right)^{1-\alpha}. \tag{3.3.35}$$

As noted previously, intermediate good producers have to finance the purchases of capital through state-contingent claims on the earnings generated by this asset. These can be thought of as equity of these firms. In particular, the firm issues claims on capital (equity) to households and banks at price $q_t$. Then, it uses these funds to buy capital from the capital good producer. Using (3.3.35), we can express the profit per unit of capital, $r_t^k$, as,

$$r_t^k \;=\; \frac{Y_t - w_t N_t - \delta}{K_t} \;=\; (1-\alpha) A_t MC_t \left(\frac{N_t}{K_t}\right)^{\alpha} - \delta, \tag{3.3.36}$$

where $\delta$ is the depreciation rate of capital. As it will be clear below, repairing depreciated capital stock is not subject to adjustment costs, and therefore its price is unity. Through perfect competition, the price of new capital goods will also be equal to $q_t$, and therefore the intermediate good producer makes zero profits state by state.

### 3.3.5 Resellers

Resellers differentiate intermediate goods and set prices, subject to quadratic adjustment costs à la Rotemberg (1982). Price setting is delegated to a measure zero of managers, that are compensated with a share of profits. As with financial intermediaries, I assume that the discount factor of managers, and therefore firms, is equal to the inverse of the real interest rate $\Lambda_{t,t+1} = 1/R_{t+1}$. [16] Managers set prices taking as given the demand for good $j$ (3.3.32), i.e., they maximize,

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \left(\frac{1}{R_{t+1}}\right)^t Y_t \left\{ \left(\frac{p_{j,t}}{P_t} - MC_t\right)\left(\frac{p_{j,t}}{P_t}\right)^{-\eta} - \frac{\eta}{2\kappa}\left(\log \frac{p_{j,t}}{p_{j,t-1}}\right)^2 \right\}. \tag{3.3.37}$$

The first-order condition yields the Phillips curve:

$$\log(1+\pi_t) \;=\; \kappa\left(MC_t - \frac{\eta-1}{\eta}\right) + \mathbb{E}_t \frac{1}{R_{t+1}}\left[\log(1+\pi_{t+1})\frac{Y_{t+1}}{Y_t}\right]. \tag{3.3.38}$$

16. As a robustness check, I have entertained different specifications for the discount factor. Results remain robust.

Additionally, managers obtain profits from adjusting the aggregate capital stock subject to adjustment costs:

$$K_{t+1} = K_t + I_t - \frac{\phi}{2}\left(\frac{K_{t+1} - K_t}{K_t}\right)^2 K_t, \tag{3.3.39}$$

where there $I_t$ denotes net aggregate investment.[17]

Since there is perfect competition in the capital market, managers will adjust the capital stock until the following first-order condition holds:

$$q_t = 1 + \phi\frac{K_{t+1} - K_t}{K_t}. \tag{3.3.40}$$

As managers have measure zero in the economy, all profits from non-financial firms go to entrepreneurs.

### 3.3.6 Government

The government is composed of a fiscal authority and a central bank. The central bank sets the nominal interest rate paid on deposits according to the following Taylor rule:

$$\frac{1 + i_{t+1}}{1 + \bar{i}} = \left(\frac{1 + i_t}{1 + \bar{i}}\right)^{\rho_i}\left(\frac{1 + \pi_t}{1 + \bar{\pi}}\right)^{\theta_\pi(1-\rho_i)}, \tag{3.3.41}$$

where $\rho_i$ captures monetary policy inertia, $\theta_\pi$ determines the response of the central bank to inflationary pressures, $1 + \bar{i}$ is the steady-state gross nominal interest rate, and $1 + \bar{\pi}$ the gross inflation rate in steady state.

On the fiscal side, I abstract from government debt. This ensures that all liquid assets in the model are an endogenous result of the intermediation activity of banks. More in detail, the fiscal authority adjusts government expenditures $G_t$ to balance the budget every period, where revenue comes proportional taxes on income: [18]

$$G_t = \tau(w_t N_t + \Xi_t). \tag{3.3.42}$$

17. Note that adjustment costs in (3.3.39) only apply to new capital created. Therefore, gross investment equals $I_t + \delta K_t$.

18. In the appendix 3.C I show that results remain robust to the alternative assumption where the government instead adjusts taxes.

### 3.3.7 Market clearing

The labor market clears if the condition (3.3.35) holds. The market for deposits clears if the following equation holds:

$$D_{t+1} = \mathbb{E}_t\Big[\nu d^*_{a,t} + (1-\nu) d^*_{n,t}\Big], \tag{3.3.43}$$

where $D_{t+1}$ denotes the aggregate supply of deposits from the financial system, and $d^*_{a,t}$ and $d^*_{n,t}$ denote the optimal demand of deposits from adjusters and non-adjusters, respectively. These policies depend on the idiosyncratic and aggregate states of the economy, as well as on current and future prices. Expectations in the right-hand side of (3.3.43) are taken with respect to the joint distribution $\Theta_t(d, k^h, h)$.

The market for capital claims clears if the aggregate claims on capital held by the household sector, $K^h_t$, and the financial sector, $K^b_t$, equals the aggregate stock of capital, $K_t$:

$$K_t = K^b_t + K^h_t. \tag{3.3.44}$$

The goods' market clears due to Walras' law if the markets for labor services, capital claims and deposits clear.

### 3.3.8 Equilibrium

A *sequential equilibrium with recursive planning* is a set of policy functions for households $\left\{d^*_{a,t}, d^*_{n,t}, k^{h*}_{a,t}, k^{h*}_{n,t}, x^*_{a,t}, x^*_{n,t}\right\}$ and banks $\left\{k^b_t, d_t\right\}$, a set of value functions for households $\left\{V^a_t, V^n_t\right\}$ and banks $\left\{V^b_t\right\}$, pricing functions $\left\{r^k_t, w_t, 1+i_t, \pi_t, \Xi_t\right\}$, aggregate capital and labor supply functions $\{K_t, N_t\}$, distributions $\Theta_t$ over individual asset holdings and productivity, and a perceived law of motion $\Gamma$, such that:

1. Given prices, households' and banks' policy and value functions solve their decision problems.
2. The labor, the final goods, the deposit, the capital claims and the intermediate good markets clear, i.e., (3.3.35), (3.3.38), (3.3.43), and (3.3.44) hold.
3. The actual law of motion and the perceived law of motion $\Gamma$ coincide, that is, $\Theta_{t+1} = \Gamma(\Theta_t)$.

## 3.4 Numerical implementation and calibration

The dynamic problem of households, characterized by (3.3.11) and (3.3.12), and therefore the recursive equilibrium, are not computable because it involves the infinite-dimensional object $\Theta_t$. Instead, I discretize the distribution $\Theta_t$ and represent it by its histogram, that is a finite-dimensional object. The household problem is solved using the endogenous grid method developed by Carroll (2006) and extended by Hintermaier and Koeniger (2010). The idiosyncratic productivity process is approximated by a Markov chain with 11 states. The time-varying probabilities of this Markov chain are obtained using the Tauchen (1986) method. I use 80 grid points for capital claims and deposits to solve the household problem.

The model is written such that the leverage constraint may be binding only occasionally. However, solving the model with heterogeneous agents, two assets, and an occasionally binding constraint is beyond the scope of the current paper. Instead, I entertain two distinct scenarios: one where the leverage constraint always binds and one where the leverage constraint never binds. Specifically, I solve the model by perturbation methods. I use first-order perturbation around the non-stochastic steady state of the model. I rely on the method proposed in Bayer and Luetticke (2020) to reduce the dimensionality of the problem. This method approximates the joint distribution $\Theta_t$ over idiosyncratic states with a distribution with time-varying marginals and a fixed copula. Moreover, the value functions of the household problem are approximated by sparse polynomials around their steady-state solutions.

### 3.4.1 Calibration

I calibrate the model to the US economy. All targets correspond to a data sample covering the period between 1983 and 2015. One period in the model is a quarter. As a baseline, the calibrated parameters imply that the leverage constraint is always binding in equilibrium. Table 3.4.1 contains the parameter values, where I use letters with bars to denote the steady-state variables.

#### 3.4.1.1 Households

The relative risk aversion of households is set to $\xi = 4$ as in Kaplan and Violante (2014). The Frisch elasticity $\gamma$ is set to 1, in line with the estimates of Chetty *et al.* (2011). The time discount factor $\beta = 0.97$ and the participation frequency $\nu = 0.13$ are jointly calibrated to match the ratio of aggregate capital to output and the ratio of liquid assets to aggregate output. I target a quarterly capital-to-output ratio of 11.4 following Bayer *et al.* (2019). Following Kaplan *et al.* (2018) and Bayer *et al.* (2019) I target a ratio of aggregate liquidity to aggregate quarterly output of 1.04. [19]

I set the quarterly long-run standard deviation of persistent shocks to idiosyncratic income, $\sigma_h$, to 0.06 and its persistence, $\rho_h$, to 0.98, as estimated in Bayer *et al.* (2019). The persistence of innovations to the variance of shocks and its quarterly autocorrelation is set to the estimated values from Bayer *et al.* (2019). These

19. Liquid assets are measured using the Survey of Consumer Finances and are composed of deposits in financial institutions (checking, saving, call, and money market accounts), government bonds, and corporate bonds net of revolving consumer credit. Deposits account for almost 89% of liquid assets (see Kaplan *et al.* 2018). As a robustness check, I have entertained an alternative calibration where liquid assets in the model were only matched to deposits. Results remain unaffected. Illiquid assets are equated to all capital goods in the NIPA tables, net of non-housing durable consumption goods (Bayer *et al.*, 2019).

**Table 3.4.1.** Calibrated parameters.

| Parameter | Description | Value | Target / Source |
|---|---|---|---|
| Households | | | |
| $\xi$ | Risk aversion | 4 | Kaplan and Violante (2014) |
| $\nu$ | Adj. probability | 0.13 | $\bar{D}/\bar{Y} = 1.04$ |
| $\beta$ | Discount factor | 0.97 | $\bar{K}/\bar{Y} = 11.4$ |
| $\gamma$ | Inverse Frisch elasticity | 1 | Chetty *et al.* (2011) |
| $\rho_h$ | Persistence productivity | 0.98 | Bayer *et al.* (2019) |
| $\sigma_h$ | Std. shocks | 0.06 | Bayer *et al.* (2019) |
| $\rho_s$ | Persistence innovations | 0.84 | Bayer *et al.* (2019) |
| $\sigma_s$ | Std. shocks to variance | 0.54 | Bayer *et al.* (2019) |
| $\iota$ | Trans. prob. from E. to W. | 1/16 | Guvenen *et al.* (2014) |
| $\zeta$ | Trans. prob. from W. to E. | 0.0005 | Gini = 0.78 |
| Non-Financial Firms | | | |
| $\delta$ | Depreciation | 1.35 % | NIPA |
| $\alpha$ | Labor share | 0.7 | Labor Income Share 66% |
| $\eta$ | Elasticity substitution | 20 | Markup 5% |
| $\kappa$ | Slope Philips curve | 0.05 | Calvo price duration 5 quarters |
| $\phi$ | Capital adj. costs | 10 | std(I)/std(Y) = 3 |
| $\rho_A$ | Persistence TFP | 0.90 | Standard value |
| $\sigma_A$ | Std. TFP shocks | 0.01 | Standard value |
| Financial Intermediaries | | | |
| $\theta$ | Divertible assets | 0.4 | Binding Leverage Constraint |
| $\sigma$ | Life bank | 0.97 | Gertler and Karadi (2011) |
| $\bar{\omega}$ | Proportional startup transfer | 0.002 | Leverage of 4 |
| $\varsigma$ | Utility cost intermediation | 0 | |
| Government | | | |
| $\rho_i$ | Inertia Taylor Rule | 0.8 | Standard value |
| $\theta_\pi$ | Response to Inflation | 1.25 | Standard value |
| $1+\bar{i}$ | Nominal Rate | 1.0091 | $\bar{R}^k - \bar{R} = 100$ bps p.a. |
| $1+\bar{\pi}$ | Inflation | 1 | 0% p.a. |
| $\tau$ | Tax Rate | 0.27 | $\bar{G}/\bar{Y} = 0.20$ |

*Notes:* Letters with bars capture steady-state variables. The main text provides further details.

values are consistent with the estimated shocks to income uncertainty used in the empirical specification discussed section 3.2. The probability of dropping out of the entrepreneurial state, $\iota$, is set to match the probability that a household falls out of the top 1% of the income distribution reported in Guvenen *et al.* (2014). The probability of entering the entrepreneurial state $\zeta$ is calibrated to match a Gini coefficient of total wealth of 0.78, a value corresponding to the average Gini coefficient in the Survey of Consumer Finances over the calibration period.

#### 3.4.1.2 Financial intermediaries

The bank survival probability $\sigma$ is set to 0.97, as in Gertler and Karadi (2011). The proportional transfer to newborn banks $\bar{\omega}$ is set to match a steady-state leverage ratio of 4, as in Gertler and Karadi (2011). The fraction of divertible assets $\theta$ is set to 0.4, implying that the leverage constraint binds. The utility cost of intermediating assets $\varsigma$ is set to zero in my baseline.

#### 3.4.1.3 Production

I set the labor share $\alpha$ to match a labor income share of 2/3. The slope of the Phillips curve $\kappa$ implies a price duration of 5 quarters in a Calvo setting. The elasticity of substitution $\eta$ is calibrated to match a steady-state markup of 5%, a common value in the literature. The adjustment cost of capital $\phi$ is calibrated to match a relative volatility of investment of 3 conditional on a TFP shock. The autocorrelation of TFP is set to $\rho_A = 0.9$, and the standard deviation of TFP shocks to $\sigma^A = 0.01$, standard values in the literature.

#### 3.4.1.4 Government

I set the steady-state tax rate on income $\tau$ to match a government-spending-to-output ratio of 20%. The steady-state inflation rate is set to zero, and the real return on deposits is set to 3.6% per year to target an excess return of capital over liquid assets of 100 basis points, as in Gertler and Karadi (2011). The monetary policy inertia parameter $\rho_i$ and the response to inflation $\theta_\pi$ are set to conventional values in the literature.

