Reserve Accumulation, Macroeconomic Stabilization and Sovereign Risk *

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Abstract

We study the use of foreign reserves for macroeconomic stabilization purposes in a small open economy. Three key features characterize our model economy: (i) nominal rigidities, (ii) fixed exchange rates, and (iii) sovereign default risk. We argue that these features are prevalent in a large number of emerging economies. In this setup, reserve accumulation not only serves a precautionary role (hedging against roll-over risk) but it is also useful for macro-stabilization goals: in bad times, when aggregate demand is low, involuntary unemployment arises and output is low, the country can use (i.e. run down) its reserves to boost aggregate demand and output. We study the country's optimal external portfolio composition (debt and reserves), how the stabilization property of reserves interacts with the typical precautionary role, and how this affects the country's default incentives.

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1 Introduction

Emerging markets with currency pegs, or limited exchange rate flexibility, tend to accumulate a larger buffer of international reserves. This fact is illustrated in Figure 1. Panel (a) in this figure splits the reserve accumulation according to the degree of exchange rate flexibility and show that "fixers" have increased reserves at a much faster pace compared to "floaters." Well-known examples include of course China and Hong-Kong. Panel (b) also shows that the fraction of economies with limited exchange rate flexibility have remained stable.

One view regarding why countries that fix the exchange rate accumulate a larger stock of reserves is due to monetary considerations. For example, currency boards are required to hold external reserves equal to 100 percent of the domestic currency in circulation. In fact, these kind of monetary considerations play an important role in indicators of reserve adequacy studies at the IMF and central banks.

In this paper, we provide an alternative theory. We argue that facing rollover risk, central banks with limited exchange rate flexibility find optimal to hoard a larger amount of reserves for macroeconomic stabilization reasons. The key idea is that if a government faces a high sovereign spread in the midst of a recession, borrowing to stabilize aggregate demand becomes too costly. Hence, the government chooses to hold reserves in good times so as to use in bad times for macroeconomic stabilization.

We study the use of foreign reserves for macroeconomic stabilization purposes using a quantitative model of endogenous sovereign default. Three key features characterize our model economy: (i) nominal rigidities, (ii) fixed exchange rates, and (iii) sovereign default risk. In this setup, reserve accumulation not only serves a precautionary role (based on the portfolio hedging properties of having long-term debt and risk free assets, as in Bianchi et al., 2018) but it is also useful for macro-stabilization purposes. The presence of downward real wage rigidity that arises because of the combination of a fixed exchange rate and downward nominal rigidity generates a larger need for a precautionary buffer of reserves. The key insight is that when output is endogenous and depends on aggregate demand, more hedging not only allows for better consumption smoothing but also reduces the severity of recessions.

