Required Reserves as a Credit Policy Tool

Preliminary Draft

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Abstract

Policymakers in both advanced and emerging countries have been exercising a variety of measures to mitigate the transmission of financial disruptions to the real sector. To that end, frictions in the financial sector have been the focal point of the recent literature on macroeconomic dynamics and policy. The goal of this paper is to contribute to this literature by analyzing a DSGE model in which (i) the banking sector is explicitly modeled, (ii) money is valued by households and the growth rate of its supply is subject to innovations and (iii) required reserves play an explicit role in connecting the central bank and the financial system. We take one step further and analyze a required reserves ratio rule as a macro prudential policy measure that responds to deviations bank leverage ratio from its long-run level. We find that (i) introducing even fixed required reserve ratios mitigates the impact of financial accelerator triggered by TFP shocks and is necessary to build the investment stimulating impact of money growth shocks. (ii) The credit policy designed as a responsive required reserve ratio rule countervails the financial accelerator mechanism created by negative TFP shocks, and overturns the adverse impact of money growth shocks on investment without reducing consumption but by increasing output more due to increased hours and capital.

Keywords: Banking sector, time-varying reserve requirements, TFP and money growth shocks

JEL Classification: G21, G28, E51

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1 Introduction

Policymakers in both advanced and emerging countries have been exercising a variety of measures to mitigate the transmission of financial disruptions to the real sector. To that end, frictions in the financial sector have been the focal point of the recent literature on macroeconomic dynamics and policy. In particular, reserve requirements have been used extensively as a macro-prudential policy tool in several emerging countries, recently. China, Brazil, Malaysia and Turkey are some of the countries among others who have used this tool for various reasons. In this regard, this paper aims to investigate the effects of reserve requirements as a macro-prudential policy tool. Specifically, we analyze the role of reserve requirements on the transmission mechanism of productivity and monetary shocks.

We build upon the monetary model of Sidrauski (1967). In order to analyze the role of reserve requirements as a macro-prudential policy tool, we incorporate the banking sector explicitly as in Gertler and Karadi (2011). The way that central bank uses reserve requirements is modeled as a counter-cyclical policy rule which responds to the deviations of banking sector leverage from its long-run level. The rest of the model economy is populated by a large number of identical households, firms and capital producers. There is aggregate uncertainty due to productivity and money growth shocks.

In order to understand the role of time-varying reserve requirements, we solve the model under three regimes; one with no reserve requirements, one with a constant reserve requirement rule, and another with a time-varying reserve requirement rule. We calibrate the model to the Turkish economy. The results imply that time-varying reserve requirements cause less volatile business cycles compared to the fixed and no reserve requirement cases, in response to both shocks. This happens because the amplification effect of the financial sector is mitigated by time-varying reserve requirements.

The mechanism behind lower volatility in real and financial variables with time-varying reserve ratios is as follows: Under fixed reserves ratio, an adverse productivity shock causes bank credit to decline both because of demand and supply channels in the deposits market. The demand for deposits declines because lower productivity of firms dampens the profitability of bank loans (in the form of equity financing) that pay state-contingent returns. The supply for deposits declines, on the other hand, because households are poorer when output declines due to reduced productivity. At this stage, the counter-cyclical reserves rule calls for a reduction in the reserves ratio because lower external finance of banks collapses leverage under the fixed reserves regime. This reduces the cost of raising external finance for banks and mitigates the fall in the profitability of banks. In return, higher demand for deposits by banks prevents credit and equity financing to decline and countervails the financial accelerator mechanism.

On the other hand, when the case of positive money growth shocks are analyzed, the model with fixed reserves ratio displays the well-known dynamics of the monetary model of Sidrauski (1967). Specifically, the expansion in the rate of money growth substitutes out households savings for consumption since it is redistributed as a lump-sum transfer to households without increasing government spending. In our model, the reduction in savings causes deposits (and therefore bank credit) to decline and results in a reduction in investment. However, when the time-varying reserves ratio rule is introduced, the central bank reduces this ratio in response to lower bank leverage. As a result, the equilibrium level of deposits increase causing the bank credit, equity prices and investment to rise. More strikingly, this increase in investment does not come at the expense of reduced consumption since output is higher than the fixed reserves ratio economy. If we shut down reserves while using the same parameter values, loan-deposit spreads become much larger and negative TFP shocks trigger a sizable financial disruption in the model.

The rest of the paper is organized as follows. Section 2 describes the model economy. Section 3 undertakes the quantitative analysis and section 4 concludes.

2 The Model

The model economy is inhabited by households, capital producers, final goods producers, banks and a government. Time is discete. The banking sector exists due to credit frictions modeled *a la* Gertler and Karadi (2011). Households are assumed to value holdings of real balances which leads to the existence of monetary equilibria *a la* the well known formulation of Sidrauski (1967). Below is a detailed description of economic agents that reside in this model economy.

2.1 Households

There is a large number of identical households who live for infinitely many periods. A representative hosuehold maximizes the discounted lifetime utility flow earned from consumption, c_t, leisure, l_t and real balances holdings, $\frac{M_{t+1}}{P_t}$,

$$E_0 \sum_{t=0}^{\infty} \beta^t u\Big(c_t, l_t, \frac{M_{t+1}}{P_t}\Big) \tag{1}$$

where $0 < \beta < 1$ the subjective discount factor and E is the mathematical expectation operator. Households in turn face the flow budget constraint,

$$c_t + b_{t+1} + \frac{M_{t+1}}{P_t} = w_t(1 - l_t) + R_t b_t + \frac{M_t}{P_t} + \Pi_t + \frac{T_t}{P_t} \tag{2}$$

where b_t is the beginning of period t balance of deposits held at commercial banks, P_t is the general nominal price level, w_t is the real wage earned per labor hour, R_t is the risk free deposits rate, Π_t is the profits remmitted from the ownership of banks and production firms and T_t is lump-sum transfers remitted by the government.

Solution of the utility maximization problem of households yield the optimality conditions,

$$u_c(t) = \beta R_{t+1} E_t u_c(t+1) \tag{3}$$

$$\frac{u_l(t)}{u_c(t)} = w_t \tag{4}$$

$$\frac{u_c(t)}{P_t} = \frac{u_m(t)}{P_t} + \beta E_t\Big(\frac{u_c(t+1)}{P_{t+1}}\Big) \tag{5}$$

where equations (3), (4) and (5) represent consumption-savings optimality condition, consumption-leisure optimality condition and consumption-money optimality condition respectively.