## 3.5 Results

The empirical findings of section 3.2 are suggestive of the state of the financial system being fundamental for the aggregate consequences of an income risk shock (and the consequent shift in the demand for liquid savings). I seek to understand next the role played by banks' endogenous liquidity provision to households, and how this is impaired by financial frictions, in driving these findings. Towards this end, I assess next the effects of an increase in labor income risk. This increase raises households' demand for liquid savings, shifting the desired liquidity of their portfolios. I first consider the baseline economy with banks and a binding leverage constraint. Then I contrast it with a counterfactual economy where the leverage constraint is not binding. This allows me to isolate how banking frictions impair liquidity transformation, and how this affects aggregate activity.[20]

### 3.5.1 The aggregate consequences of liquidity transformation

Figure 3.5.1 shows the impulse response functions to a one standard-deviation increase in household income risk. The shock itself is depicted in panel (a). Blue solid lines show the aggregate effects of this shock in the baseline economy where the leverage constraint of financial intermediaries is binding. Red dashed lines display the response to the same shock in the counterfactual economy where the leverage constraint does not bind.[21]

Focus first on the economy where the leverage constraint does not bind; the dashed red lines. Recall that in this case the supply of deposits is fairly elastic (Figure 3.3.1, panel a). The increase in idiosyncratic income risk induces households to reduce consumption (panel c) to build a buffer of precautionary savings. Next to this, households seek to rebalance their portfolios away from illiquid claims on capital to liquid bank deposits. Banks are able to meet the increase in demand for liquid savings, leading to a peak increase in deposits of almost 2% (panel g). This tilts households' portfolios towards the liquid asset (panel e). Banks use deposits to increase loans to non-financial firms (panel i). That is, while the household sector backs on investment (panel h), banks take over instead. As a consequence, there is no increase in excess returns (panel l). With the economy-wide savings increasing, overall investment rises by almost 0.5% (panel d). The effect of the shock on aggregate output is rather mild, it falls by only 0.3% (panel b). In sum, an unconstrained financial system makes the economy resilient to shocks that shift the desired liquidity composition of households' portfolios.

The solid blue lines in Figure 3.5.1, instead, show the case when the leverage constraint binds. Recall that if the financial system is constrained, banks cannot easily issue more deposits. As a result, the supply of liquid savings is rather inelastic (cf. panel (b) in Figure 3.3.1). In this case, banks cannot meet the households' increased demand for deposits. Figure 3.3.1 focused on the deposit market only. There, equilibrium was achieved through a fall in the interest rate. At the same time, Figure 3.3.1 assumed that the demand for deposits moves exogenously and that the real rate can flexibly fall. The case here is more complicated, however. On the one hand, the rise in demand for deposits goes in hand with a fall in aggregate demand (and incomes). On the other hand, monetary policy shapes the response of the real interest rate. The Taylor rule (3.3.41) used here is meant to capture a conventional

20. I adjust the utility costs of bank asset intermediation, $\varsigma$, to match the same steady-state excess return between capital and deposits as in my baseline. This ensures that the steady state of both economies is exactly the same.

21. Figure 3.B.1 in appendix 3.B provides impulse responses of additional variables.

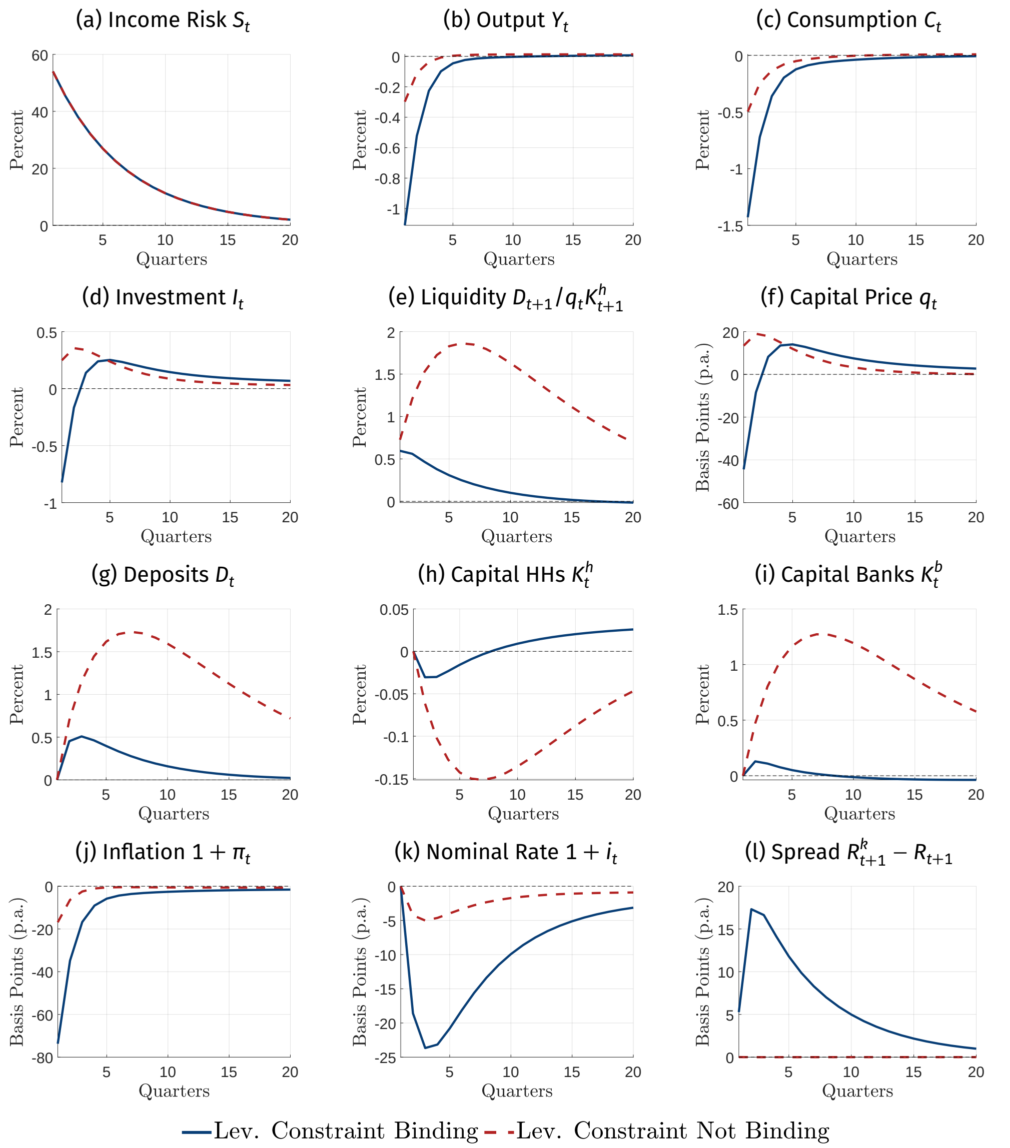


**Figure 3.5.1.** Impulse Response Functions to an Income Risk Shock

*Notes:* Impulse response functions to one standard-deviation increase in the variance of income shocks. Blue solid lines show the response in the baseline model, where the leverage constraint of financial intermediaries is binding. Red dashed lines show the response in a counterfactual economy where the leverage constraint is not binding.

monetary response. Monetary policy does not explicitly account for the rise in income risk. Thereby, and combined with sticky prices, the real interest rate does not fall enough to clear the market for deposits at given incomes. Instead, other quantities and prices move. On the one hand, the excess demand for deposits translates into low aggregate demand, leading incomes to fall. On the other hand, the excess demand for deposits is mirrored by a lack of demand for illiquid assets. In equilibrium, then the price of these assets falls sharply as well. Falling household incomes and falling asset prices weaken households' demand for liquid savings, restoring equilibrium.

More precisely, heightened income risk induces households to increase their demand for a more liquid portfolio and to reduce consumption. An impaired financial system cannot provide the household sector with enough liquid savings. Sticky prices imply that inflation (panel j), and hence the nominal interest rate (panel k), moves little. As a result, the real rate remains too high. Thus, households further reduce demand for consumption goods, amplifying the fall in aggregate consumption to almost 1.5% (panel c). With sticky prices the supply of goods is demand-determined: the fall in demand for goods induces firms to cut back on production, and hence households' income drops. This weakens households' desire to increase savings. Next to this, the binding leverage constraint mutes the response of bank credit (panel i). Consequently, now investment falls more than 0.5% (panel d). As a result, the price of capital falls markedly (panel f), leading to a rise in expected excess returns (panel l). Higher spreads discourage households from saving in the liquid asset, inducing them to hold a more illiquid portfolio (panel e). In sum, a decline in income and an increase in expected excess returns of illiquid assets dampen households' demand for liquid savings. Thus, markets clear with a muted creation of liquid deposits, that now only increase by 0.5% (panel g). The limited supply of liquid assets, however, comes with marked falls in both consumption and investment, amplifying the drop in aggregate output to 1%.

Overall, the dynamics observed in Figure 3.5.1 capture the gist of the empirical findings discussed in section 3.2. The aggregate consequences of an increase in households' demand for liquid savings, resulting from higher income risk, crucially depend on the state of the financial system. When the banking sector is unconstrained, the creation of liquid savings in equilibrium is ample. Furthermore, the intermediation of deposits into lending helps to stabilize investment. A binding leverage constraint, instead, impairs banks' liquidity transformation: the response of liquid deposits and credit are muted and much lower than if banks are unconstrained. This leads to marked falls in aggregate consumption and investment, amplifying the recessionary impact of the shock.

It bears noting that the financial frictions do not amplify all shocks to the same extent. Rather, they amplify in particular shocks that induce households to shift their portfolios towards liquid savings. Appendix 3.B.3, for example, shows that financial frictions do not amplify a shock to the discount factor $\beta$. This shock makes households more patient, inducing them to reduce consumption and increase savings in all assets. In this case, liquidity creation is also lower when the leverage constraint binds. Households, however, meet their higher desire to increase overall savings by increasing their holdings of the illiquid asset, even if this means that the liquidity of their portfolios falls.

### 3.5.2 The role of liquidity transformation

The current model gives a dual role to banks: they intermediate funds between households and firms, and they provide liquid savings to the household sector. At the same time, financial frictions impair both lending to firms and liquidity transformation. As we have seen, banking frictions crucially shape the aggregate consequences of a shock to household income risk that shifts the demand for liquid savings. I seek to understand and quantify next each of the roles of the financial system in driving the amplification to such shock. Towards this end, I analyze two counterfactuals that allow me to isolate the role of liquidity transformation, the focus of this paper.

#### 3.5.2.1 An economy with a fixed supply of liquid assets

For the household sector, the banking system is the main supplier of liquid assets. The previous section has shown that banking frictions are fundamental in shaping how a shock to household income risk (and the ensuing shift in the demand for liquid assets) propagates to economic activity. In order to obtain a better understanding of the role played by banks' liquidity transformation, this section abstracts from liquidity creation. In particular, I entertain the same two-asset model as above but assuming that the supply of liquid deposits and bank credit are in fixed supply, at the steady-state levels of the baseline economy. See appendix 3.D for details on the set up.

Figure 3.5.2 shows with solid black lines with circles the responses to an increase in income risk in the economy without liquidity transformation. It also displays the responses of the baseline economy with a binding and non-binding constraint, discussed above. If the supply of liquid assets is fixed, and there is no liquidity transformation, the recession is deeper still.[22] Output falls around 1.5% on impact, observe panel (b). This amplification is driven by a larger initial drop in consumption (panel c), that falls 2% on impact. What is more, the larger contraction of consumption is not explained by a deeper fall in investment: investment falls just as much as when the supply of deposits is not exogenous. Instead, the reason for this result is a fixed supply of liquid assets (panel f). Recall that households seek to hold more liquid portfolios. With the supply of liquidity fixed, however, the supply curve is entirely vertical (an extreme case of the right panel in Figure 3.3.1). Thus, any shift in demand for deposits cannot be an equilibrium outcome. Instead, the demand for liq-

22. Note that this result contrasts with the financial accelerator literature (e.g. Bernanke *et al.* 1999; Gertler and Kiyotaki 2010) that generally finds that removing the financial system together with financial frictions is stabilizing. In my model, however, financial intermediaries also have the central role of endogenously creating the liquid assets that households demand to self-insure.

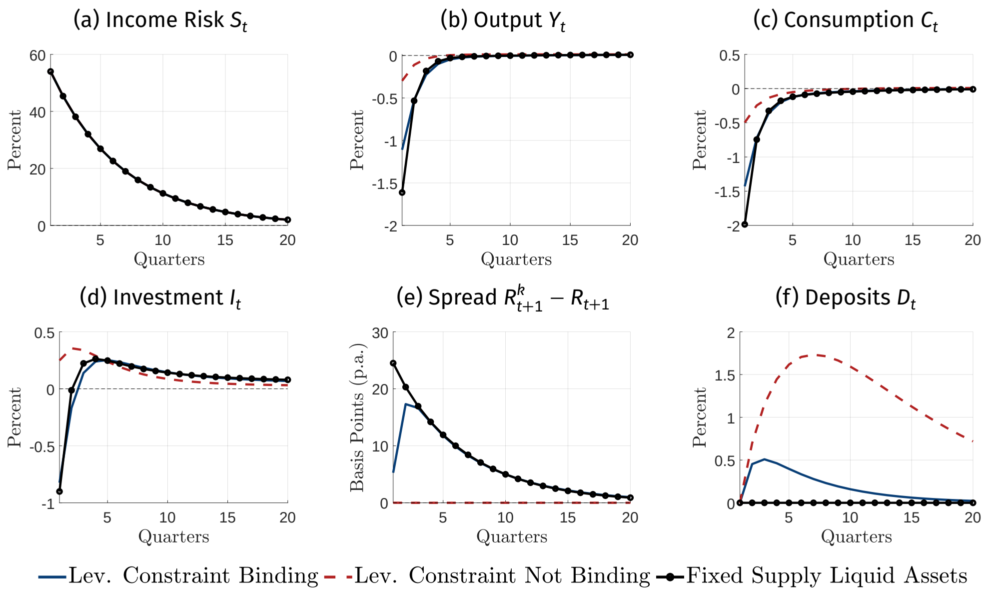


**Figure 3.5.2.** Comparison to an Economy Without Liquidity Transformation

*Notes:* Impulse response functions to 1 standard-deviation increase in the variance of income shocks. Blue solid lines show the response in the baseline model, where the leverage constraint is binding. Red dashed lines show the response in a counterfactual economy where the leverage constraint is not binding. Black lines with circles show the responses in the economy with an exogenous supply of liquid assets.

uid savings is curbed by increasing excess returns (panel e) and falling household income, amplifying the drop in consumption. This suggests that the limited supply of liquid savings is central for the larger contraction in consumption observed in Figure 3.5.1.

Figure 3.5.2 shows that, overall, the presence of the financial system can be stabilizing: it provides households with the liquid store of value that they demand, using these assets to provide credit for the economy. Furthermore, it suggests that banking frictions that impair liquidity transformation are central for the amplification of consumption and output, over and beyond constraints on lending. In the next counterfactual, I explicitly quantify the contribution of each of the roles of the banking sector in driving the amplification of the recession.

### 3.5.2.2 Stabilization policy and the role of liquidity transformation

My second counterfactual quantifies the role of liquidity provision through looking at unconventional monetary policy. More precisely, I consider a credit policy that attempts to mimic the quantitative easing policies conducted by the Federal Reserve during the last financial crisis. I model this credit policy following Gertler and Karadi (2011). The literature has emphasized the effects on asset prices and credit of these policies. Instead, I highlight the liquidity consequences of the monetary intervention.