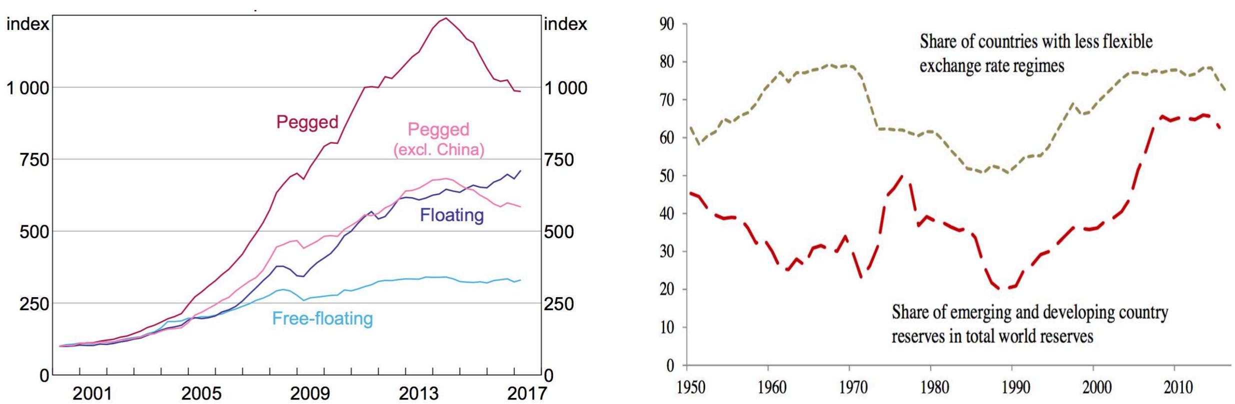

Figure 1: Reserves and exchange rate flexibility. The left panel is from Sunner et al. (2017) and it measures reserve accumulation as an index, with 2000.Q1=100. The right panel is from Ilzetzki et al. (2017).

Related literature. `To be written.`

Layout. The rest of the article proceeds as follows. Section **??** presents empirical evidence motivating our work. Section 2 introduces a quantitative model of a small open economy with tradable and non-tradable goods, downward wage rigidity and sovereign default risk. Section 3 discusses the calibration of the model, and section 4 studies the main results and quantitative implications of the theory. Section 5 concludes and outlines avenues for future research.

2 Model

2.1 Households

Households' preferences are given by

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \, u(c_t), \tag{1}$$

where c_t denotes private consumption in period t, $\beta \in (0,1)$ is the subjective discount factor, and $\mathbb{E}_t$ denotes expectation operator conditional on the information set available at time t.

The consumption good is assumed to be a composite of tradable (c^T) and non-tradable goods (c^N), with a constant elasticity of substitution (CES) aggregation technology:

$$c = C(c^T, c^N) = [\omega(c^T)^{-\mu} + (1-\omega)(c^N)^{-\mu}]^{-1/\mu}$$

where $\omega \in (0,1)$ and $\mu > -1$. The elasticity of substitution between tradable and non-tradable consumption is therefore $1/(1+\mu)$.

Each period households receive an endowment of tradable goods, y_t^T, and profits from the ownership of firms producing non-tradable goods, ϕ_t^N. We assume that y_t^T is stochastic and follows a stationary first-order Markov process. Households inelastically supply $\overline{h}$ hours of work to the labor market. Due to the presence of the wage rigidity (discussed in detail in the next subsections), households will only be able to sell $h_t \leq \overline{h}$ hours in the labor market. The actual number of hours worked, h_t, is determined by firms' labor demand and it is taken as given by the households. As it is usual in the sovereign debt literature, we assume that households are hand-to-mouth and that the government can distribute proceedings from external borrowing to the households using transfers, T_t, expressed in tradable units.[1] Households' sequential budget constraint, expressed in terms of tradables, is therefore given by

$$c_t^T + p_t^N c_t^N = y_t^T + \phi_t^N + w_t h_t + T_t, \tag{2}$$

where p_t^N denotes the relative price of non-tradables in terms of tradables and w_t denotes the wage rate in terms of tradable goods.

The households' problem consists of choosing sequences of c_t^T and c_t^N to maximize equation (1) given the sequence of prices $\{p_t^N, w_t\}_{t=0}^{\infty}$, endowments $\{y_t^T\}_{t=0}^{\infty}$, profits $\{\phi_t^N\}_{t=0}^{\infty}$, and transfers $\{T_t\}_{t=0}^{\infty}$. The optimality condition of this problem yields the equilibrium price of non-tradable goods as a function of the ratio between tradable and non-tradable consumption:

$$p_t^N = \frac{1-\omega}{\omega}\left(\frac{c_t^T}{c_t^N}\right)^{\mu+1}. \tag{3}$$

That is, the relative price of non-tradables is equal to the marginal rate of substitution between tradables and non-tradables.

2.2 Firms

Firms are competitive and have access to a decreasing-returns-to-scale technology to produce non-tradable goods with labor:

$$y_t^N = F\left(h_t\right), \tag{4}$$

where y_t^N denotes output of non-tradable goods in period t, $F(\cdot)$ is a continuous, differentiable, increasing and concave function. Firms' profits (expressed in units of tradables) each period are then given by

$$\phi_t^N = p_t^N y_t^N - w_t h_t. \tag{5}$$

[1] These transfers T_t can be either positive or negative. If the latter case, they constitute taxes.