2.2 Banks

The modeling of financial sector closely follows that in Gertler and Karadi (2011). To summarize the key ingredients, we denote the period t balance sheet of a representative bank as,

$$q_t s_t = (1 - rr_t) b_{t+1} + n_t. \tag{6}$$

The right hand side of the balance sheet denotes the resources of the bank, namely, net worth, n_t and deposits, b_{t+1} needed to finance its credit releases to productive firms, $q_t s_t$. The loans to firms serve as state-contingent claims s_t towards the ownership of firms and are traded at the market price q_t. Note that the bank can only loan $(1 - rr_t)$ fraction of deposits to the firms where rr_t is the required reserve ratio set by the government as we describe below. The balance sheet of banks described in equation (3) imply an evolution equation for net worth as follows:

$$n_{t+1} = \left[R_{kt+1} - \left(\frac{R_{t+1} - rr_t}{1 - rr_t}\right)\right] q_t s_t + \left(\frac{R_{t+1} - rr_t}{1 - rr_t}\right) n_t \tag{7}$$

It is evident in equation (4) that an increase in the required reserve ratio rr_t decreases the effective spread, $\left[R_{kt+1} - \left(\frac{R_{t+1} - rr_t}{1 - rr_t}\right)\right]$, between the credit extended to firms and interest paid on deposits, and increases the importance of existing net worth in accumulating more.

We assume that each household is composed of a worker and a banker who perfectly insure each other. Workers are assumed to supply labor to the production firms and deposit their savings in the banks owned by the banker member of other households. Moreover, bankers have a finite life and survive to the next period with probability θ. At the end of each period $1 - \theta$ number of new bankers are born and are remitted $\frac{\epsilon}{1-\theta}$ of the net worth owned by the exiters. Bankers' objective is to maximize the present discounted value of the terminal net worth of their financial firm, V_t, by choosing the amount of claims against the firm ownership, s_t. That is,

$$V_t = \max_{s_t} E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} \left\{ \left[R_{kt+1+i} - \left(\frac{R_{t+1+i} - rr_{t+i}}{1 - rr_{t+i}}\right)\right] q_{t+i} s_{t+i} + \left(\frac{R_{t+1+i} - rr_{t+i}}{1 - rr_{t+i}}\right) n_{t+i} \right\} \tag{8}$$

The finite life of bankers, $\theta < 1$, at this point ensures that bankers never possess unbounded amount of net worth.

The key feature of the financial sector at this point unfolds around a moral hazard friction between banks and households: In this model of banking, households believe that banks might divert λ fraction of their total assets for their own benefit. This might be thought of as investing part of $q_t s_t$ in excessively risky projects that go bankrupt eventually and not paying back the corresponding liability to the depositor. In this case, depositors shall cause a bank run and lead to the liquidation of the bank altogether. Therefore, bankers' optimal plan regarding the choice of s_t at any date t should satisfy an incentive compatibility constraint,

$$V_t \geq \lambda q_t s_t \tag{9}$$

This inequality suggests that the loss of bankers, V_t, from diverting the funds and investing them in risky projects that would likely fail should be greater than or equal the diverted portion of the assets, $\lambda q_t s_t$.

By using an envelope condition and algebraic manipulation, one can write the optimal value of banks as

$$V_t^* = \nu_t q_t s_t^* + \eta_t n_t^* \tag{10}$$

where the recursive objects,

$$\nu_t = E_t \left\{ (1-\theta)\beta\Lambda_{t,t+1} \left[R_{kt+1} - \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) \right] + \theta\beta\Lambda_{t,t+1} \frac{q_{t+1}s_{t+1}}{q_t s_t} \nu_{t+1} \right\} \tag{11}$$

and

$$\eta_t = E_t \left\{ (1-\theta)\beta\Lambda_{t,t+1} \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) + \theta\beta\Lambda_{t,t+1} \frac{n_{t+1}}{n_t} \eta_{t+1} \right\} \tag{12}$$

represent the marginal values of relaxing credit and accumulating net worth for the bank respectively. Under the assumption that the former is positive and less than λ, equations (6) and (7) imply that[1]

$$\nu_t q_t s_t + \eta_t n_t = \lambda q_t s_t. \tag{13}$$

which in turn produces the endogenous borrowing constraint for the bank as

$$q_t s_t = \frac{\eta_t}{\lambda - \nu_t} n_t. \tag{14}$$

This endogenous constraint which emerges from the costly enforcement problem described above ensures that banks' leverage might always be equal to $\frac{\eta_t}{\lambda - \nu_t}$ and is decreasing with the fraction of funds (λ) that depositors believe that banks will divert.

[1]For a proof, see Gertler and Karadi (2011).

The evolution of aggregate net worth depends on evolution of net worth of the surviving bankers (n_{et+1}) and the start-up funds of the new entrants (n_{nt+1}), that is, $\frac{\epsilon}{1-\theta}$ fraction of $(1-\theta)n_t$.

$$n_{t+1} = n_{et+1} + n_{nt+1}. \tag{15}$$

where the former depends on the leverage. Then,

$$n_{et+1} = \theta \left\{ \left[R_{kt+1} - \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) \right] \left[\frac{\eta_t}{\lambda - \nu_t} \right] + \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) \right\} n_t. \tag{16}$$

and

$$n_{t+1} = \theta \left\{ \left[R_{kt+1} - \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) \right] \left[\frac{\eta_t}{\lambda - \nu_t} \right] + \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) + \epsilon \right\} n_t. \tag{17}$$

2.3 Firms

Firms produce the consumption good by using physical capital and labor as production factors. They operate with a constant returns to scale technology $F(.,.)$ that is subject to total factor productivity shocks, z_t

$$y_t = exp(z_t)F(k_t, h_t) \tag{18}$$

where

$$z_{t+1} = \rho_z z_t + \epsilon_{zt+1} \tag{19}$$

with zero mean, constant variance innovations, ϵ_{zt+1}.

Firms finance capital at date t by issuing claims s_t to financial intermediaries and acquire capital k_{t+1} from capital producers. Therefore,

$$q_t s_t = q_t k_{t+1} \tag{20}$$

with q_t is the market price of the firms' equity and capital.