In particular, I consider two ways of financing the credit policy. One with issuance of reserves, that increases the supply of liquid savings; the other without reserves, that does not. Two findings arise from this counterfactual. First, impaired banks' liquidity provision can explain around half of the amplification of a shock to household income risk observed in Figure 3.5.1. Second, and related, liquidity creation is an important channel of the monetary intervention, over and beyond the effects on credit.[23]

**Credit policy**

The stabilization policy works as follows. The central bank purchases claims on physical capital from financial intermediaries. Contrary to banks, the monetary authority is only constrained by its balance sheet, and contrary to households the central bank can adjust its asset holdings every period. Let $K_t^{CB}$ denote the total amount of claims on capital purchased by the central bank. Then, under this policy, the market clearing condition for claims on capital (3.3.44) is now given by,

$$K_t \;=\; K_t^h + K_t^b + K_t^{CB}. \tag{3.5.1}$$

Recall that a tightening of the leverage constraint goes in hand with a rise in spreads. The central bank purchases capital claims when banks' leverage constraint is binding in an attempt to reduce expected excess returns. In particular, I assume that central bank's capital purchases obey the following rules:

$$K_{t+1}^{CB} \;=\; \psi_t^{CB} K_{t+1}, \tag{3.5.2}$$

$$\psi_t^{CB} \;=\; \theta^{CB}\mathbb{E}_t\big[(R_{t+1}^k - R_{t+1}) - (\bar{R}^k - \bar{R})\big], \tag{3.5.3}$$

that is, the monetary authority increases asset purchases when expected excess returns are above their steady-state value. By purchasing claims on capital, the central bank eases the leverage constraint (3.3.25). This stimulates lending and investment, inducing an increase in asset prices and a fall in excess returns. How this policy is financed is crucial here, however, because it affects the creation of liquid deposits. I look at two financing schemes that allow me to disentangle the effects of liquidity provision.

**Central bank intervention with issuance of reserves**. In the first financing scheme, the central bank entirely finances asset purchases by issuing interest-bearing reserves $M_t^{CB}$ to banks. Contrary to claims on capital, I assume that banks cannot divert reserves. Therefore, they do not enter directly in the leverage constraint (3.3.25).

23. Cui and Sterk (2021) also discuss the liquidity consequences of quantitative easing in a model without banking frictions and limited household heterogeneity.

As a result, by non-arbitrage, the real interest rate paid on reserves is the same as on deposits.

The swap of claims on capital for reserves in the balance sheet of banks is non-neutral to the extent that banks are constrained. The central bank, by purchasing assets from banks, directly relaxes the leverage constraint (3.3.25). Note that central for this is the assumption that reserves (that banks obtain in exchange for selling the claims on capital) do not enter in the leverage constraint. This allows banks to purchase new claims. This has two consequences. First, the monetary intervention stimulates lending and, therefore, the demand for investment goods. What is more, this policy expands the supply of liquid assets. In order to finance the new purchases of capital claims, banks issue more liquid deposits to households. Therefore, this unconventional monetary policy not only supports investment but also increases the supply of liquid assets. Finally, following Gertler and Karadi (2011), I assume that any capital gains or losses incurred by the monetary authority are rebated to the fiscal authority.

**Central bank intervention without issuance of reserves**. Above, liquidity creation and asset purchases go hand in hand. In order to tell these two roles apart, I also entertain a tax-financed scheme. This second financing scheme assumes that the central bank does not issue reserves $M_t^{CB} = 0$. Instead, asset purchases are financed through lump-sum taxes on the shareholders of banks, entrepreneurs.[24] Entrepreneurs, being wealthy households, have low marginal propensities to consume and are hence less likely to respond strongly to lump-sum taxes.

More precisely, the monetary authority obtains funds from taxing entrepreneurs. Then the central bank uses these funds to purchase capital claims from banks. This, again, relaxes the leverage constraint of banks. Therefore, the policy still stimulates lending and investment. Now, however, banks do not have to issue more deposits to increase lending. Instead, banks purchase new claims on capital using the funds obtained from selling their assets to the central bank. Thus, this policy does not command a direct increase in the supply of liquid assets. This is so because this policy does not involve a swap of assets. As a consequence, comparing this financing scheme to the previous one allows me to gauge the effects of liquidity provision. Finally, in order to avoid large fiscal distortions, I assume here that any capital losses or gains are rebated to the entrepreneurs in form of lump-sum transfers.[25]

24. This second financing scheme does not attempt to model an actual policy conducted by central banks. Instead, it is a useful device to disentangle the channel of liquidity provision.

25. Fiscal consequences can be large here because the government does not have to pay interest rates on reserves. Rebating capital gains to entrepreneurs avoids this.

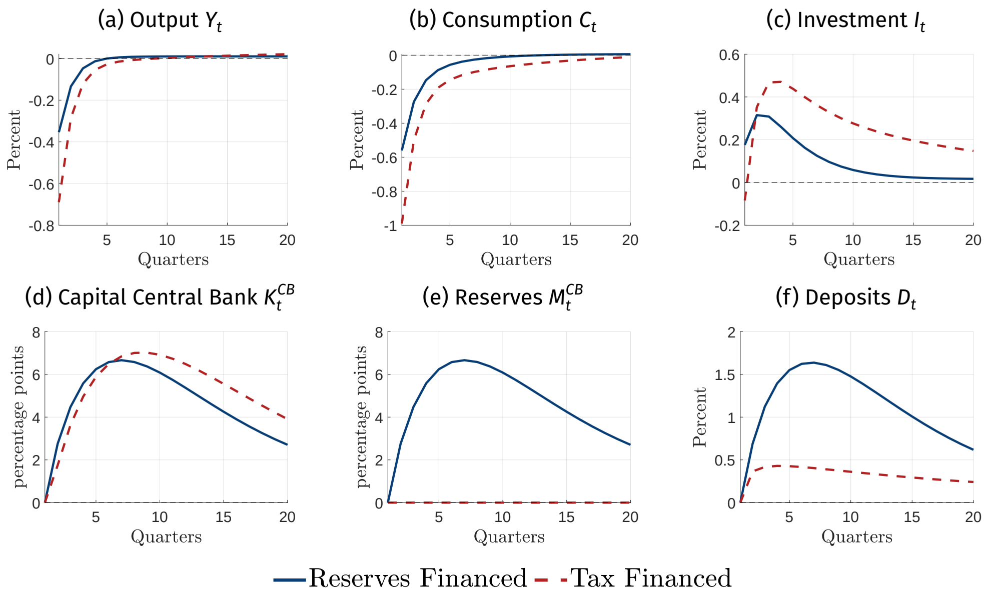


**Figure 3.5.3.** Stabilization Policy: The Role of Liquidity

*Notes:* Impulse responses to a one-standard deviation income risk shock when the leverage constraint is binding under credit policy. Blue solid lines shows the case where the central bank finances asset purchases by issuing reserves to banks. In this case, I set the response of the monetary authority to fluctuations in excess returns to $\theta^{CB} = 100$, see equations (3.5.2) and (3.5.3). Red dashed lines show the situation where, instead, asset purchases are financed through lump-sum taxes on entrepreneurs. In this case, I set the response to excess returns to target a similar increase in the balance sheet of the central bank as in the case of a reserves-financed scheme. This implies $\theta^{CB} = 17$.

### The liquidity consequences of credit policy

Figure 3.5.3 shows the impulse responses under the credit policy to a one-standard deviation income risk shock when the leverage constraint is binding. Blue solid lines show the case where the credit policy is financed by issuing reserves to banks. In this case, I set the response of the central bank to fluctuations in expected excess returns equal to $\theta^{CB} = 100$. This implies that, in this scenario, the central bank almost eliminates fluctuations in expected excess returns entirely – not shown –, replicating the dynamics observed when the leverage constraint does not bind (cf. red dashed lines, panel l in Figure 3.5.1). Red dashed lines show the responses in the situation where asset purchases are financed through lump-sum taxes on entrepreneurs, the shareholders of banks. Here, I set the response to fluctuations in expected excess returns to target a similar increase in the balance sheet of the central bank as in the case of a reserve-financed scheme. This implies $\theta^{CB} = 17$. Recall that tax-financed asset purchases have limited effects on the supply of liquid assets, but similar effects on lending. This allows me to disentangle the consequences of impaired liquidity transformation.

Under the reserves-financed scheme (solid blue lines), the central bank completely eliminates the amplification arising from a binding leverage constraint (cf. Figure 3.5.1). The central bank purchases claims on capital from banks (panel d), in exchange for reserves (panel f). This relaxes the leverage constraint, allowing banks to increase lending. As a result, aggregate investment increases (panel c) by about 0.3%. Importantly, the monetary intervention expands the supply of liquid assets. In order to finance new asset purchases, banks issue more deposits (panel f), that now increase more than 1.5%. Therefore, now, banks satisfy households' increased demand for liquid savings, arising from heightened income risk. Since now households achieve the desired liquidity of their portfolios, consumption is stabilized (panel b). The increase in investment and the muted consumption response dampen the contraction in output (panel a). Thus, the central bank, by stimulating lending and the supply of liquid assets, stabilizes the economy and replicates the dynamics observed when the leverage constraint does not bind (compare to red dashed lines in Figure 3.5.1).

Liquidity provision is essential for stabilizing the economy, observe red dashed lines. In this case, a similar increase in the balance sheet of the central bank (panel d) is now financed through lump-sum taxes on entrepreneurs. Again, the central bank, by purchasing assets from banks, relaxes the leverage constraint. This allows banks to extend more loans, increasing investment (panel c). The increase in investment is now even larger than with a reserves-financed scheme. The response of investment is stronger because, without liquidity provision, excess returns remain higher – not shown–, inducing banks to lend more. Recall that this financing scheme has weaker effects on the supply of liquid assets. As a result, the expansion in deposits is now three times smaller (panel f). Although investment expands more, consumption (panel b), and hence output (panel a), still fall twice as much as with a reserves-financed scheme: without liquidity creation, the effectiveness of policy halves. Figure 3.B.3 in appendix 3.B.2 makes this point even starker. There, I show that without the expansion in liquid assets the central bank has to double asset purchases, relative to a reserves-financed policy, in order to stabilize expected excess returns.

In other words, liquidity transformation is central for an economy to be resilient to shocks that shift the demand for liquid savings. A policy that increases both lending and the supply of liquid assets entirely eliminates the amplification arising from banking frictions. In contrast, a policy that only stimulates investment but does not improve liquidity provision is only able to reduce the amplification by a half. The implications of this finding are twofold. First, liquidity provision is an important channel of the monetary intervention. Second, impaired banks' liquidity transformation can explain around half of the amplification of a shock to household income risk when the leverage constraint binds. Thus, banking frictions not only amplify shocks by constraining lending to firms, but also by hampering the supply of liquid assets to households.

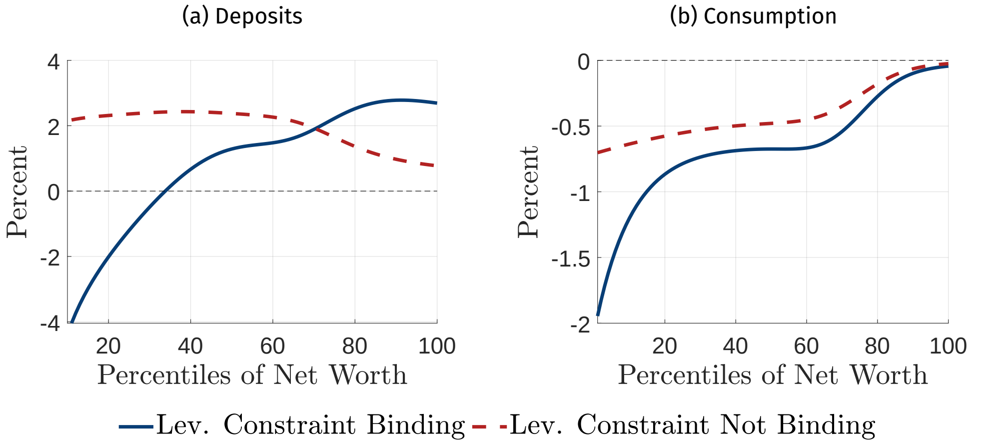


**Figure 3.5.4.** Change in Deposits and Consumption by Percentile of Net Worth

*Notes:* Left panel displays the equilibrium change in deposits over the net worth distribution two quarters after the household income risk shock. The bottom 10% of the distribution is not shown since some households hold zero deposits. The right panel shows the equilibrium change in consumption two quarters after the household income risk shock. Red dashed lines show the case of non-binding leverage constraint. Blue solid lines show the scenario with a binding leverage constraint. Changes computed using a local linear regression technique with a Gaussian kernel and a bandwidth of 0.1.

### 3.5.3 The role of heterogeneity and inequality

Banking frictions, by impairing liquidity transformation, amplify shifts in the demand for liquid assets. Beyond the aggregate consequences, financial frictions also affect households to different extents, depending on their wealth and portfolio composition, and have marked implications for inequality. This section first discusses how the state of the financial system affects the heterogeneous responses of households to an increase in income risk and, second, its implications for wealth inequality.

#### 3.5.3.1 Heterogeneous household responses to income risk

Figure 3.5.4 shows the equilibrium response of households' deposits and consumption over the net worth distribution. It focuses on the response two quarters after the shock to household income risk. Blue solid lines show the case when the leverage constraint binds. Red dashed lines show the case of a non-binding leverage constraint.

When the financial system is unconstrained, all households increase their holdings of liquid deposits in response to the shock to household income risk, observe the red dashed line in panel (a). Households at the bottom half of the wealth distribution increase their savings in bank deposits particularly strongly. They hold little wealth to begin with and, therefore, are poorly insured against the surge in income risk. The mirror image of this is that households at the bottom of the wealth distribution cut their consumption by around 0.7%, while wealth-rich households are able to smooth the fall in income arising from the recession, see the red dashed line in panel (b). Recall that in this case the supply of liquid assets was relatively elastic (cf. panel (a) in Figure 3.3.1).

This picture changes dramatically when the leverage constraint prevents banks from issuing deposits. This case is shown by the solid lines in Figure 3.5.4. In this situation, the financial system is not able to meet the increase in households' demand for deposits. Instead, households have to be discouraged from demanding deposits through a larger fall in income. Not all households are equally affected by this larger contraction in income, however. Households at the bottom of the wealth distribution are unable to smooth the larger decline in aggregate income when the leverage constraint binds. As a consequence, their consumption drop more than doubles, to almost 2%. This is so although they run down their liquid savings in an attempt to smooth consumption, observe the solid line in panel (a). Consequently, wealth-poor households not only cut consumption more when the financial system is impaired, but they become more exposed to the increase in income uncertainty too.

The consumption decline of households at the middle of the wealth distribution does not exhibit such a marked amplification. Still, also the middle class accumulates less liquid deposits than when the leverage constraint is not binding. This contrasts with the behavior of households at the top of the distribution, who barely see their consumption affected by the deeper recession. These households even increase their holdings of bank deposits by more. This is so because many households at the top of the wealth distribution are entrepreneurs that receive profit income. Markups are countercyclical due to sticky prices.[26] Recessions, thus, mean windfall gains to this group of households. As a consequence, it is particularly costly for them to become workers in a deeper recession, when labor income is lower, and they self-insure against this event by accumulating even more liquid assets.