The optimal choice of labor h_t equates the value of the marginal product of labor and the wage rate, all expressed in tradable units,

$$p_t^N F'(h_t) = w_t. \tag{6}$$

2.3 Government

As in Arellano and Ramanarayanan (2012) and Hatchondo and Martinez (2009), we assume that a bond issued in period t promises a deterministic infinite stream of coupons that decreases at an exogenous constant rate δ. In particular, a bond issued in period t promises to pay $\delta(1-\delta)^{j-1}$ units of the tradable good in period $t+j$, for all $j \geq 1$. Hence, debt dynamics can be represented by the following law of motion:

$$b_{t+1} = (1-\delta)b_t + i_t, \tag{7}$$

where b_t is the number of bonds due at the beginning of period t, and i_t is the amount of bonds issued in period t. The government issues these bonds at a price q_t, which in equilibrium depends on the government's portfolio decisions and the exogenous shocks.

The government has also access to a one-period risk-free reserve asset that pays one unit of the consumption good in the next period and is traded at a constant price q_a. Let $a_t \geq 0$ denote the government's reserve holdings at the beginning of period t.[2]

The above asset structure implies that the government faces the following budget constraint during each period in which it has access to debt markets:

$$T_t = a_t + q_t i_t - q_a a_{t+1} - \delta b_t - p_t^N g^N - g^T, \tag{8}$$

where g^T and g^N denote time-invariant expenditures in public goods (both tradable and non-tradable). This captures rigidities in the government budget constraint.

Upon default, the government retains control of its reserves and access to savings, but cannot borrow in the default period. Hence, the budget constraint becomes

$$T_t = a_t - q_a a_{t+1} - p_t^N g^N - g^T. \tag{9}$$

Government's default entails a utility loss $\psi_{d,t}$, which we assume to be increasing in tradable income. We think of this utility loss as capturing various default costs related to reputation,

[2] We could allow government to go short in a and have short-term and long-term debt. We expect this might be the case in situations in which income is relatively low and the government does not default. These are cases in dilution risk is more severe and hence short-term debt becomes more attractive (see Hatchondo et al., 2016).

sanctions, or misallocation of resources. [3]. We abstract from additional financial exclusion as a default penalty mechanism (i.e., the government can borrow again from international markets in the next period following a default).

2.4 Foreign Lenders

Bonds are priced in a competitive market inhabited by a large number of identical lenders, which implies that bond prices are pinned down by a zero expected profit condition. To introduce risk premium shocks, we assume that foreign lenders price bonds' payoffs using the following stochastic discount factor:

$$m_{t,t+1} = e^{-r-\kappa_t\left(\varepsilon_{t+1}+0.5\kappa_t\sigma_\varepsilon^2\right)}, \quad \text{with} \quad \kappa_t \geq 0. \tag{10}$$

This formulation introduces a positive risk premium because bond payoffs are more valuable to lenders in states in which the government defaults (i.e., in states in which tradable income shocks ε are low). Here, r is the discount rate, and κ_t is the parameter governing the risk premium shock. The risk premium shock follows a two-state Markov process with values $\kappa_L = 0$, $\kappa_H > 0$ and transition probabilities π_{LH}, π_{HL}. We assume that in normal times $\kappa_t = \kappa_L = 0$ and lenders are risk neutral. When $\kappa_t = \kappa_H$, lenders become risk averse and require a higher expected return to buy government bonds. A higher value of κ_H can be seen as capturing how correlated the small open economy is with respect to the lenders' income process, or alternatively, the degree of diversification of foreign lenders.