Banks' claim against the ownership of the firm pays out its dividend via the marginal product of capital in the next period. Hence, the cost of credit to the firm is state-contingent. As a result, the cost of credit to the firm must satisfy

$$R_{kt} = \frac{exp(z_t)F_k(k_t, h_t) + q_t(1-\delta)}{q_{t-1}} \tag{21}$$

Finally, the optimal labor demand of the firm must satisfy the usual static condition,

$$w_t = exp(z_t)F_h(k_t, h_t) \tag{22}$$

2.4 Capital Producers

Capital producers are introduced in order to obtain variation in the price of capital which is necessary for the financial accelerator mechanism to operate. To that end, capital producers provide physical capital to the firms and repair the depreciated capital and incur the cost of investment. Consequently, the optimization problem of capital producers read,

$$\max_{i_t} q_t k_{t+1} - q_t(1-\delta)k_t - i_t \tag{23}$$

subject to the capital accumulation technology,

$$k_{t+1} = (1-\delta)k_t + \Phi\Big(\frac{i_t}{k_t}\Big)k_t \tag{24}$$

where the function $\varphi(.)$ represents the capital adjustment cost. The optimality condition that emerges from the solution to this problem is the well-known "q" relation that pins down the price of capital,

$$q_t = \Big[\Phi'\Big(\frac{i_t}{k_t}\Big)\Big]^{-1} \tag{25}$$

2.5 Government

The government is essentially responsible for coordinating monetary policy. To that end, it controls the supply of money M_{0t+1} and determines the required reserve ratio rr_t. Any growth of the monetary base is remitted to households in the form of lump-sum transfers, T_t. The monetary base grows at the rate mu_t,

$$M_{0t+1} = exp(\mu_t)M_{0t} \tag{26}$$

where the growth rate of money supply is subject to zero mean, constant variance normally distributed innovations so that,

$$\mu_{t+1} = (1-\rho_\mu)\bar{\mu} + \rho_\mu \mu_t + \epsilon_{\mu t+1} \tag{27}$$

In order to contain the financial accelerator mechanism, the government uses required reservs as an automatic stabilizer. Specifically, the required reserves ratio is assumed to follow a rule that reacts to deviations in the credit-to-GDP ratio from its steady-state, $\frac{\bar{qs}}{\bar{y}}$:

$$rr_t = \bar{rr} + \phi\left[\frac{q_t s_t}{y_t} - \frac{\bar{qs}}{\bar{y}}\right] \tag{28}$$

where, $\bar{rr}$ is the steady-state value of the required reserves ratio and $\phi > 0$. Consequently, the central bank increases the effective rate of return of extending new loans when credit relative to GDP is scarce and vice versa. Within this framework, the money market equilibrium turns out as the following condition:

$$M_{0t+1} = M_{t+1} + P_t rr_t b_{t+1} \tag{29}$$

where P_t is the general price level of the consumption good.

2.6 Competitive Equilibrium

Notice that nominal monetary base and prices grow constantly in this model, which renders the equations listed above non-stationary. Therefore, following Cooley and Hansen (1995), we make the model stationary by applying the following normalizations: $\widehat{P_t} = P_t/M_{0t+1}$ and $\hat{m}_t = M_{t+1}/(\widehat{P_t}M_{0t+1})$ and solve the model locally around a deterministic steady state.

A competitive equilibrium of this model economy is defined by sequences of allocations $\{c_t, k_{t+1}, i_t, l_t, h_t, s_t, n_t, b_{t+1}, \Lambda_{t,t+1}, \nu_t, \eta_t, \hat{m}_{t+1}, \pi_t\}_{t=0}^{\infty}$, prices $\{q_t, R_{kt+1}, R_{t+1}, w_t, \widehat{P_t}\}_{t=0}^{\infty}$, shock processes $\{z_t, \mu_t\}_{t=0}^{\infty}$ and the government policy $\{rr_t\}_{t=0}^{\infty}$ that satisfy the following optimality and market clearing conditions:

$$u_c(t) = \beta R_{t+1} E_t u_c(t+1) \tag{30}$$

$$\Lambda_{t,t+1} = \frac{u_c(t+1)}{u_c(t)} \tag{31}$$

$$\frac{u_l(t)}{u_c(t)} = w_t \tag{32}$$

$$\frac{u_c(t)}{\widehat{P_t}} = \frac{u_m(t)}{\widehat{P_t}} + \beta E_t\Big(\frac{u_c(t+1)}{\widehat{P_{t+1}} exp(\mu_{t+1})}\Big) \tag{33}$$

$$q_t s_t = (1 - rr_t) b_{t+1} + n_t \tag{34}$$

$$q_t s_t = \frac{\eta_t}{\lambda - \nu_t} n_t \tag{35}$$

$$\nu_t = E_t \left\{ (1-\theta)\beta\Lambda_{t,t+1} \left[R_{kt+1} - \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) \right] + \theta\beta\Lambda_{t,t+1} \frac{q_{t+1}s_{t+1}}{q_t s_t} \nu_{t+1} \right\} \tag{36}$$

$$\eta_t = E_t \left\{ (1-\theta)\beta\Lambda_{t,t+1} \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) + \theta\beta\Lambda_{t,t+1} \frac{n_{t+1}}{n_t} \eta_{t+1} \right\} \tag{37}$$

$$n_{t+1} = \theta \left\{ \left[R_{kt+1} - \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) \right] \left[\frac{\eta_t}{\lambda - \nu_t} \right] + \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) + \epsilon \right\} n_t \tag{38}$$

$$w_t = exp(z_t) F_h(k_t, h_t) \tag{39}$$

$$R_{kt} = \frac{exp(z_t)F_k(k_t, h_t) + q_t(1-\delta)}{q_{t-1}} \tag{40}$$

$$k_{t+1} = (1-\delta)k_t + \Phi\Big(\frac{i_t}{k_t}\Big)k_t \tag{41}$$

$$q_t = \Big[\Phi'\Big(\frac{i_t}{k_t}\Big)\Big]^{-1} \tag{42}$$

$$exp(z_t)F(k_t, h_t) = c_t + i_t \tag{43}$$

$$s_t = k_{t+1} \tag{44}$$

$$1 = l_t + h_t \tag{45}$$

$$exp(\pi_t) = exp(\mu_t)\frac{\widehat{P_t}}{\widehat{P_{t-1}}} \tag{46}$$

$$z_{t+1} = \rho_z z_t + \epsilon_{zt+1} \tag{47}$$

$$\mu_{t+1} = (1-\rho_\mu)\bar{\mu} + \rho_\mu \mu_t + \epsilon_{\mu t+1} \tag{48}$$