#### 3.5.3.2 Response of wealth inequality to income risk

The different saving decisions of households induced by the deeper recession when the financial system is impaired have marked implications for wealth inequality. This can be observed in Figure 3.5.5, that displays the response of the Gini coefficient for net worth, panel (a), and the response of the wealth share of the top 10%, panel (b), after the shock to household income risk. Blue solid lines show the case of a constrained financial system, and the dashed red lines the situation where the leverage constraint does not bind. Although effects on wealth inequality are not large, the dynamics of inequality crucially depend on the state of the financial system. When the leverage constraint is not binding, inequality falls after the first quarters, since

26. The impulse response of aggregate profits is provided in Figure 3.B.1 in appendix 3.B.

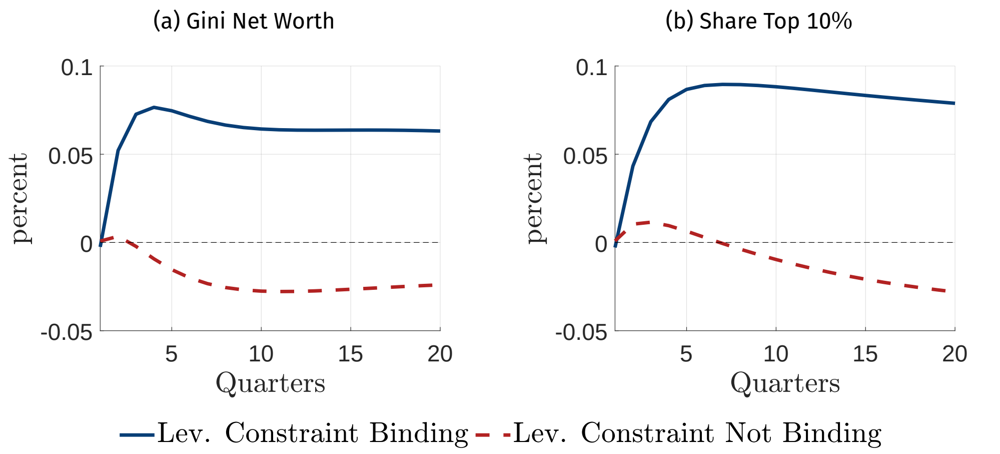


**Figure 3.5.5.** Consequences of a Household Income Risk Shock on Wealth Inequality

*Notes:* Impulse responses of the Gini index for net worth (left panel) and the wealth share of the top 10% of the net worth distribution (right panel) to a household income risk shock. Blue solid lines: leverage constraint binding. Red dashed lines: leverage constraint not binding. A 0.1% increase in the Gini coefficient for net worth, implies that the Gini indexes increases from its steady-state value of 0.78 to 0.7808.

wealth-poor households are the ones that accumulate precautionary savings more strongly, as discussed previously.

Wealth inequality increases in response to the shock to household income risk when the leverage constraint binds, however. At first glance, this is surprising since the desired shift in the portfolio allocation sharply reduces the price of capital when the leverage constraint binds. Heterogeneity in households portfolios implies that wealth-rich households lose the most from falling asset prices. To understand this, Figure 3.5.6 shows the estimated holdings of liquid deposits relative to illiquid capital by quintile of the net worth distribution in the steady state. The bottom quintile is not reported since some of these households hold non-positive amounts of capital. The liquidity of household portfolios is clearly declining with wealth. [27] Therefore, falling asset prices hurt the wealth-rich the most, that hold more illiquid portfolios. Yet, as shown previously, when the financial system is impaired, wealth-poor households reduce their liquid savings in response to the fall in aggregate income, while rich households still increase their liquid savings.[28] Therefore, this second channel dominates over the change in asset prices. This leads to an overall increase in wealth inequality when the financial system is constrained.

27. This pattern is consistent with the data, see Bayer *et al.* (2019) and Luetticke (2021).
28. In appendix 3.B.1 I provide the change in total savings and capital holdings, see Figure 3.B.2.

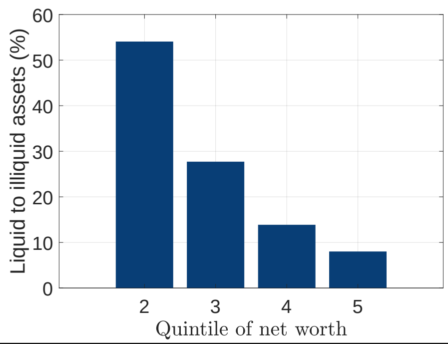


**Figure 3.5.6.** Liquid Deposits over Illiquid Assets at the Steady State by Wealth Quintile
*Notes:* Holdings of liquid deposits relative to estimated illiquid assets by quintile of the net worth distribution at the steady state. Computed using a local linear regression technique with a Gaussian kernel and a bandwidth of 0.1.

## 3.6 Conclusion

This paper investigates how financial frictions, by impairing banks' liquidity transformation, affect the propagation of shocks that shift the desired liquidity of households' portfolios. I first provide novel empirical evidence that one such shock, a shock to household income uncertainty, is more recessionary when financial frictions are tight. Second, I study the drivers behind these findings in a two-asset New Keynesian model with heterogeneous households and banks that perform liquidity transformation, subject to a leverage constraint.

At the empirical level, I find that the state of the financial system is fundamental for the aggregate consequences of a shock to household income risk. If financial conditions are loose, the creation of liquid deposits is ample, and the recessionary consequences of the shock mild. On the contrary, if financial conditions are tight, the economy sees a deep recession and a muted creation of liquid savings.

Next, at the theoretical level, I study how financial frictions and liquidity transformation affect the propagation of swings in the demand for liquid savings in a formal business-cycle model with heterogeneous agents. Next to sticky prices, I incorporate portfolio choice between liquid bank deposits and illiquid claims on capital. Banks perform liquidity transformation, subject to a leverage constraint. I use the model to study the interaction between shifts in the demand for liquid savings and the ability of the financial system to perform liquidity transformation. I do so through looking at a household income risk shock. I find that a binding leverage constraint amplifies the aggregate consequences of such shock, capturing the gist of the empirical findings. A limited supply of liquid assets from the banking sector when the leverage constraint binds is central for this. Constrained banks cannot meet the households' increased demand for liquid deposits. With sticky prices, the deposit market clears through falling household income and falling asset prices, amplifying the drop in consumption. I show that the impaired ability of the financial system to perform liquidity transformation can account for half of the amplification when the leverage constraint binds. The other half being accounted by a muted response of bank credit. Thus, banking frictions not only matter because they constrain lending, but also because they restrict the supply of liquid savings to the household sector.

There are fruitful areas for future research. This paper highlights that the financial system, through the provision of liquid deposits, is an important source of insurance for households that can be hampered by financial frictions. The work on the optimal design of both, insurance policies, as unemployment benefits (McKay and Reis, 2021), and macro-prudential regulation (Elenev *et al.*, 2021), could be extended to account for this feature. Financial frictions usually come with highly non-linear dynamics (Brunnermeier and Sannikov, 2014; Bocola, 2016). In future work, it could be interesting to extend the model to examine the non-linear interaction between precautionary savings and an occasionally binding leverage constraint, using recent advances in global solution methods for economies with heterogeneous agents (Fernández-Villaverde *et al.*, 2019).

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## Appendix 3.A Empirical appendix

This appendix regards the empirical analysis discussed in section 3.2. I first provide the exact source and definition of variables used in the analysis. Next, I show the empirical response to a household income risk shock of further variables and the difference between tight and loose financial condition. Finally, I provide the details regarding robustness checks discussed in the main text.

### 3.A.1 Data

Unless otherwise noted, all data are taken from the FRED, Federal Reserve of Saint Louis. Nominal variables are deflated using the Consumer Price Index for All Urban Consumers: All Items.

- Output; Real Gross Domestic Product, Billions of Chained 2012 Dollars, Quarterly, Seasonally Adjusted Annual Rate
- Consumption: Real Personal Consumption Expenditures, Billions of Chained 2012 Dollars, Quarterly, Seasonally Adjusted Annual Rate
- Investment: Real Gross Private Domestic Investment, Billions of Chained 2012 Dollars, Quarterly, Seasonally Adjusted Annual Rate
- Unemployment: Unemployment Rate, Percent, Quarterly, Seasonally Adjusted
- Nominal interest rate: 3-Month Treasury Bill: Secondary Market Rate, Percent, Quarterly, Not Seasonally Adjusted
- Income risk shocks: Bayer *et al.* (2019)
- Credit: Bank Credit, All Commercial Banks, Billions of U.S. Dollars, Quarterly, Seasonally Adjusted
- Deposits: Households and Nonprofit Organizations; Total Currency and Deposits Including Money Market Fund Shares; Asset, Level, Billions of Dollars, Quarterly, Not Seasonally Adjusted minus Households and Nonprofit Organizations; Money Market Fund Shares; Asset, Level, Billions of Dollars, Quarterly, Not Seasonally Adjusted
- NFCI: Chicago Fed National Financial Conditions Index, Index, Monthly, Not Seasonally Adjusted. Aggregated to quarterly frequency by averaging over the quarter.

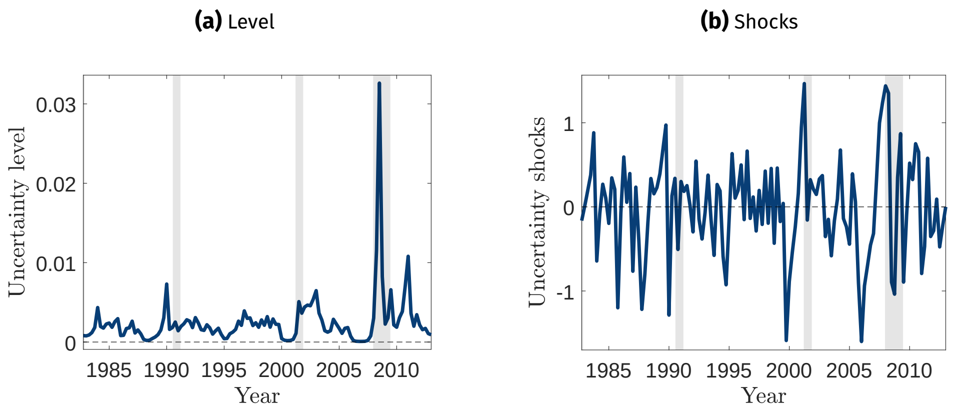


**Figure 3.A.1.** Estimated level of household uncertainty and income risk shocks

*Notes:* Panel (a): Estimated standard-deviation of persistent income shocks. Panel (b): Shocks to income risk. Both series have been estimated in Bayer *et al.* (2019). NBER recession dates are displayed with gray areas.

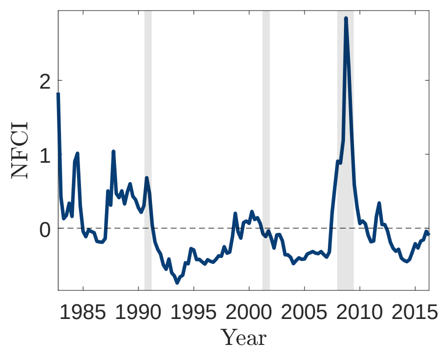


**Figure 3.A.2.** National Financial Conditions Index (NFCI)

*Notes:* Time series of the National Financial Conditions Index (NFCI) from 1983 to 2013. Weekly data aggregated to quarterly observations by averaging over the period and demeaned such that positive values indicate tighter financial conditions than average. NBER recession dates are displayed with gray areas.

### 3.A.2 Baseline empirical responses

This appendix provides further empirical responses to a household income risk shock, complementary to those discussed in section 3.2.2. Figure 3.A.3 provides the empirical responses to a household income risk shock when financial conditions are tight (top panel) and when financial conditions are loose (bottom panel). Furthermore, Figure 3.A.4 shows the estimated difference between the response during times of tight and loose financial conditions. In both cases, gray areas delimited by dashed lines show block bootstrapped 66% confidence bounds.

Figure 3.A.3 makes clear that the aggregate consequences of shock to household income risk crucially depend on the state of the financial system. Output drops nearly five times more when financial conditions are tight and remains depressed for a longer period, relative to periods of loose financial conditions, observe panels (a). This is driven by a larger fall in both aggregate consumption and investment. In times of tight financial conditions, consumption drops by about 0.5% and investment contracts by around 3%. These responses contrast with the muted responses observed in periods of benign financial conditions, observe the bottom panel of Figure 3.A.3. Consumption barely falls and aggregate investment tends to increase after eight quarters, leading to an increase in both output and consumption. These different responses impact the labor market too, see panels (f). Unemployment persistently increases with tight financial conditions, reaching a maximum increase of about 0.5 percentage points, while it barely moves when financial conditions are loose. The behavior of household deposits and bank credit markedly depend of the state of the financial system. During periods of tight financial conditions, despite the increase in household income uncertainty, the overall contraction in output leads to a drop of aggregate deposits of nearly one percent, while bank credit contracts by almost 0.5%. This contrasts with the marked increase in households deposits during periods of benign financial conditions, while credit does not fall in this case, as observed in times of tight financial conditions. Moreover, Figure 3.A.4 shows that the differences just highlighted are statistically significant.