2.5 Equilibrium

In equilibrium the market for non-tradable goods clears:

$$c_t^N + g_t^N = F(h_t). \tag{11}$$

For the labor markets we follow Schmitt-Grohé and Uribe (2016) and assume that nominal wages (W_t) have a lower bound $\bar{w}$, by which $W_t \geq \bar{w}$ for all t.[4] The small open economy is under a currency peg therefore, assuming that the law of one price holds for tradable goods and that the price of foreign tradable goods is constant and normalized to one, implies that the wage rigidity

[3]For models of endogenous costs of defaults within the Eaton and Gersovitz (1981) framework see Mendoza and Yue (2009) and Sosa-Padilla (2017)

[4]In Schmitt-Grohé and Uribe (2016), $\bar{w}$ depends on the previous period wage. For numerical tractability, we take $\bar{w}$ as an exogenous (constant) value, as in Bianchi et al. (2016).

can be expressed as

$$w_t \geq \bar{w}, \tag{12}$$

where w_t is the real wage in units of tradables. That is, the nominal-wage downward rigidity becomes a real-wage downward rigidity.

Actual hours worked cannot exceed the inelastically supplied level of hours:

$$h_t \leq \overline{h}. \tag{13}$$

Labor market equilibrium implies that the following slackness condition must hold for all dates and states:

$$(w_t - \bar{w})\left(\overline{h} - h_t\right) = 0. \tag{14}$$

This condition implies that when the nominal wage rigidity binds, the labor market can exhibit involuntary unemployment, given by $\overline{h} - h_t$. Similarly, when the nominal wage rigidity is not binding, the labor market must exhibit full employment.

Combining the equilibrium price equation equation (3) with the market clearing condition for non-tradables equation (11), the relative price p_t^N can be expressed as

$$p_t^N = \mathcal{P}^N(c_t^T, h_t, g_t^N) = \frac{1-\omega}{\omega}\left(\frac{c_t^T}{F(h_t) - g_t^N}\right)^{\mu+1} \tag{15}$$

Using the households' budget constraint equation (2), the definition of the firms' profits, the market clearing condition equation (11), and the government budget constraint, we can write the economy's aggregate resource constraint as

$$c_t^T + g^T + q_a a_{t+1} = a_t + y_t^T + [q_t i_t - \delta b_t] \tag{16}$$

in periods in which the government repays, and

$$c_t^T + g^T + q_a a_{t+1} = a_t + y_t^T \tag{17}$$

when the government defaults.

A competitive equilibrium given government policies in our economy is then defined as follows:

Definition 1 (Competitive Equilibrium given policy). *Given initial values a_0 and b_0, an exogenous process $\{y_t^T\}_{t=0}^{\infty}$, government policies $\{T_t, b_{t+1}, d_t, g_t^N, g_t^T\}_{t=0}^{\infty}$, a competitive equilibrium is a sequence of allocations $\{c_t^T, c_t^N, h_t\}_{t=0}^{\infty}$ and prices $\{p_t^N, w_t, q_t\}_{t=0}^{\infty}$ such that:*

1. *Allocations solve households' and firms' problems at given prices,*
2. *Government policies satisfy the government budget constraint equation (8) - equation (9),*

3. *Bond pricing equation equation (22) holds,*
4. *The market for non-tradable goods clears,*
5. *The labor market satisfies conditions equation (12) - equation (14).*

2.6 Determination of Government Policies

Simplifying assumptions. In order to get simpler equilibrium conditions and to get a clearer picture of the incentives at play, we make some simplifying assumptions regarding households' preferences, the firms' production function and the public consumption of non-tradables. [5] Namely:

$$\begin{aligned} F(h_t) &= zh^{\alpha}, \\ u(c^T, c^N) &= \log\left(c^T\right) + \log\left(c^N\right), \text{ and} \\ g^N &= 0. \end{aligned}$$

We then have that equations equation (3), equation (6), and equation (11) become:

$$\begin{aligned} p_N &= \frac{c_T}{c_N}, \\ \alpha p_N h^{\alpha-1} &= w, \text{ and} \\ c_N &= zh^{\alpha} \end{aligned}$$

Combining these conditions we obtain:

$$h = \frac{\alpha}{w} c^T. \tag{18}$$

This is the equilibrium condition that will appear as an additional constraint in the government's problem below.