$$rr_t = \bar{rr} + \phi\left[\frac{q_t s_t}{y_t} - \frac{\bar{qs}}{\bar{y}}\right] \tag{49}$$

$$\frac{1}{\widehat{P_t}} = \hat{m}_{t+1} + rr_t b_{t+1} \tag{50}$$

3 Quantitative Analysis

Parameters regarding the financial system are calibrated to match financial statistics of the Turkish economy in the period 2006-2011. The rest of the parameterization is in general standard and in line with the existing literature. The parameter values used in the quantitative analysis are reported in Table 1. The benchmark model involves the macro-prudential policy rule illustrated in equation (28) which does not alter the steady state of the model but affect the dynamics around it. With the parameterized economy, we analyze the impulse responses to one standard deviation negative productivity and money growth shocks.

3.1 Functional Forms

Preferences: We use a Cobb-Douglas aggregator for consumption and real balances within a CRRA utility function and separable log utility for leisure:

$$u\Big(c_t, l_t, \frac{M_{t+1}}{P_t}\Big) = \frac{(c_t^{\gamma} m_{t+1}^{1-\gamma})^{1-v}}{1-v} + \psi \log l_t \tag{51}$$

with $m_{t+1} = \frac{M_{t+1}}{P_t}, 0 < \gamma < 1, v > 1, \psi > 0$.

Production: Firms produce according to a constant returns to scale Cobb-Douglas production function:

$$exp(z_t)F(k_t, h_t) = exp(z_t)k_t^{\alpha} h_t^{1-\alpha} \tag{52}$$

with $0 < \alpha < 1$.

Capital Producers: Capital producers are subject to a convex adjustment cost function:

$$\Phi\Big(\frac{i_t}{k_t}\Big) = \frac{\varphi}{2}\Big[\frac{i_t}{k_t} - \delta\Big]^2 \tag{53}$$

3.2 Findings

In the following, we compare the dynamics of real, financial and monetary variables of three model economies in response to one standard deviation TFP and money growth shocks. In all six figures, the straight plots correspond to the benchmark economy with macro-prudential policy rule (Economy 1), the dashed plots correspond to an economy with fixed required reserves ratio (RRR) (Economy 2), and the straight plots with stars correspond to an economy with no reserves (Economy 3). Unless otherwise is stated, the numbers in the y-axes correspond to percentage deviations of variables from their long-run values.

3.2.1 Impulse Responses to TFP Shocks

In this section, we focus on the comparison of Economies 1 and 2 since the dynamics of Economy 3 are almost identical with those of Economy 2. The general observation that emerges from Figures 1, 2 and 3 is that the macro-prudential required reserves policy dampens the impact of the financial accelerator on investment, bank credit and price of equity in response to TFP shocks and interestingly, this happens at the expense of lower output and consumption.

In Economy 2 with fixed RRR, as expected, households reduce their demand for consumption and supply of deposits in response to the adverse TFP shocks since the output and the profits that accrue from the ownership of banks and capital producers are lower. This is observed in the

Table 1: Paremeter Values in the Benchmark Model

Description	Value	Target
Preferences		
Quarterly discount factor (β)	0.9885	Annualized real deposit rate (4.73%)
Relative utility weight of consumption (γ)	0.80	
CRRA parameter in the utility (v)	5	Literature
Relative utility weight of leisure (ψ)	0.65	Hours worked (0.3342)
Production Technology		
Share of capital in output (α)	0.36	Labor share of output (0.64)
Capital adjustment cost parameter (φ)	12	Relative volatility of investment = 2.080
Depreciation rate of capital (δ)	0.025	Average annual ratio of investment to capital (10%)
Government		
Steady-state value of RRR ($\bar{rr}$)	0.05	Pre macro-prudential policy period
Adjustment parameter in the RRR rule (ϕ)	0.025	
Financial Intermediaries		
Fraction of diverted loans (λ)	0.155	Annual commercial & industrial loan spread (1.96%)
Prop. transfer to the entering bankers (ϵ)	0.001	2.74% of aggregate net worth
Survival probability of the bankers (θ)	0.9635	Capital adequacy of 20% for commercial banks
Shock Processes		
Persistence of TFP process (ρ_z)	0.9821	Estimated from detrended $\log TFP_t = \rho_z \log TFP_{t-1} + \epsilon_{zt}$
Std. deviation of productivity shocks (σ_z)	0.0183	
Persistence of money growth process (ρ_μ)	0.8535	Estimated from $\log \Delta M1_t = \rho_\mu \log \Delta M1_{t-1} + \epsilon_{\mu t}$
Std. deviation of money growth shocks (σ_μ)	0.0347	

middle panel of Figure 1 that ex-post return to capital falls on impact. On the banks' side, the reduced TFP highlights the reduction in the profitability of equity loans to firms, causing them to reduce their demand for deposits. The decline in supply of deposits by households outweighs the decline in the demand for deposits by banks and accordingly, equilibrium deposits rate (the bottom-right panel of Figure 1) slightly increases and the quantity of deposits (the top-middle panel of Figure 2) fall on impact.

The nominal price level increases (the bottom-left panel of Figure 3) for two reasons: first, the economy is now less productive in generating output, and second, the reserves demand of banks have been reduced given the decline in deposits. Hence, inflation deviates about 0.9% from its steady-state level and distorts the consumption-real balances margin of households. Consequently, consumption velocity of monetary base increases and the real balances demand plummets by about 4%. The reduction in real balances demand dominates the increase in velocity and calls for an increase in the labor supply of households, once the consumption-leisure optimality condition is taken into account. This, coupled with the reduced demand of firms for labor causes the equilibrium quantity of hours to increase and the real wage to decline.