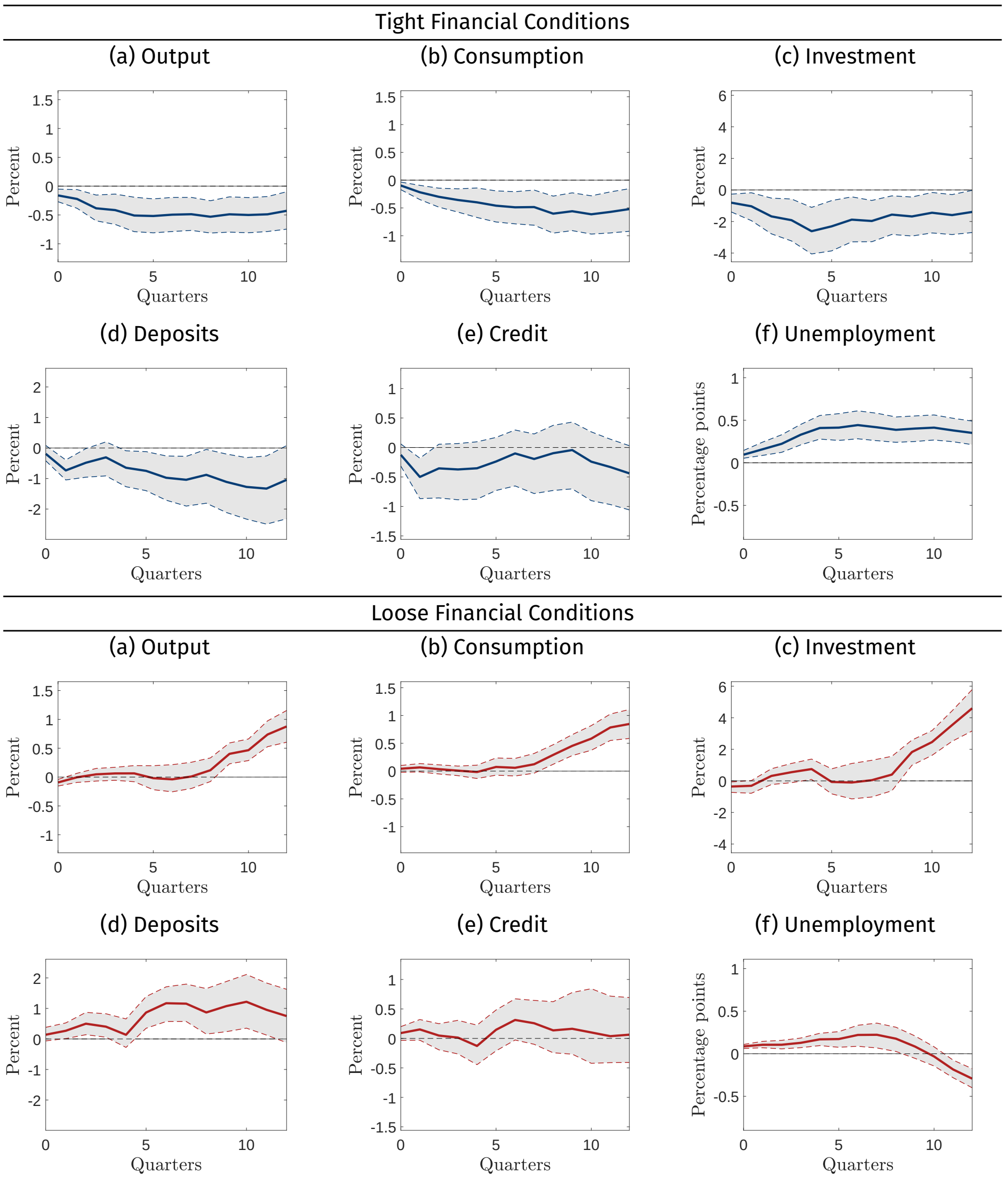


**Figure 3.A.3.** Empirical response to a household income risk shock

*Notes:* Estimated responses to one standard-deviation shock to household income risk, as identified in Bayer *et al.* (2019). The top panel shows the empirical responses when financial conditions are tight as measured by the National Financial Condition Index (NFCI). The bottom panel shows the responses when financial conditions are loose. Block bootstrapped 66% confidence bounds are shown in gray areas delimited by dashed lines. The unemployment rate is expressed in percentage points, the rest of variables in percents.

### 3.A.3 Robustness of empirical results

This appendix provides several robustness checks for the empirical results discussed in section 3.2. First, I show that results are similar after controlling for the business

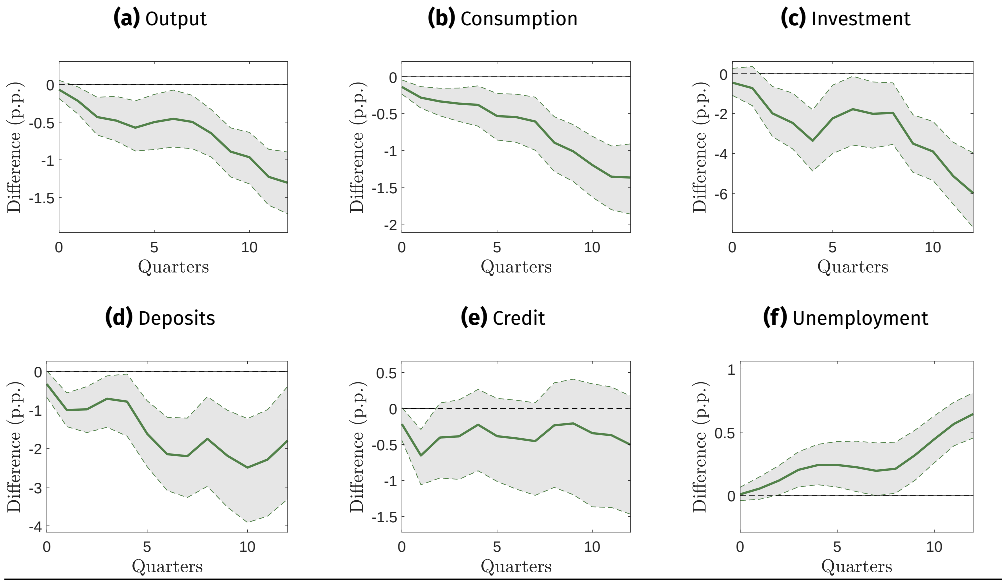


**Figure 3.A.4.** Difference Between Times of Tight and Loose Financial Conditions

*Notes:* Difference in the empirical response to a household income-risk shock, identified in Bayer *et al.* (2019), between times of tight financial conditions and times of loose financial conditons. For example, a value of $-1$ in panel (d), deposits, means that the response of deposits to a household income-risk shock during times of tight financial conditions is 1 percentage point smaller than during periods of loose financial conditions. Block bootstrapped 66% confidence bounds are shown in gray areas with dashed lines.

cycle. Next, I show that similar results are obtained if I use leverage as a measure for financial conditions. Finally, I discuss the results based on an alternative identification scheme that controls for the contemporaneous response of aggregate variables.

#### 3.A.3.1 Controlling for the state of the business cycle

As can be observed in Figure 3.A.2, times of tight financial conditions sometimes coincide with economic slumps, the last financial crisis being a salient example of this. Therefore, a potential concern is that the empirical findings presented in section 3.2.2 are driven by state-dependent responses between expansions and recessions, and not by the state of the financial system. In order to address this issue, I extend my baseline specification (3.2.1) in order to control for the state of the business cycle too. Towards this end, I first construct an indicator for the state of the business cycle, $\mathbb{I}^{BC}$, by using the unemployment rate. More precisely, I define the business cycle to be in an expansion $\mathbb{I}^{BC} = 1$ when the unemployment rate is above its mean over the period, and in a recession otherwise $\mathbb{I}^{BC} = 0$. Using this indicator, I consider the following specification:

$$
\begin{aligned}
y_{t+l} =& \mathbb{I}^{FT}_{t-1}\left[\alpha_{FT,l} + \phi_{FT,l}(L)\mathbf{x}_t + \beta_{FT,l}\frac{\varepsilon^s_t}{\sigma_s} + \mathbb{I}^{BC}_{t-1}\beta_{FTBC,l}\frac{\varepsilon^s_t}{\sigma_s}\right] \\
&+ (1-\mathbb{I}^{FT}_{t-1})\left[\alpha_{FNT,l} + \phi_{FNT,l}(L)\mathbf{x}_t + \beta_{FNT,l}\frac{\varepsilon^s_t}{\sigma_s} + \mathbb{I}^{BC}_{t-1}\beta_{FNTBC,l}\frac{\varepsilon^s_t}{\sigma_s}\right] \\
&+ \gamma_l \text{trend}_t + \nu_{t+l}\,,\; l \geq 0. \qquad (3.A.1)
\end{aligned}
$$

Therefore, now $\beta_{FT,l}$ ($\beta_{FNT,l}$) provides the response of variable $y_{t+l}$, at horizon $l$, to a household income risk shock when financial conditions are tight (loose) outside of recessions, while $\beta_{FTBC,l}$ ($\beta_{FNTBC,l}$) measures the additional effects of a period with tight (loose) financial conditions and a high unemployment rate $\mathbb{I}^{BC}_{t-1} = 1$. Figure 3.A.5 shows the estimated coefficients $\beta_{FT,l}$ and $\beta_{FNT,l}$ under specification (3.A.1) with black lines with circles, along the baseline estimated responses. As can be observed, results remain quite similar. Figure 3.A.6 shows the difference between responses during times of tight and loose financial conditions after controlling for the state of the business cycle.

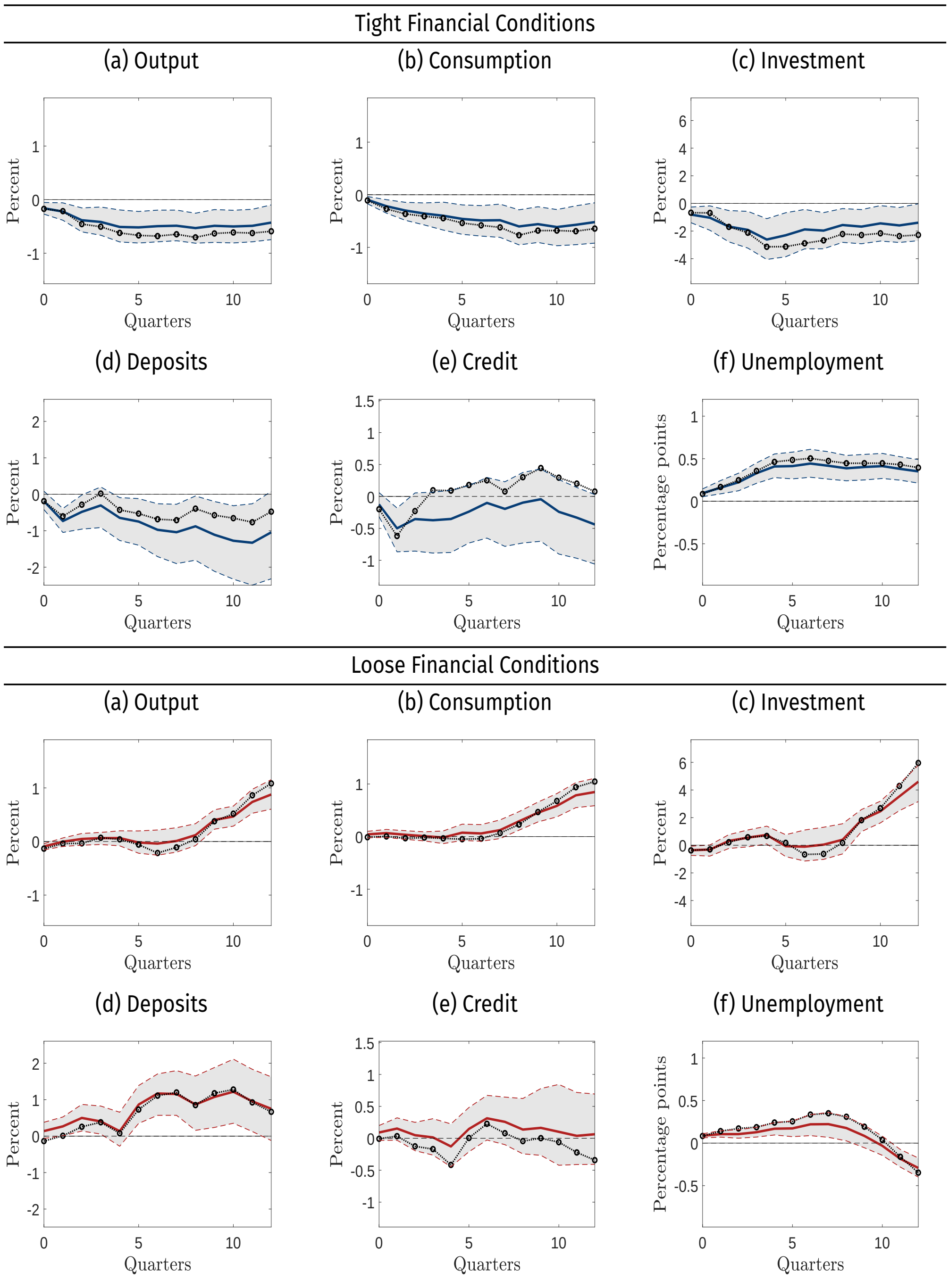


**Figure 3.A.5.** Aggregate consequences of an increase in income risk - Controlling for the state of the business cycle

*Notes:* Empirical response to a household income-risk shock. The top panel shows with blue lines the empirical responses when financial conditions are tight. The bottom panel shows with red lines the responses when financial conditions are loose. Black lines with circles show the response when financial conditions are tight (top panel) or loose (bottom panel) after controlling for the state of the business cycle. The economy is defined to be in a recession if the unemployment rate is above its average over the period. Block bootstrapped 66% confidence bounds are shown in gray areas delimited with dashed lines.

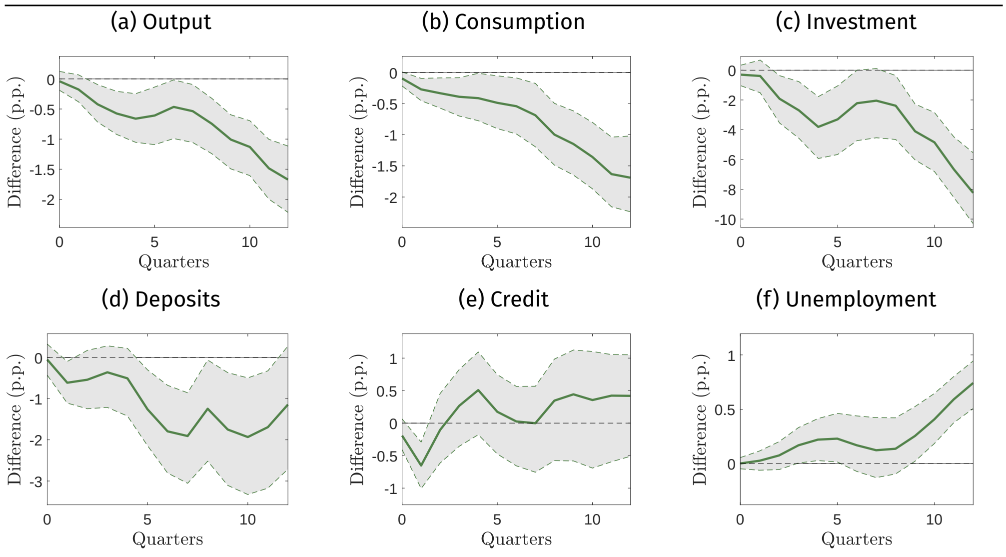


**Figure 3.A.6.** Difference between times of tight financial conditions and loose financial conditions - Controlling for the state of the business cycle

*Notes:* Difference in the empirical response to a household income-risk shock between times of tight financial conditions and times of loose financial conditons after controlling for the state of the business cycle. The economy is defined to be in a recession if the unemployment rate is above its average over the period. Block bootstrapped 66% confidence bounds are shown in gray.

### 3.A.3.2 Leverage as state variable

In the model presented in section 3.3, the state of the financial system is tightly linked to leverage in the financial sector. Yet, my indicator of financial conditions in the empirical results in section 3.2, the National Financial Conditions Index (NFCI), is composed by a leverage subindex, a risk subindex and a credit subindex. In order to ensure that leverage in my model is a good proxy for the financial conditions in the data, I use here the leverage subindex in my baseline specification (3.2.1) to measure financial conditions. More precisely, I define financial conditions to be tight, $\mathbb{I}^{FT}_{t-1} = 1$, if the leverage subindex of the NFCI is above its average over the period and to be loose otherwise.