Recursive Government Problem. We consider the optimal policy of a benevolent government with no commitment, that chooses foreign reserve levels, external borrowing, and transfers to maximize households' welfare, subject to the aggregate resource constraint and implementability conditions. We focus on the Markov recursive equilibrium in which all agents choose sequentially.

Every period the government enters with access to financial markets, it evaluates the lifetime utility of households if debt contracts are honored against the lifetime utility of households if they

[5] All of the intuition developed below carries through relaxing the assumptions made in this subsection.

are repudiated. The government problem with access to financial markets can be formulated in recursive form as follows:

$$V\left(b,a,y^T\right)=\max_{d\in\{0,1\}}\left\{(1-d)V^r\left(b,a,y^T\right)+dV^d\left(a,y^T\right)\right\}, \tag{19}$$

where $d\in\{0,1\}$ is the discrete default decision, with 1 (0) representing default (repayment). $V^r(b,a,y^T)$ and $V^d(a,y^T)$ denote, respectively, the value of repayment and the value of default. The former is given by the Bellman equation

$$V^r\left(b,a,y^T\right)=\max_{b',a',h,c^T}\left\{u\left(c^T\right)+u\left(zh^\alpha\right)+\beta\mathbb{E}_{y^{T\prime}|y^T}\left[V\left(b',a',y^{T\prime}\right)\right]\right\} \tag{20}$$

subject to

$$\begin{aligned}c^T+g^T+q_a a' &= a+y^T+q\left(b',a',\ y^T\right)\left(b'-(1-\delta)b\right)-\delta b,\\ h &\leq \frac{\alpha}{\bar{w}}c^T,\ \text{and}\\ h &\leq \bar{h},\end{aligned}$$

where $q(b',a',y^T)$ denotes the bond price schedule, taken as given by the government. The value of default is given by

$$V^d\left(a,y^T\right)=\max_{c^T,h,a'}\left\{u\left(c^T\right)-\psi_d\left(y^T\right)+u\left(zh^\alpha\right)+\beta\mathbb{E}_{y^{T\prime}|y^T}\left[V\left(0,a',y^{T\prime}\right)\right]\right\} \tag{21}$$

subject to

$$\begin{aligned}c^T+q_a a' &= y^T+a,\\ h &\leq \frac{\alpha}{\bar{w}}c^T,\ \text{and}\\ h &\leq \bar{h}.\end{aligned}$$

Let $\mathbf{S}\equiv\left\{b,a,y^T\right\}$ and let $\left\{\hat{d}(\mathbf{S}),\hat{a}(\mathbf{S}),\hat{b}(\mathbf{S}),\hat{c}^T(\mathbf{S}),\hat{h}(\mathbf{S}),\hat{T}(\mathbf{S})\right\}$ be the optimal policy rules associated with the government problem. A Markov perfect equilibrium is then defined as follows.

Definition 2 (Markov perfect equilibrium)**.** *A Markov perfect equilibrium is defined by value functions $\{V(\mathbf{S}),V^r(\mathbf{S}),V^d(a,y^T)\}$, policy functions $\left\{\hat{d}(\mathbf{S}),\hat{a}(\mathbf{S}),\hat{b}(\mathbf{S}),\hat{c}^T(\mathbf{S}),\hat{h}(\mathbf{S}),\hat{T}(\mathbf{S})\right\}$, a bond price schedule $q(b',a',y^T)$ and $p^N(\mathbf{S})$ such that*

1. *Given the bond price schedule, policy functions solve problems equation (19), equation (20), and equation (21),*