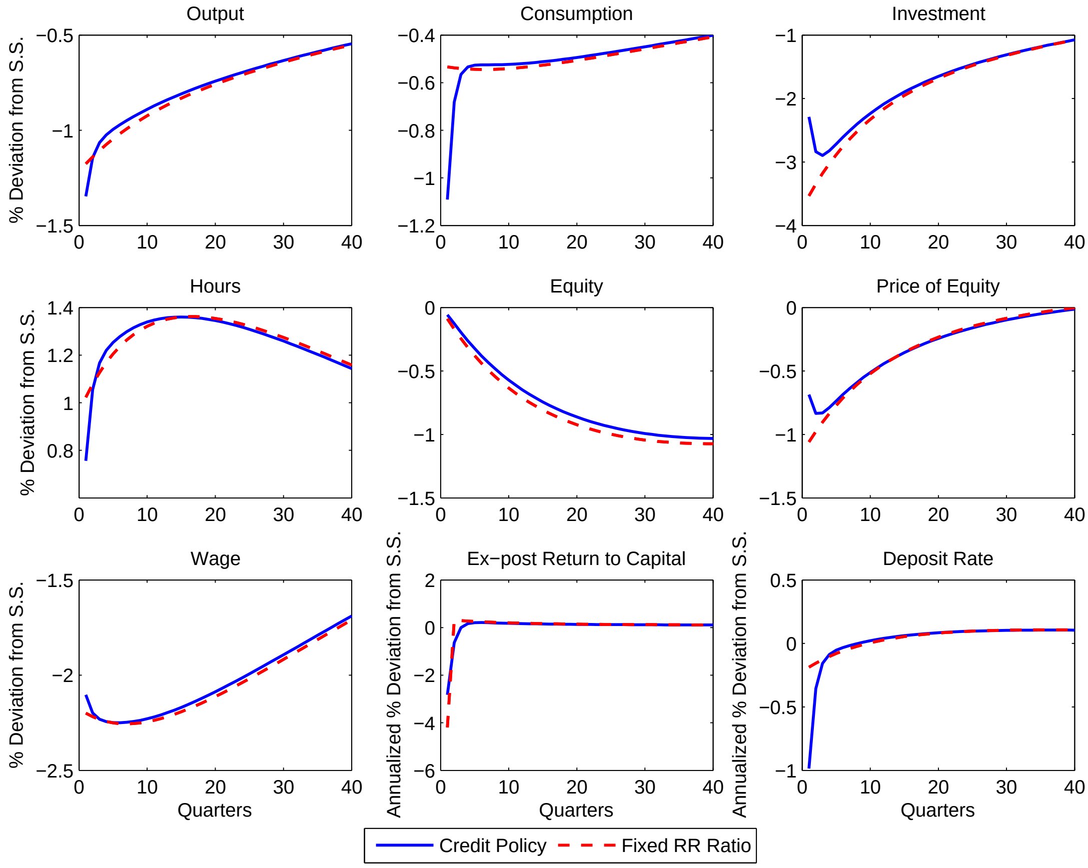

Figure 1: The Effect of Negative Productivity Shocks on Real Variables

Under fixed reserves, the immediate jump in the ex-post return to capital implies a slight surge in the loan-deposit spreads and helps banks accumulate some net worth in the initial periods. However, due to scarce deposits, the total sum of financing for banks is downsized. Therefore, banks shrink their demand for firm equity, causing their leverage to fall by about 3.4%. On the other hand, production firms decrease their supply of equity as well, since they are less productive and paying out the state-contingent equity debt becomes more costly. As a result, both equity and its price reduces on impact and stay lower than their long-run levels by about 10 years. The reduction in the quantity of equities traded and the collapse in asset prices triggers a downsizing in bank credit of about 6.5% and gets even worse to an amount of 9% over the course of ten years. As a natural outcome, investment falls.

Now, we explain how the credit policy defined by a counter-cyclical required reserves ratio rule mitigates the impact of the financial accelerator on investment, bank credit and equity prices. Since the collapse in bank credit outweighs the reduction in output, credit-to-GDP falls on impact in Economy 2. Note that the reduction in this ratio causes credit to be scarce and

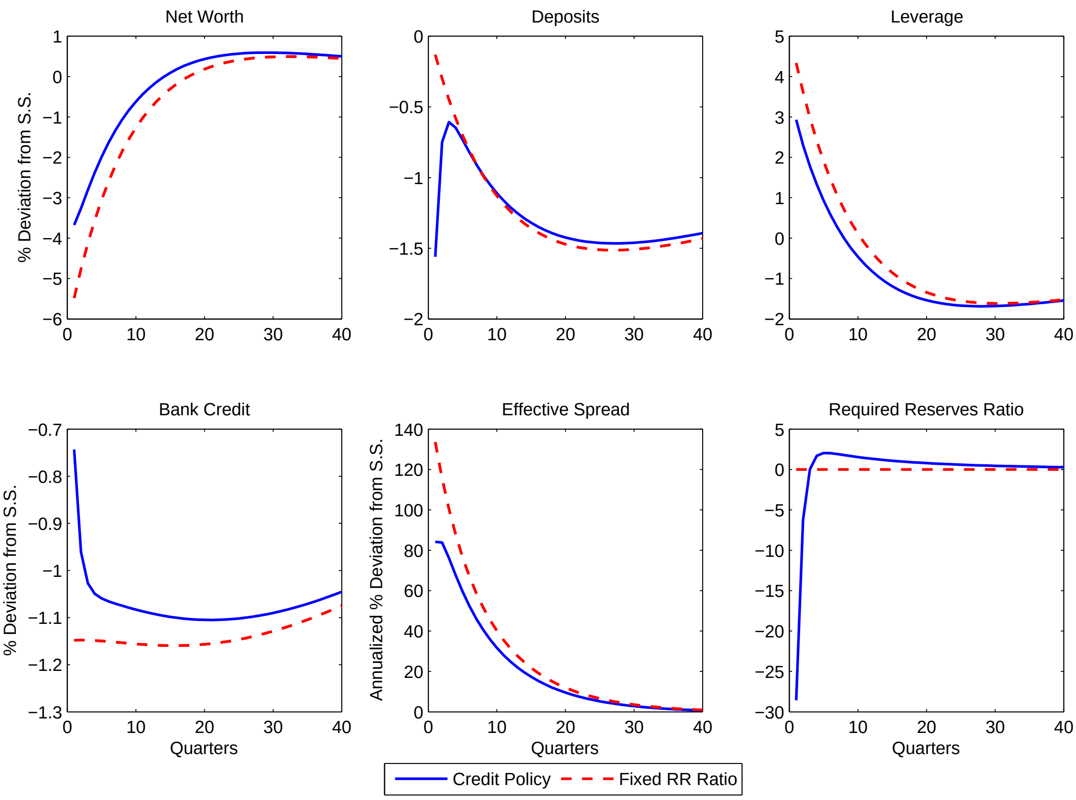

Figure 2: The Effect of Negative Productivity Shocks on Financial Variables

this induces the policy rule in Economy 1 to reduce the RRR by about 1.5%, which can be seen in the bottom-right panel of Figure 2. This increases the effective spread, i.e., $R_k - \frac{(R-rr)}{1-rr}$, faced by banks and creates a substitution from reserves to loans in the asset side of the balance sheet of banks. Since extending loans is more preferable now, stronger demand for equity causes price of equity to decline by 0.3% instead of 0.6% in the fixed reserves ratio economy. Consequently, total value of credit and investment declines by half of how much they decline in the fixed reserves economy.