Figure 3.A.7 displays the estimated responses to an increase in household income risk when the leverage subindex is used to measure financial conditions with black lines with circles, along with the baseline responses discussed in section 3.2.2. As it can be observed, the state-dependent nature of the responses becomes even more pronounced, and the differences remain statistically significant as shown in figure 3.A.8.

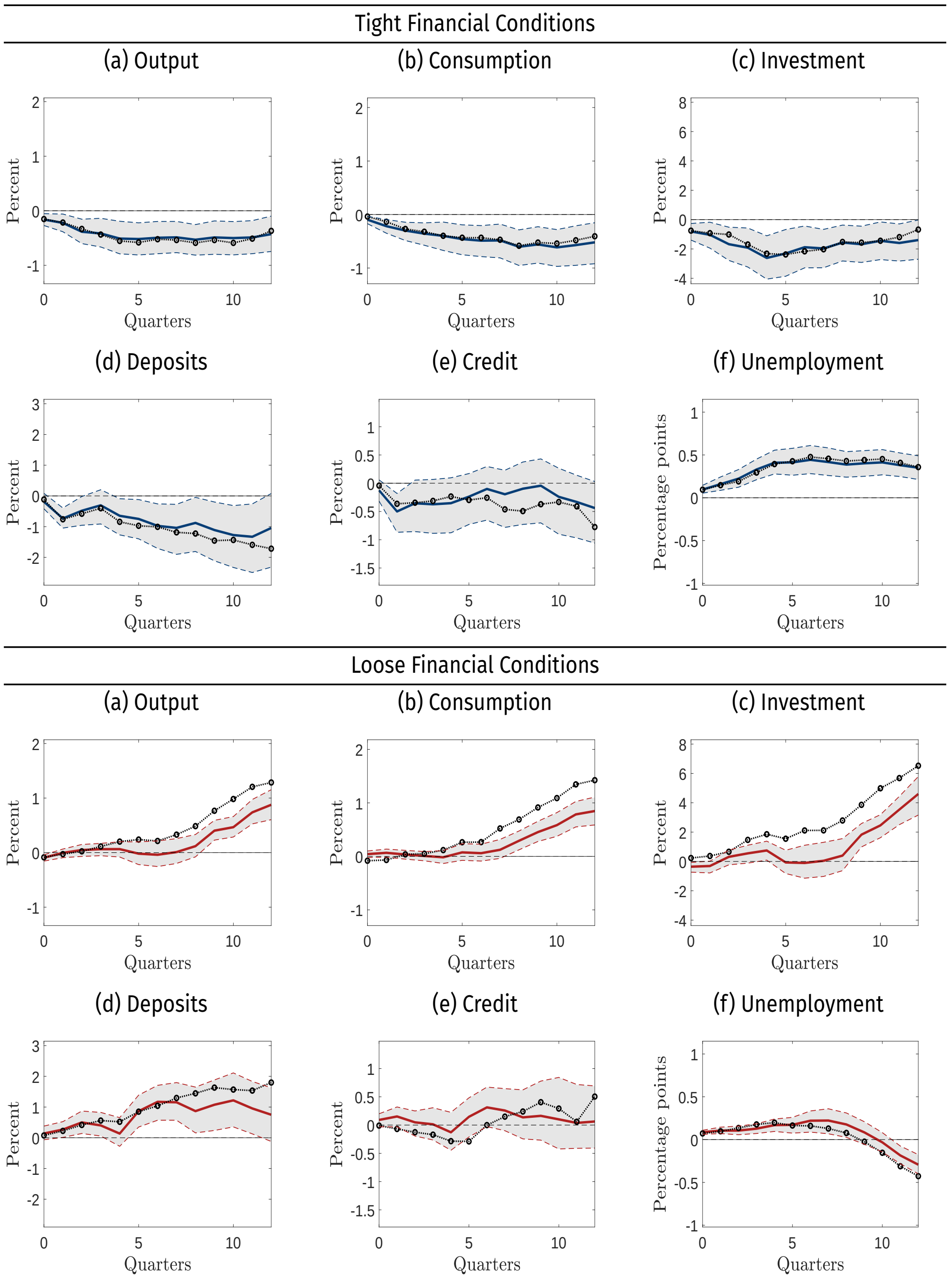


**Figure 3.A.7.** Aggregate consequences of an increase in income risk - Leverage as state variable

*Notes:* Empirical response to a household income-risk shock. The top panel shows the empirical responses when financial conditions are tight. The bottom panel shows the responses when financial conditions are loose. Black solid lines with circles show the responses when financial conditions are measured according to the leverage subindex of the NFCI. Block bootstrapped 66% confidence bounds are shown in gray areas delimited with dashed lines.

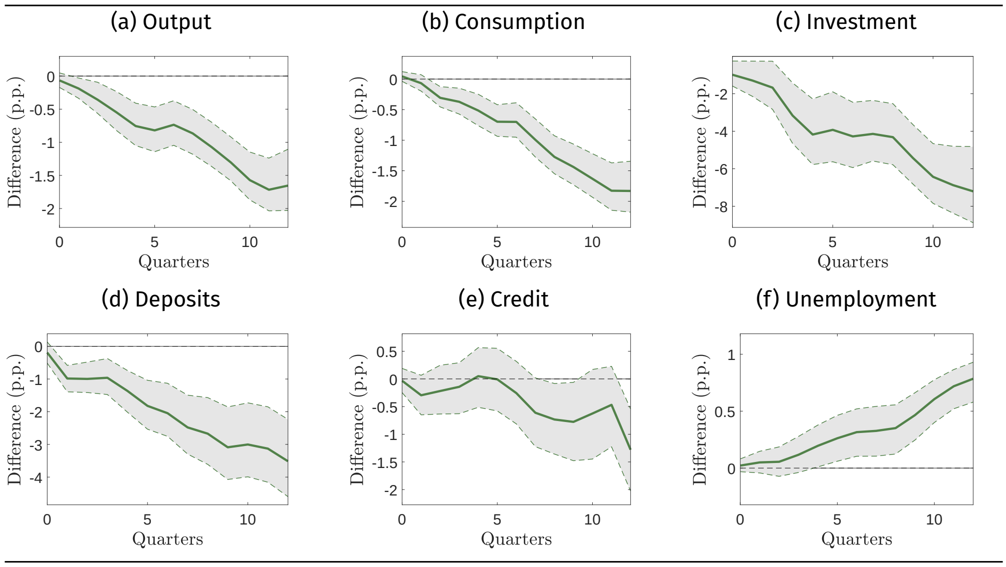


**Figure 3.A.8.** Difference between times of tight financial conditions and loose financial conditions - Leverage as state variable

*Notes:* Difference in the empirical response to a household income-risk shock between times of tight financial conditions and times of loose financial conditons as measured by the leverage subindex of the NFCI. Block bootstrapped 66% confidence bounds are shown in gray.

### 3.A.3.3 Alternative identification scheme

An important assumption in the baseline regression (3.2.1) is that the estimated shocks to household income risk identified in Bayer *et al.* (2019) are purely exogenous and orthogonal to other structural shock $\nu_{t+l}$ in the economy. Despite that by focusing on shocks to the variance of the persistent component of income, the uncertainty shocks that I employ are less likely to be contaminated by transitory fluctuations in the economy, I present additional empirical evidence in this appendix based on an alternative identification scheme.

My baseline specification can be understood as an Cholesky identified SVAR where income risk is ordered first. Here, I take opposite extreme assumption and control for all contemporaneous controls, except for income uncertainty itself. More precisely, I estimate:

$$
\begin{aligned}
y_{t+l} \;=\; & \mathbb{I}^{FT}_{t-1}\left[\alpha_{FT,l} + \phi_{FT,\tilde{x}_t,l}\tilde{\mathbf{x}}_t + \phi_{FT,x_{t-1},l}\mathbf{x}_{t-1} + \beta_{FT,l}\frac{\varepsilon^s_t}{\sigma_s}\right] \\
& + (1-\mathbb{I}^{FT}_{t-1})\left[\alpha_{FNT,l} + \phi_{FNT,\tilde{x}_t,l}\tilde{\mathbf{x}}_t + \phi_{FNT,x_{t-1},l}\mathbf{x}_{t-1} + \beta_{FNT,l}\frac{\varepsilon^s_t}{\sigma_s}\right] \\
& + \gamma_l \text{trend}_t + \nu_{t+l}\,,\, l \;\geq\; 0, \qquad (3.A.2)
\end{aligned}
$$

where $\tilde{\mathbf{x}}_t$ is a set of contemporaneous controls that include the unemployment rate, the log of real output, and the 3-month Treasury Bill. The lagged controls $x_{t-1}$ additionally include a lag of income uncertainty and a lag of the variable of interest $y$.

Figure 3.A.9 shows with black lines with circles the aggregate impulse responses under the alternative identification scheme (3.A.2), along with the baseline results discussed in section 3.2.2. Overall, the responses are close to the ones obtained under the baseline specification.

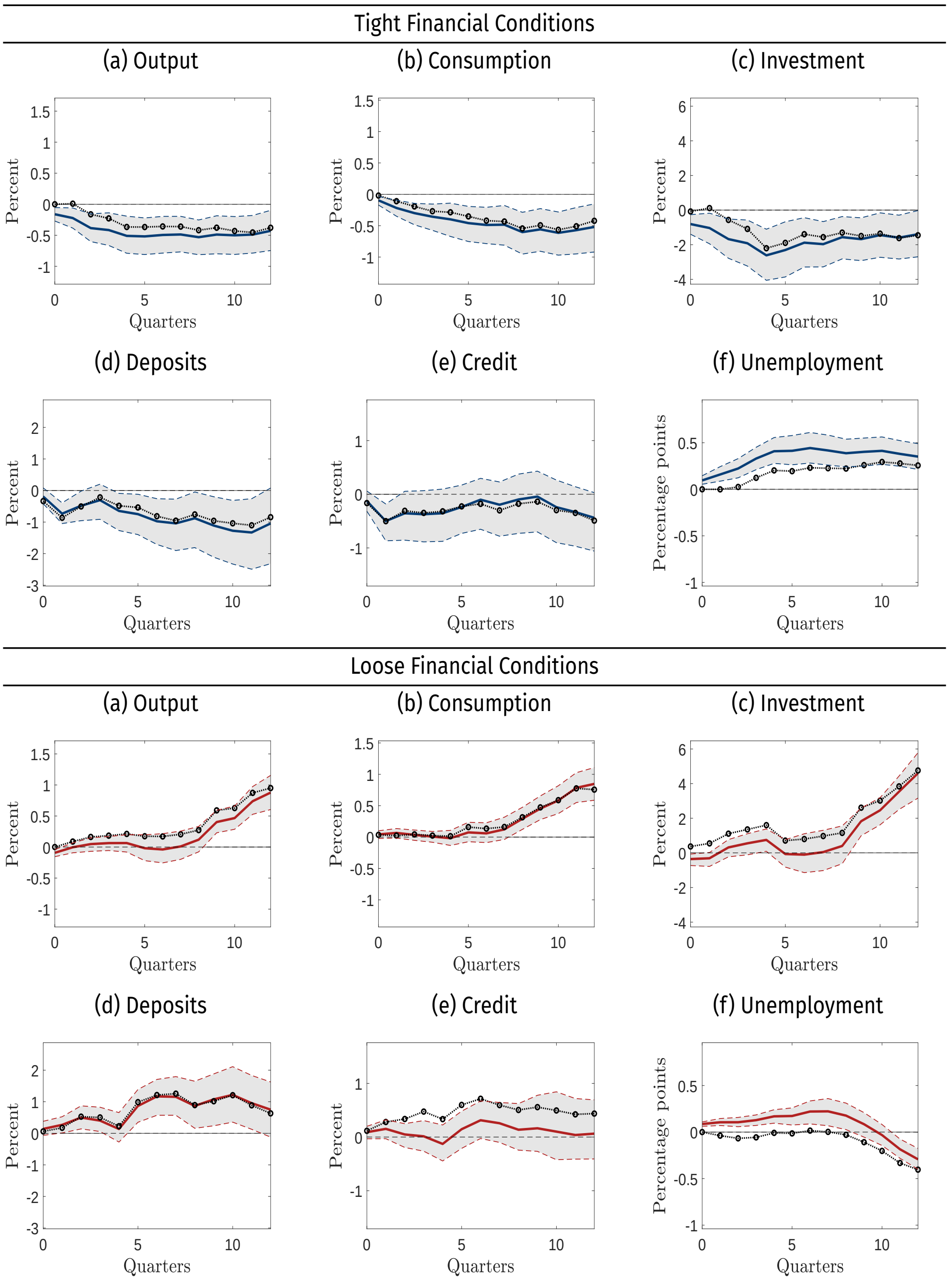


**Figure 3.A.9.** Aggregate consequences of an increase in income risk - Alternative Identification Scheme

*Notes:* Empirical response to a household income-risk shock. The top panel shows the empirical responses when financial conditions are tight. The bottom panel shows the responses when financial conditions are loose. Black solid lines with circles show the responses in a specification that includes contemporaneous controls, except income uncertainty itself. Block bootstrapped 66% confidence bounds are shown in gray areas delimited with dashed lines.

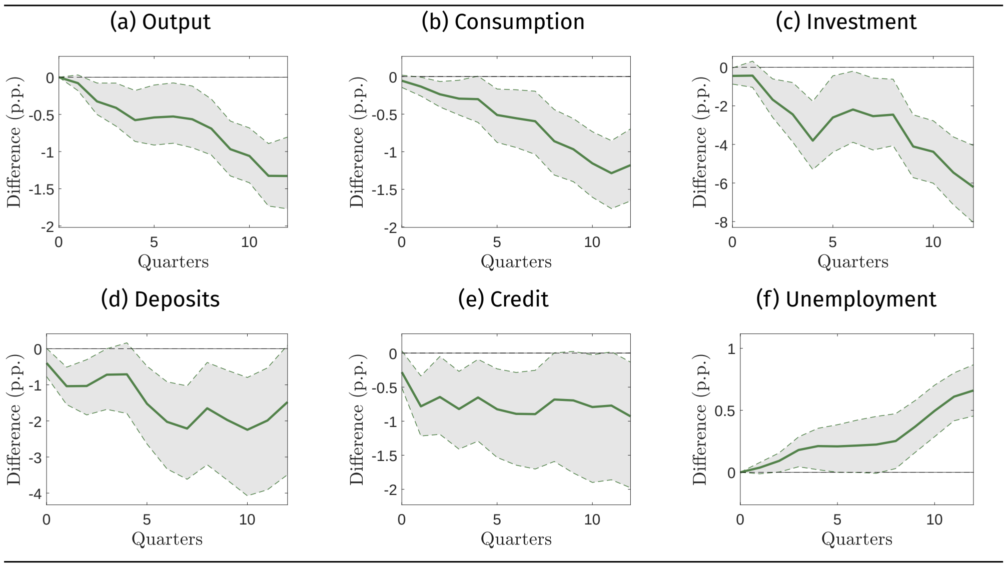


**Figure 3.A.10.** Difference between times of tight financial conditions and loose financial conditions under alternative identification scheme

*Notes:* Difference in the empirical response to a household income-risk shock between times of tight financial conditions and times of loose financial conditons in a specification that controls for contemporaneous controls, except for income uncertainty itself. Bootstrapped 66% confidence bounds are shown in gray.