2. *The bond price schedule satisfies the bond pricing equation,*

$$q\left(a',b',y^T\right)=\mathbb{E}_{y^{T\prime}|y^T}\left\{m\left(y^{T\prime},y^T\right)\left[1-\hat{d}(\mathbf{S}')\right]\left[\delta+(1-\delta)q\left(a'',b'',y^{T\prime}\right)\right]\right\}, \tag{22}$$

where

$$b'' = \hat{b}(\mathbf{S}') \quad and \quad a'' = \hat{a}^r(\mathbf{S}').$$

2.7 Inspecting the Mechanism

Now we turn to analyzing how the macro-stabilization properties of reserves work and to studying the key forces shaping the optimal portfolio of the sovereign. We are going to do this in two steps: first, we analyze the labor market equilibrium, show how reserves can alleviate recessions, and then argue that this is specially good in times of high borrowing costs. Secondly, we show how that in general equilibrium the government takes into account the benefits of reserves when optimally choosing policy.

Labor market equilibrium. The key to the stabilization property of reserve accumulation lies in the labor market. To see this let's write down the equilibrium labor supply function (which can easily be derived from the slackness condition in the labor market, equation 14):

$$h(w) = \begin{cases} 0, & \text{for } w < \bar{w} \\ \bar{h}, & \text{for } w \geq \bar{w} \end{cases} \tag{23}$$

Recall that the equilibrium labor demand function (derived in equation 18) is given by:

$$h = \frac{\alpha}{w} c^T.$$

The equilibrium in the labor market is graphed in Figure 2. In there we can see the workings of the complementary slackness condition: either the wage rigidity constraint binds, $w = \bar{w}$, and there is involuntary unemployment (like in points A and B), or the wage rigidity does not bind and there is full employment (like in point C).

We can see how increasing c^T reduces unemployment and boosts non-tradable output: moving from equilibrium point A to B (in Figure 2) is achieved precisely by increasing c^T, keeping everything else constant.[6] The key question is then *"how to increase c^T?."* The answer is either increase foreign borrowing (qi), or decrease the level of reserves ($a' < a$), or both. In bad times, the first option is particularly costly as borrowing terms worsen (q is very low). It is in these cases where the reserves can serve better the goal of increasing output (i.e. macro-stabilization). This becomes even clearer during defaults: in the period of debt repudiation the government cannot borrow, and hence the macro-stabilization falls entirely on the stock of foreign reserves.

[6] The externality associated with these macroeconomic effects is studied in Schmitt-Grohé and Uribe (2016).

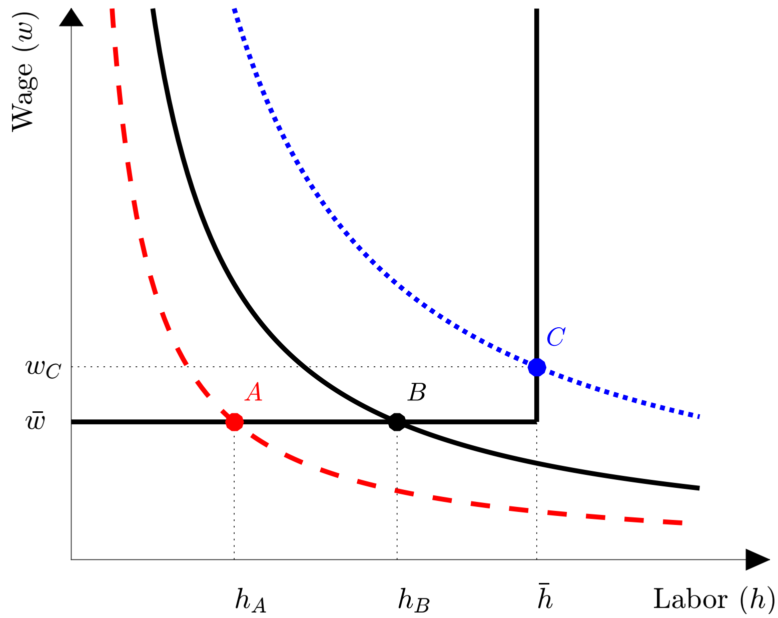

Figure 2: Labor market equilibrium under wage rigidity. The dotted, solid, and dashed lines represent the labor demand under low, medium, and high values for c^T, respectively.