The lower deposits demand (which is induced by lower reserves demand) causes the deposit rate do decline by 50 basis points relative to its steady state in annual terms. This reduces the opportunity cost of borrowing for banks and in turn reduces the attractiveness to accumulate internal financing. Therefore, net worth of banks follow a declining trajectory in initial periods as opposed to the fixed reserves economy. Bank leverage also decreases by half of the fixed reserves economy and the above-mentioned performance of net worth causes it to be higher than that of the fixed reserves economy for 10 quarters.

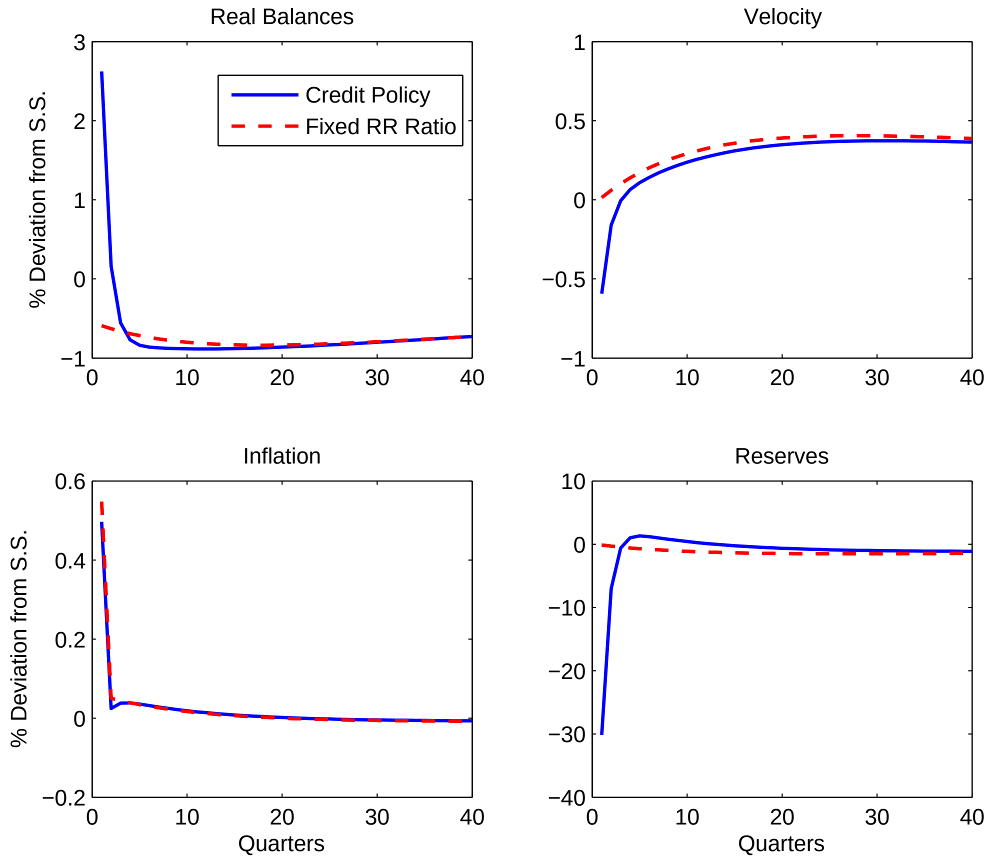

Figure 3: The Effect of Negative Productivity Shocks on Monetary Variables

The immediate reversal in the path of reserves demand drives up the price of money, which in turn is the reciprocal of the price of consumption good. Therefore, inflation stabilizes immediately and even stays below its long run value for several quarters causing the real balances demand to increase. The stronger outlook of real balances causes hours to increase by 0.35% instead of 0.5% (via the intra-temporal margin) and amplifies the decline in output by 0.25%. Wages as a result fall by less due to the weaker supply of labor. Finally, we obtain larger decline in consumption because of the weaker trajectory of output and the stronger trajectory of investment.

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To sum up, we obtain the interesting result that the macro-prudential RRR policy mitigates the impact of the financial accelerator triggered by TFP shocks at the expense of creating inflation. Now, we explore the dynamics driven by money growth shocks and the differences implied by the macro-prudential RRR policy rule that responds to bank leverage. The comparison of the starred plots with others also highlight that the adverse effects of negative productivity shocks are much more disruptive when there are no reserves. This is because loan-deposit spreads are much larger with zero reserves ratio and the reduction in spreads after a negative TFP shock triggers a sizable financial distress, causing net worth, deposits and bank credit to collapse.

3.2.2 Impulse Responses to Money Growth Shocks

In this section, we analyze the dynamics of model economies in response to a one-standard deviation positive money growth shock. We should firstly note that the dynamics of the model with fixed RRR and no reserves strongly resemble the properties of the usual Sidrauski (1967) model of money in general equilibrium. This mechanism is broadly summarized by the idea that an expansionary shock to the growth rate of money supply stimulates household consumption and dampens savings, since it is in the form of a transfer from the government. Yet, in our framework, the nature of the decline in investment and the increase in hours depend on the financial accelerator mechanism and the specification of the utility function respectively.