## Appendix 3.B Additional impulse responses

This section contains complementary impulse responses to those shown in the main text. I first provide the response of additional variables to a household income risk shock. I next provide the aggregate consequences of a discount factor shock.

### 3.B.1 Aggregate and heterogeneous consequences

Figure 3.B.1 shows the response of additional variables to the household income risk shock considered in section 3.5.1. Blue solid lines show the impulse response functions when the leverage constraint is binding. Red dashed lines display the impulse response functions when the leverage constraint is not binding. Since capital and investment fall substantially more when the leverage constraint binds (see Figure 3.5.1), the dividends on this asset (panel a) and the price of capital (panel b) drop markedly. The larger contraction in output with an impaired financial system has a larger impact on tax revenues, and hence the government cuts government spending more strongly to balance the budget (panel c). A common feature of New Keynesian models with sticky prices is that profits are countercyclical to inflation (panel d), and they increase more when the leverage constraint binds, as a consequence of larger fall in output and, hence, inflation. Bank leverage increases in both situations, but

substantially more when the financial system is unconstrained (panel e).[29]. This is so despite that banks' net worth markedly drops with a binding leverage constraint (panel f), as a consequence of the drop in asset prices (panel b).

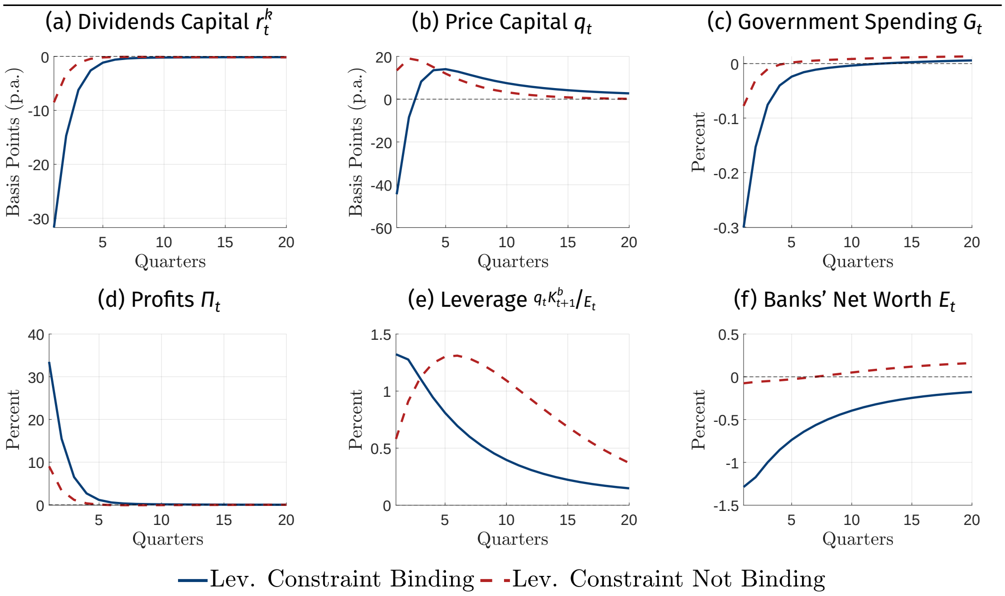


**Figure 3.B.1.** Impulse Response Functions to an Income Risk Shock

*Notes:* Impulse response functions to one standard-deviation increase in the variance of income shocks. Blue solid lines show the response in the baseline model, where the leverage constraint of financial intermediaries is binding. Red dashed lines show the response in a counterfactual economy where the leverage constraint is not binding.

Figure 3.B.2 shows the equilibrium response of total savings, $d_{i,t+1} + q_t k_{i,t+1}^h$, and illiquid claims on physical capital, $k_{i,t+1}^h$ along the net worth distribution two quarters after the shock to household income risk. Blue solid lines display the change when the leverage constraint binds. Red dashed lines show the case of a non-binding leverage constraint. In both cases, households reduce their holdings of illiquid claims on physical capital (panel b). This reduction is more pronounced when the leverage constraint is not binding, since excess returns do not increase (see Figure 3.5.1 in the main text). The difference is more pronounced for wealth-poor households. When the leverage constraint binds, these households already run down their savings in liquid deposits (see Figure 3.5.4 in the main text), and it is, therefore, more costly for them to further reduce their savings even in form of illiquid assets. Yet, because wealth-poor households hold most of their savings in form of liquid deposits, their total savings markedly fall when the leverage constraint binds (panel a). In the case

29. Leverage increases more on impact when the leverage constraint is binding because asset prices fall (see panel (b) in Figure 3.B.1). Leverage quickly takes over with an unconstrained financial system, since the expansion in credit is larger in this case (see Figure 3.5.1).

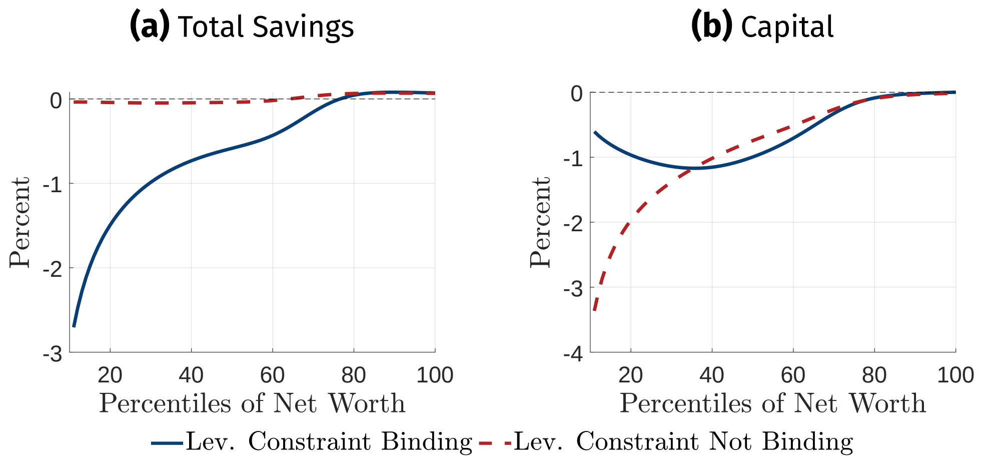


**Figure 3.B.2.** Change in individual total savings and capital

*Notes:* Left panel displays the equilibrium change in individual total savings $d_{i,t+1} + q_t k^h_{i,t+1}$ over the net worth distribution two quarters after the household income risk shock. The right panel shows the equilibrium change in capital holdings $k^h_{i,t}$ two quarters after the household income risk shock. The bottom 10% of the distribution is not shown since some households hold zero assets. Red dashed lines show the case of non-binding leverage constraint. Blue solid lines show the scenario with a binding leverage constraint. Changes by net worth percentile are computed using a local linear regression technique with a Gaussian kernel and a bandwidth of 0.1.

of a non-binding leverage constraint, overall savings move little at all percentiles of the wealth distribution, as the fall in claims on physical capital (panel b) is largely offset by the increase in savings in form of liquid bank deposits (see Figure 3.5.4).[30]

### 3.B.2 Stabilization policy

Figure 3.B.3 shows the impulse responses under the credit policy to a one-standard deviation income risk shock that increases households' demand for liquid savings when the leverage constraint is binding. Blue solid lines show the case where credit policy is financed by issuing reserves to banks. Red dashed lines show the responses in the situation where asset purchases are financed through lump-sum taxes on entrepreneurs, the shareholders of banks. In both situations I assume that the responses of the central bank to expected excess returns is equal to $\theta^{CB} = 100$. This implies that in both cases the central bank almost eliminates fluctuations in expected

30. The small changes in total savings when the leverage constraint is not binding (dashed line in panel (a) of Figure 3.B.2) is consistent with the muted response on impact of wealth inequality (dashed lines, Figure 3.5.5 in the main text). The response of individual total savings a few quarters later – not reported here – does show an larger build up of precautionary savings by wealth-poor households when the leverage constraint does not bind. This is consistent with the later fall in wealth inequality observed in Figure 3.5.5 for the case of an unconstrained financial system.

excess returns – not shown. As it can be observed in panel (d), the central bank has to double the size of its balance sheet when asset purchases are financed through lump-sum taxes (red dashed line) in order to achieve a similar stabilization to the case where the policy increases liquid assets (blue solid line).

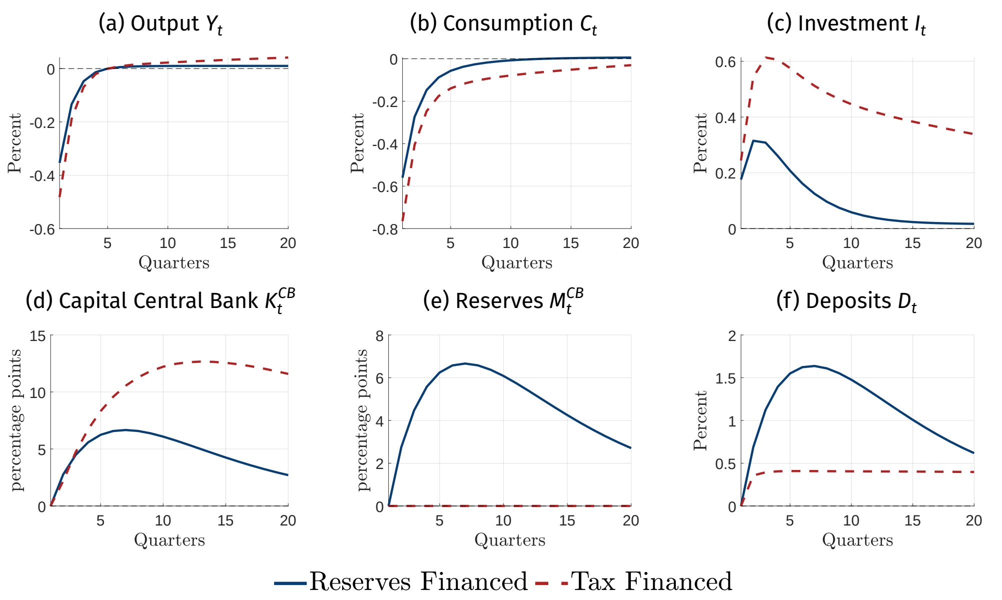


**Figure 3.B.3.** Stabilization Policy

*Notes:* Impulse responses to a one-standard deviation income risk shock when the leverage constraint is binding under credit policy. Blue solid lines shows the case where the central bank finances asset purchases by issuing reserves to banks. Red dashed lines show the situation where, instead, asset purchases are financed through lump-sum taxes on entrepreneurs. In both cases, I set the response of the monetary authority to excess returns to $\theta^{CB} = 100$, see equations (3.5.2) and (3.5.3).

### 3.B.3 Discount factor shock

Figure 3.B.4 shows the effects of a shock that increases the discount factor of households $\beta$ by 1%. The shock is assumed to follow a $AR(1)$ process with persistence equal to 0.8. Blue solid lines show the responses when the leverage constraint is binding. Red dashed lines display the responses when the leverage constraint is not binding.

The increase in the discount factor makes households more patient, inducing them to reduce consumption and increase savings. More precisely, households seek to increase savings in all assets: both in the illiquid and liquid asset. Therefore, this shock does not increase the preference of households for a more liquid portfolio. As a result, financial frictions do not amplify the aggregate consequences of an increase in the discount factor, observe panels (b), (c) and (d). This is so although the financial system creates less liquid deposits when the leverage constraint binds (panel g). In this case, since households only seek to increase overall savings, they simply accumulate more illiquid claims on physical capital (panel h).

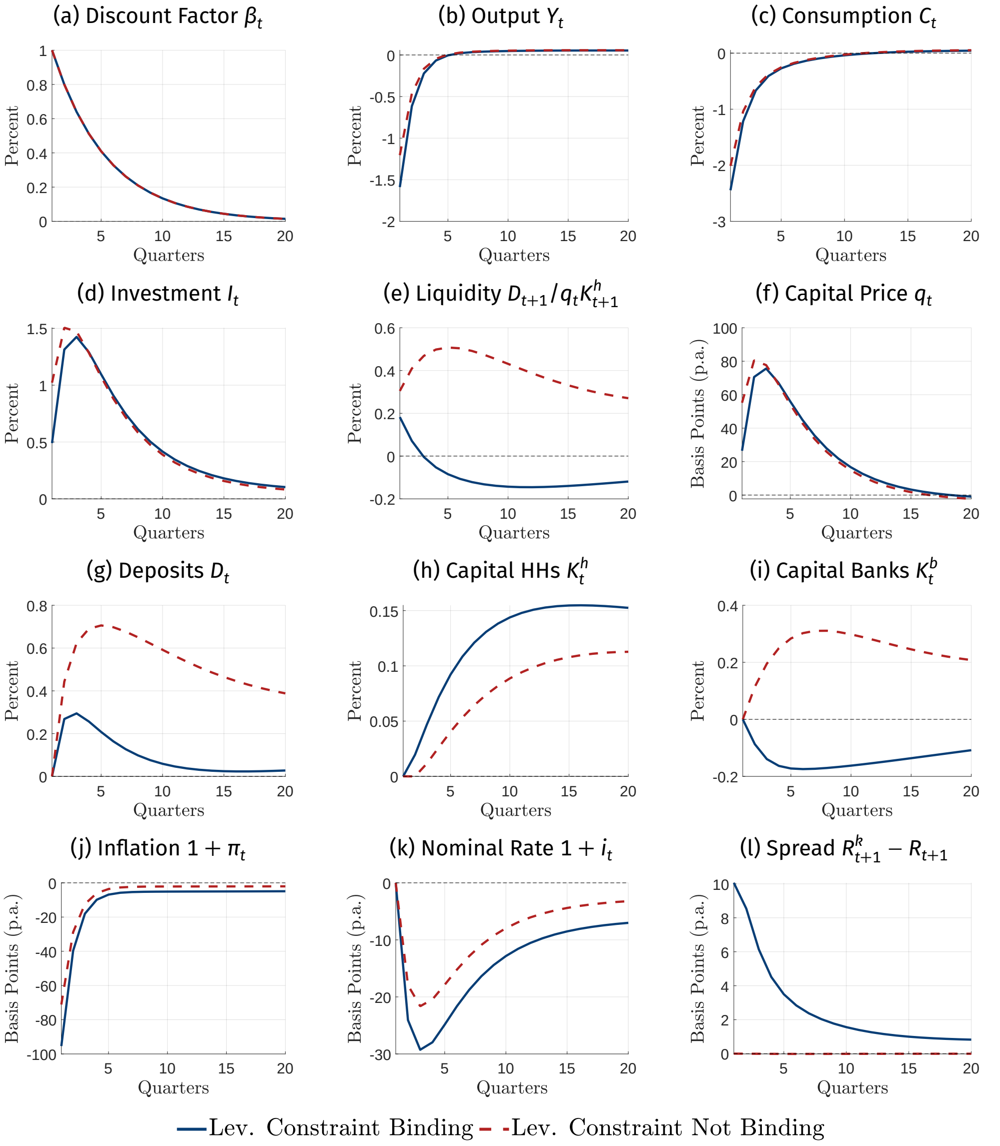


**Figure 3.B.4.** Impulse Response Functions to a Discount Factor Shock

*Notes:* Impulse response functions to one percent increase in the discount factor $\beta$ with persistence 0.8. Blue solid lines show the response in the baseline model, where the leverage constraint of financial intermediaries is binding. Red dashed lines show the response in a counterfactual economy where the leverage constraint is not binding.