Naturally, there are also states of the world (like point C in Figure 2) where labor demand is sufficiently high, and the economy has reached full employment. In this cases, additional units of tradable consumption (either by increased borrowing or reserves decumulation) do not have a stabilization effect, and will only increase the real wage and shrink firms' profits.

Portfolio policies. We now study how in general equilibrium the government considers the costs and benefits of using debt and reserves, and ultimately how the optimal portfolio is decided. To do this, we use the first-order conditions in the government problem.

It is first useful to consider the first-order condition with respect to c^T

$$c^T: \quad u'(c^T) + \xi \frac{\alpha}{\bar{w}} = \lambda$$

where ξ is the Lagrange multiplier on the wage rigidity constraint ($h \leq \frac{\alpha}{\bar{w}} c^T$). This condition reveals that increase in current tradable consumption not only has a direct marginal utility value, but also a benefit resulting from GE effects on the price of non-tradables and the reduction in unemployment (precisely the effect discussed above). This will play a key impact when the government chooses the portfolio as we analyze below.

For labor, we have

$$h: \quad u'(zh^{\alpha}) z\alpha h^{\alpha-1} = \eta + \xi,$$

where η is the Lagrange multiplier on the hours worked constraint ($h \leq \bar{h}$).

Under debt repayment, we obtain the following Euler equations for debt and reserves:

$$(u_{T,t} + \xi \frac{\alpha}{\bar{w}}) \underbrace{\left[q + \frac{\partial q(b', a', s)}{\partial b'} i\right]}_{\text{Increase of this-period consumption}} = \beta \mathbb{E}_{s'|s} \left[(u_{T,t+1} + \xi_{t+1} \frac{\alpha}{\bar{w}}) \underbrace{[\delta + q'(1-\delta)](1-d')}_{\text{Decline of next-period consumption}} \right] \tag{24}$$

$$(u_{T,t} + \xi \frac{\alpha}{\bar{w}}) \underbrace{\left[q_a - \frac{\partial q(b', a', s)}{\partial a'} i\right]}_{\text{Increase of this-period consumption}} \geq \beta \mathbb{E}_{s'|s} (u_{T,t+1} + \xi_{t+1} \frac{\alpha}{\bar{w}}) \underbrace{\mathbb{1}}_{\text{Increase of next-period consumption}} \tag{25}$$

The key element in these Euler equations is that having more consumption in states in which the wage rigidity is binding allows to increase employment. This is the effect that would magnify the benefits from reserves.

Consider the marginal benefits of issuing one unit of debt to purchase reserves. As in Bianchi et al. (2018), we can decompose the marginal cost of issuing debt into an expected cost and a covariance term as follows:

$$\begin{aligned} u'(c) \left[q + \frac{\partial q(b', a', s)}{\partial b'} i\right] &= \beta \mathbb{E}_{s'|s}[1-d'] \mathbb{E}_{s'|s,d'=0} \left[\delta + (1-\delta) q'\right] \mathbb{E}_{s'|s,d'=0} \left[(u_{T,t+1} + \xi_{t+1} \frac{\alpha}{\bar{w}}) \right] \\ &+ \beta \mathbb{E}_{s'|s}[1-d'] \mathbb{COV}_{s'|s,d'=0} \left(\delta + (1-\delta) q', (u_{T,t+1} + \xi_{t+1} \frac{\alpha}{\bar{w}}) \right). \end{aligned} \tag{26}$$

The key hedging and stabilization motive arises because in low income states tomorrow, we have that the payoffs from issuing debt to purchase reserves $\delta + (1-\delta)q'$ are positive, and these are states with high marginal utility of consumption and binding wage rigidity.

3 Quantitative analysis

Coming soon.

4 Results

Coming soon.

5 Conclusions

Coming soon.

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