In the model with fixed RRR, the equilibrium quantity of deposits decline (by about 0.5%) and the deposit rate increases on impact, due to the dissaving effect in the Sidrauski model (See the bottom-right panel of Figure 4 and the top-middle panel of Figure 5). Note that the increase in the deposit rate bids up the opportunity cost of raising external finance and consequently, net worth of banks rises. Comparing the magnitudes of the dynamics in deposits and net worth, we observe that bank leverage plummets by 4% (see the upper panel of Figure 5). Due to the same reason, total financing of banks reduce and which causes them to demand less of firm equity. This calls for a slight reduction in the amount of equities traded and causes equity price to reduce. Lower revenue for firm equity implies lower bank credit, therefore investment falls. With less capital orders, the ex-post return to equity increses slightly (see Figure 4). Hours increase due to the net effect of changes in real balances demand and consumption velocity, which are described below.

In terms of the monetary variables, the dynamics of the model are as expected: There is a sharp decline in real balances demand (15%), a surge in consumption velocity (3.5%) and inflation (18%), and a slight decline in reserves (due to lower deposits and fixed reserves ratio). However, when the time-varying reserves ratio rule is analyzed, the central bank reduces this ratio in response to lower bank leverage. As a result, the equilibrium level of deposits increase causing the bank credit, equity prices and investment to rise. More strikingly, this increase in investment does not come at the expense of reduced consumption since output is higher than the fixed reserves ratio economy.