## Appendix 3.C Robustness model results

This section provides robustness checks regarding the main quantitative results of the paper. Figure 3.C.1 shows dynamics of aggregate variables following an increase in income risk when the government adjusts the tax rate on income $\tau_t$ instead of government spending to balance the budget. In Figure 3.C.2 I consider an scenario with more flexible prices $\kappa = 0.09$, implying an average price duration of four quarters. Finally, Figure 3.C.3 entertains an scenario with a stronger response on the nominal interest rate to inflation $\theta_\pi = 1.5$. The amplification of idiosyncratic income risk shocks when financial frictions bind remain robust in all these scenarios.

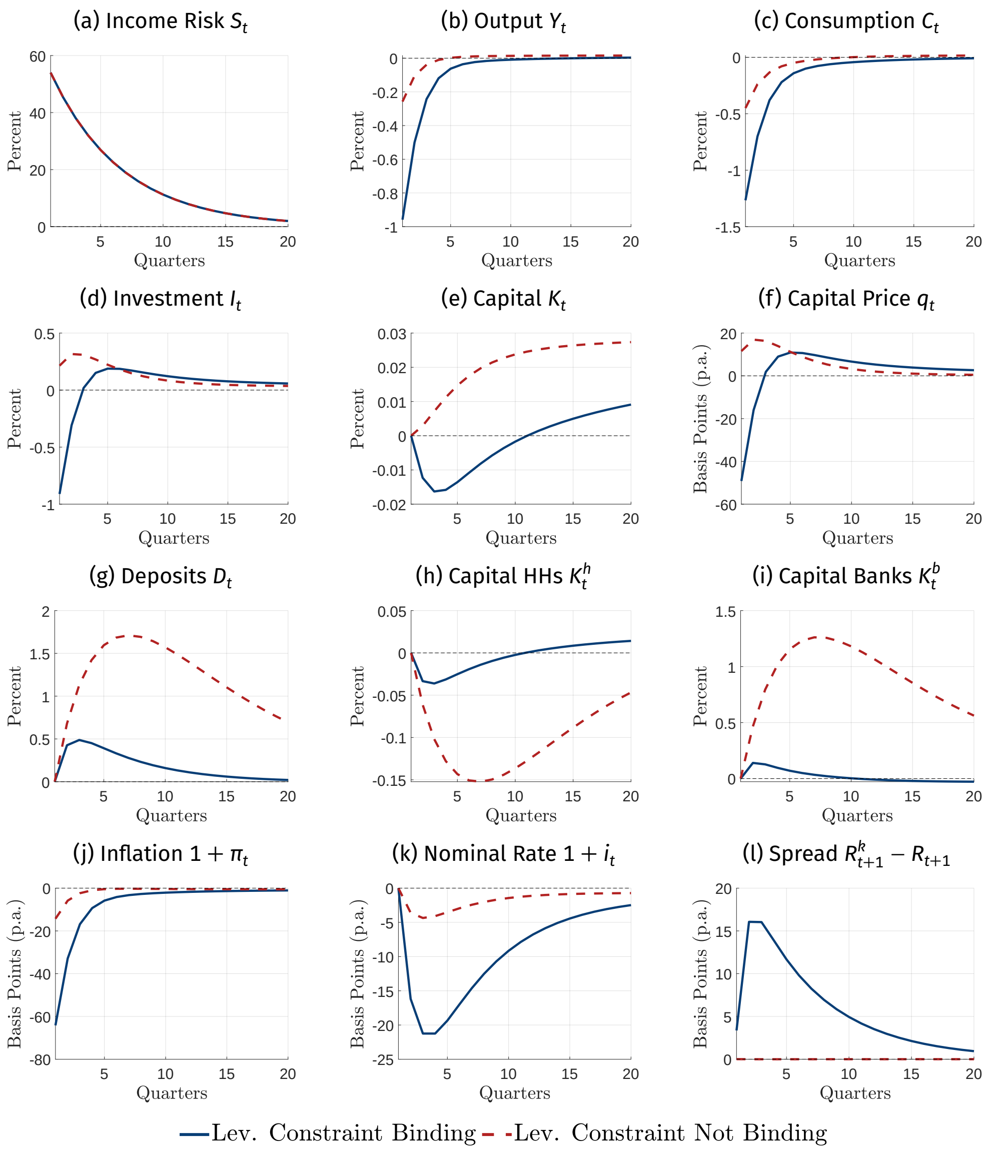


**Figure 3.C.1.** Aggregate consequences of an increase in income risk - $\tau_t$ adjusts

*Notes:* Impulse response functions to 1 standard-deviation increase in the variance of income shocks, when the income tax $\tau_t$ adjusts. Blue solid lines show the response in the baseline model. Red dashed lines show the response in a counterfactual economy where the leverage constraint is not binding.

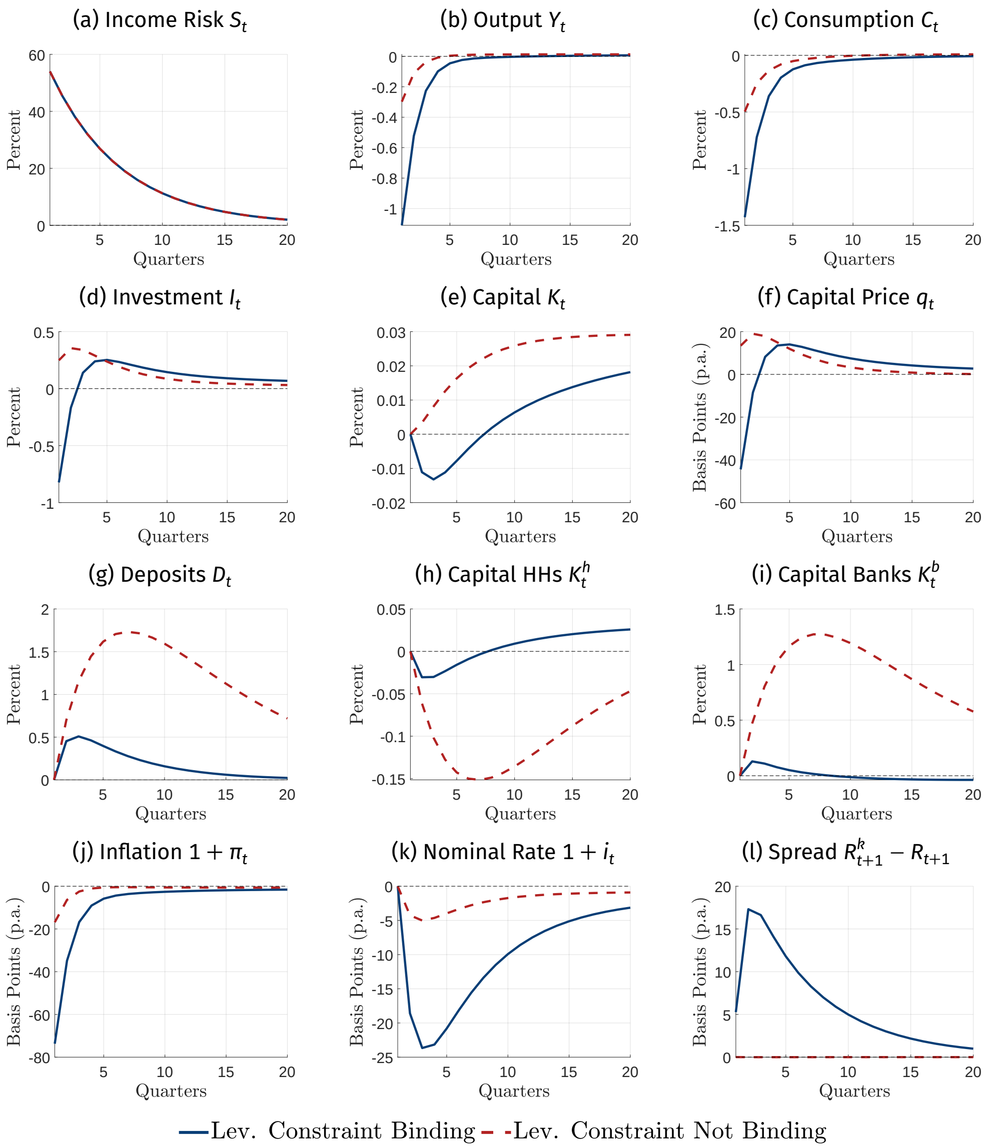


**Figure 3.C.2.** Aggregate consequences of an increase in income risk - More flexible prices

*Notes:* Impulse response functions to 1 standard-deviation increase in the variance of income shocks, with $\kappa = 0.09$ implying an average calvo duration of prices of 4 quarters. Blue solid lines show the response in the baseline model. Red dashed lines show the response in a counterfactual economy where the leverage constraint is not binding.

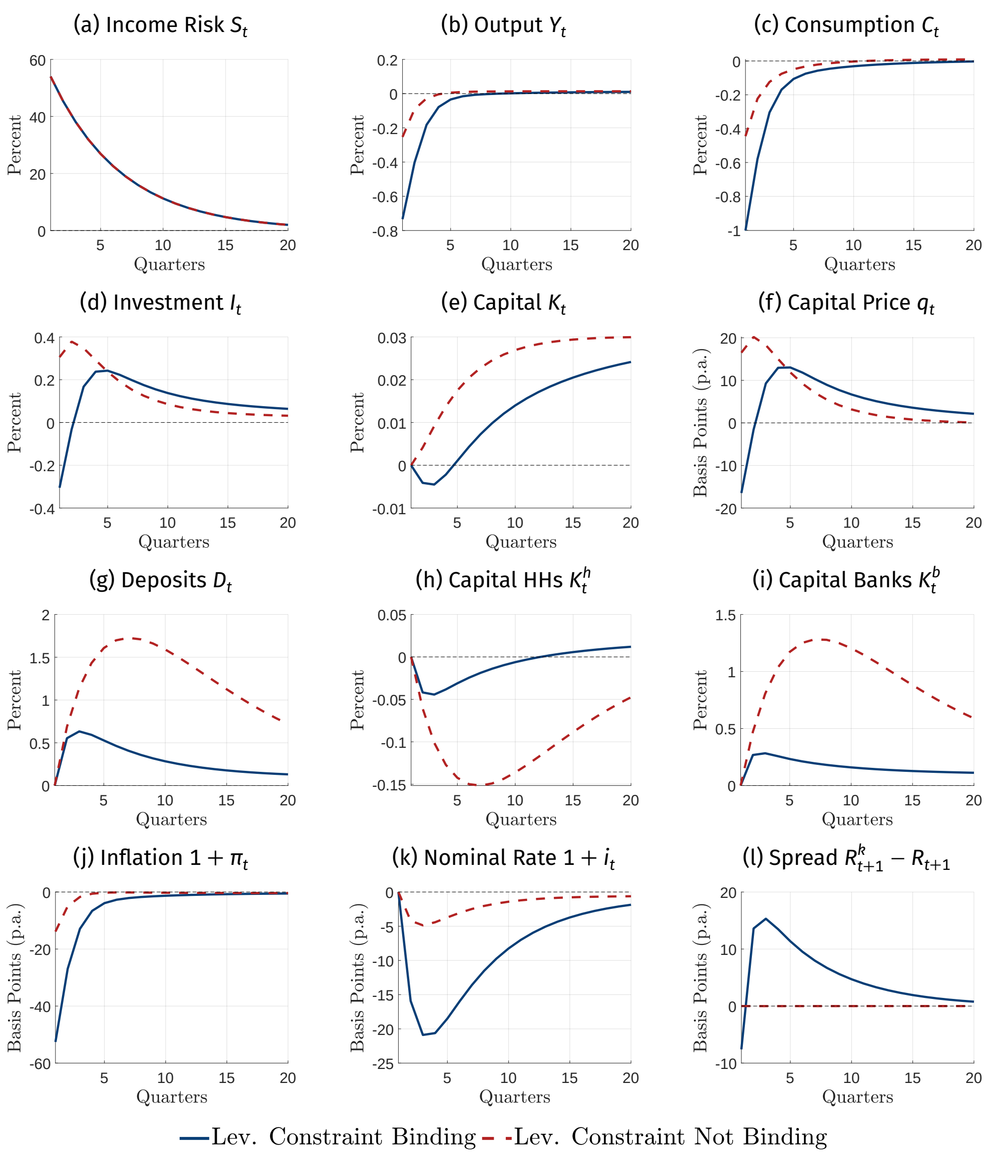


**Figure 3.C.3.** Aggregate consequences of an increase in income risk - Stronger response of monetary policy

*Notes:* Impulse response functions to 1 standard-deviation increase in the variance of income shocks, with a stronger response of the central bank to inflation $\theta_\pi = 1.5$. Blue solid lines show the response in the baseline model. Red dashed lines show the response in a counterfactual economy where the leverage constraint is not binding.

## Appendix 3.D Model with a fixed supply of liquid assets

This appendix contains the details regarding the two-asset model with a fixed supply of liquid assets discussed in section 3.5.2.1.

In this economy, the leverage constraint is not binding. More precisely, I assume that financial intermediaries always keep their supply of deposits, $D_t$, fixed at the steady-state level $\bar{D}$. Similarly, financial intermediaries are also assumed to keep their capital holdings fixed at the steady-state level $K_t^b = \bar{K^b}$. This assumption, effectively renders banks irrelevant for aggregate dynamics. I further assume that any capital gains or losses incurred by financial intermediaries are rebated to shareholders, the entrepreneurs. This ensures that the steady state of this economy without an active financial sector is the same as in my baseline, presented in section 3.3. The market clearing conditions for capital, (3.3.44), and deposits, (3.3.43), now read:

$$K_t = K_t^h + \bar{K^b}, \tag{3.D.1}$$

$$\bar{D} = \mathbb{E}_t\Big[\nu d_{a,t}^* + (1-\nu) d_{n,t}^*\Big]. \tag{3.D.2}$$