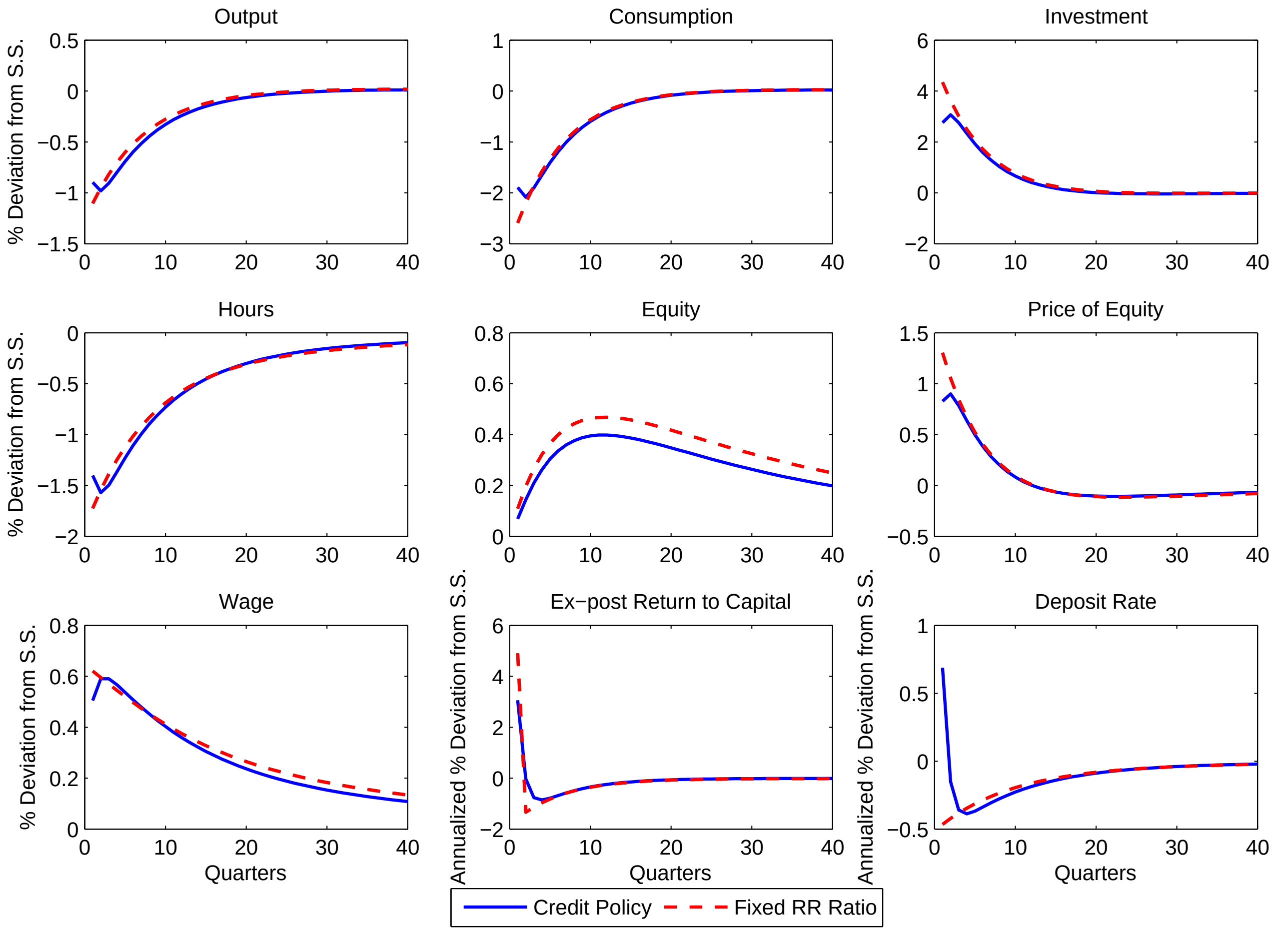

Figure 4: The Effect of Positive Money Growth Shocks on Real Variables

3.2.3 Effect of Credit Policy on Relative Volatilities

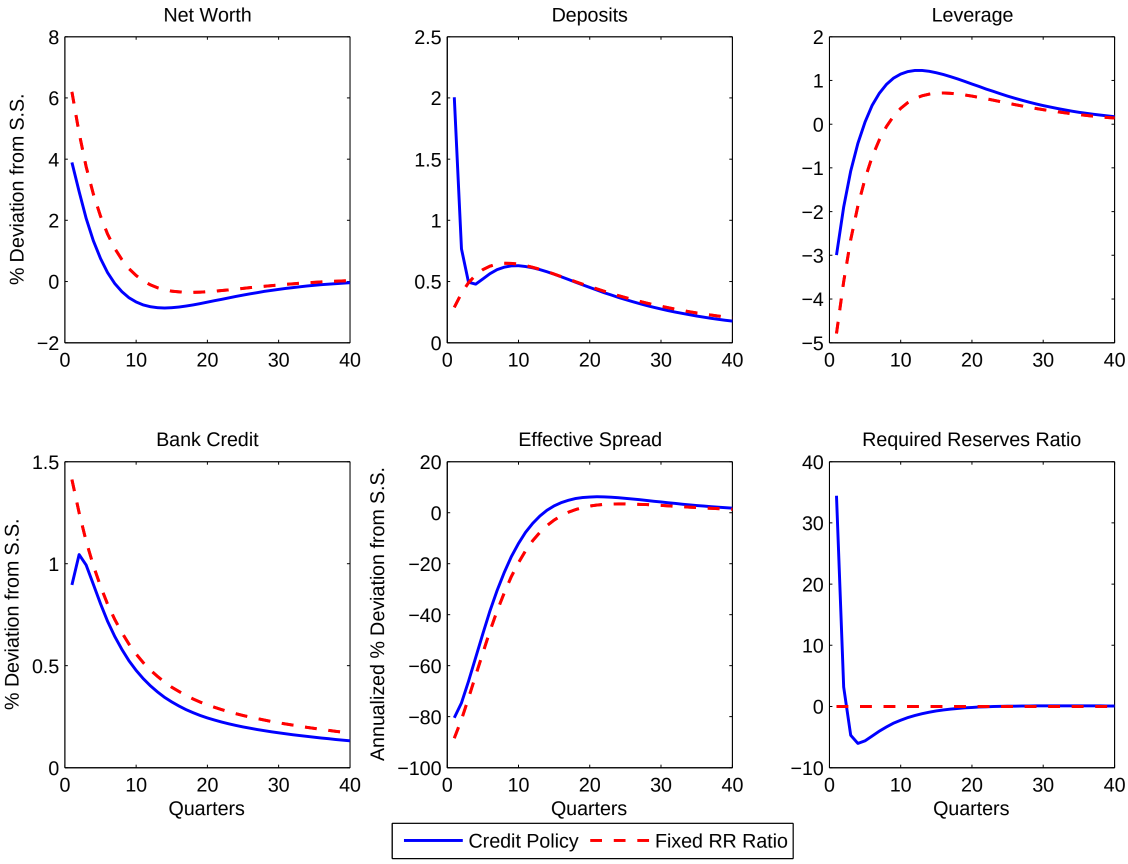

Figure 5: The Effect of Positive Money Growth Shocks on Financial Variables

4 Conclusion

The recent financial crisis has taught all of us that taking bold action to prevent crises is as vital as "mopping-up after the crash as put by Korinek and Jeanne (2011). We would like to emphasize that we are not analyzing the impact of large financial shocks in this paper, but rather focus on creating macro-prudential mechanisms that are designed to countervail the amplification effect of financial frictions in transmission of conventional adverse shocks. We find that, a time-varying required reserves ratio rule that responds to financial system leverage dampens the volatility of the real and financial variables created by adverse productivity shocks. We also find that in response to inflationary money growth shocks, the same policy rule overturns the adverse dynamics of investment in the Sidrauski model and maintains larger increase in output and consumption with respect to their long run value. Our analysis also touches on the discussion about the tradeoff between price stability and financial stability. The quantitative results imply a higher inflation in the case of time-varying reserve requirements. Therefore, smoother investment and output cycles comes with the cost of higher inflation, which highlights

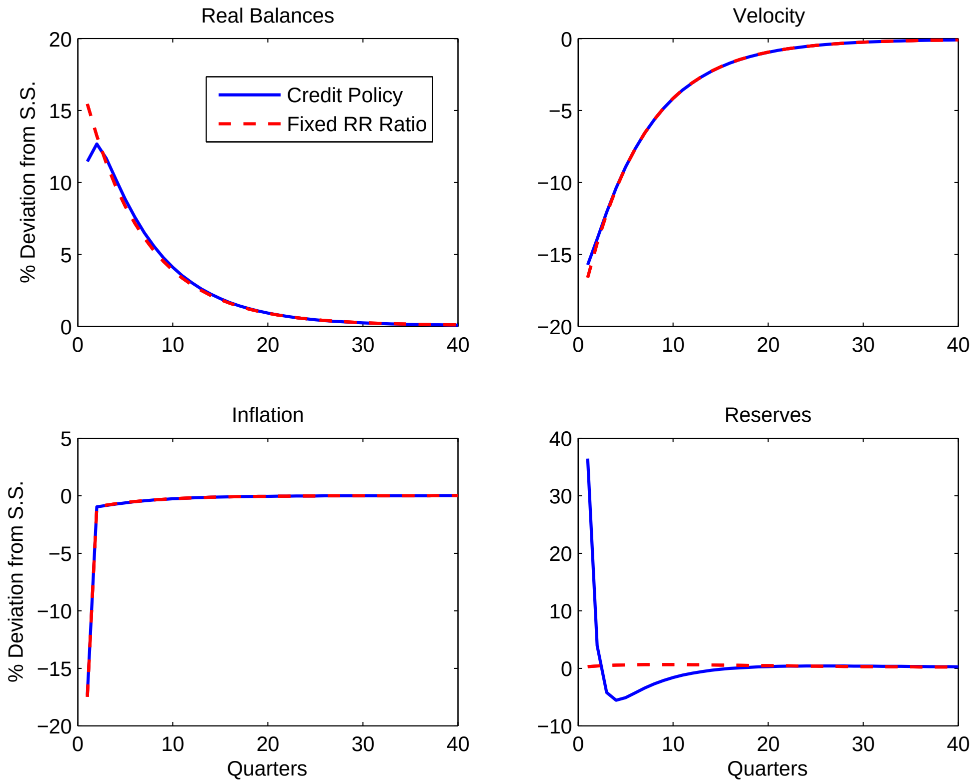

Figure 6: The Effect of Positive Money Growth Shocks on Monetary Variables

further research questions.

References

[1] Gertler, M. and Karadi, P. (2011). "A Model of Unconventional Monetary Policy," Journal of Monetary Economics 58, 17-34.

[2] Korinek, A. and Jeanne, O. (2011). "Macroprudential Regulation Versus Mopping Up After the Crash," *unpublished manuscript*.

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Table 2: Relative Volatilities with Respect to Output

Variable	Fixed Reserves	Credit Policy
c	**1.60**	**1.47**
k	0.22	0.22
i	**2.35**	**2.08**
h	**1.72**	**1.66**
n	**0.81**	**0.74**
b	1.11	2.00
q	**0.66**	**0.59**
lev	**1.38**	**1.30**
R_k	**0.48**	**0.29**
ESP	10.19	15.74
m	**10.32**	**9.34**
credit	**0.78**	**0.70**