Required reserves as a credit policy tool

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Abstract

This paper conducts a quantitative investigation of the role of reserve requirements as a macroprudential policy tool. We build a monetary DSGE model with a banking sector in which (i) an agency problem between households and banks leads to endogenous capital constraints for banks in obtaining funds from households, (ii) banks are subject to time-varying reserve requirements that countercyclically respond to expected credit growth, (iii) households face cash-in-advance constraints, requiring them to hold real balances, and (iv) standard productivity and money growth shocks are two sources of aggregate uncertainty. We calibrate the model to the Turkish economy which is representative of using reserve requirements as a macroprudential policy tool recently. We also consider the impact of financial shocks that affect the net worth of financial intermediaries. We find that (i) the time-varying required reserve ratio rule countervails the negative effects of the financial accelerator mechanism triggered by adverse macroeconomic and financial shocks, (ii) in response to TFP and money growth shocks, countercyclical reserves policy reduces the volatilities of key real macroeconomic and financial variables compared to fixed reserves policy over the business cycle, and (iii) a time-varying reserve requirement policy is welfare superior to a fixed reserve requirement policy. The credit policy is most effective when the economy is hit by a financial shock. Time-varying required reserves policy reduces the intertemporal distortions created by the credit spreads at expense of generating higher inflation volatility, indicating an interesting trade-off between price stability and financial stability.

Keywords: Banking sector, time-varying reserve requirements, macroeconomic and financial shocks

JEL Classification: E44, E51, G21, G28

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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 and macroprudential policy instruments have been the focal point of the recent literature on macroeconomic dynamics and policy. Among many, reserve requirements have been used extensively as a macroprudential policy tool in several emerging countries, recently. China, Brazil, Malaysia, Peru, Colombia and Turkey are some of the countries among others who have used this tool mostly to curb excessive credit growth in upturns along with other reasons.[1] In terms of their main objectives, they employ reserve requirements either as a monetary policy tool to achieve price stability or as a macroprudential policy tool to foster financial stability, or both. In this paper, we explicitly focus on the second objective: financial stability.

Central banks use reserve requirements to achieve financial stability in the following manner as Montoro and Moreno (2011) noted: they can raise reserve requirements to contain credit growth in the boom part of the business cycle in order to counteract financial imbalances in the economy or in an economic downturn, they can lower reserve requirements to utilize reserve buffers accumulated during the boom part, having the banking sector extend more credit to non-financial businesses. Therefore, reserve requirements can be used as a cyclical policy instrument to ease credit fluctuations in the financial sector, and hence to stabilize the real economy.

The goal of this study is to investigate the effectiveness of reserve requirements that respond to expected credit growth in moderating the real and financial cycles of an economy. We do so in a model where real and financial fluctuations are amplified by a financial accelerator mechanism. Specifically, we explore the stabilizing role of reserve requirements as a credit policy tool, on the transmission mechanism of productivity, monetary and financial shocks. The results suggest that a time-varying reserve requirement policy mitigates the fluctuations in key macroeconomic variables and improves welfare vis-a-vis a fixed reserve requirement policy.[2]

We build a monetary DSGE model in which the financial intermediation between depositors and non-financial firms are explicitly described as in Gertler and Karadi (2011). In this model, the amplification of TFP and money growth shocks are larger due to the so-called financial accelerator mechanism built in endogenous capital constraints faced by financial intermediaries. Endogenous capital constraints emerge from an agency problem assumption which posits that banks might divert a fraction of assets that they have expanded to non-financial firms. When this is realized by depositors, a bank run is initiated causing the bank to liquidate. Therefore, the contracting problem between depositors and banks requires an incentive compatibility condition to hold, i.e. the liquidation value of banks must be larger than or equal to the amount of diverted funds. As

[1] See Montoro and Moreno (2011), Montoro (2011), Gray (2011), Glocker and Towbin (2012) for the discussion of country experiences.

[2] At this point, we acknowledge that cancelling reserve requirements altogether might improve aggregate welfare of the economy. However, mostly due to precautionary reasons, positive reserve requirements do exist in practice and since it is beyond the scope of this paper, we do not bring any micro-foundation to this institutional framework in what follows.

expected, in this environment, depositors abstain from providing as much funds as they would have provided under the absence of this agency problem.

We extend the basic financial intermediation framework to one in which "money" is explicitly modelled via a cash-in-advance constraint. Arguably, explicit accounting of "quantity of money" is topical contemporaneously because it has been used as an operative monetary policy instrument to combat the recent global financial crisis by many central banks. Consequently, we introduce required reserves into the model in a very tractable way, since we have the concept of a monetary base.

We calibrate the model to the Turkish economy which exemplifies the use of reserve requirements as a macroprudential tool since the end of 2010 (see figure 1). In particular, the Central Bank of the Republic of Turkey (CBRT, hereafter) has increased weighted average of required reserves ratio – henceforth, RRR – from 5% to 13% between the period October 2010 and April 2011, in a stepwise manner. This period also coincides with the aftermath of the second phase of quantitative easing implemented by monetary authorities in a number of advanced economies. Evidently, this period is characterized by an increase in the risk appetite of global investors and excessive credit growth in emerging economies such as Turkey. On the other hand, same measure of RRR has been reduced to about 10% around November 2010 by the CBRT following the debt crisis of the Euro area.

Our quantitative exercise involves comparing a "fixed RRR economy" in which the RRR is calibrated to its "long-run" value preceding the interventions of the CBRT and the "time-varying RRR economy" in which the RRR is countercyclical with respect to expected credit growth.[3] We also simulate the model under moderate and aggressive required reserve policies in order to understand the effectiveness of the policy as a macroprudential policy tool.

There are three main results of the paper: First, the time-varying required reserve ratio rule countervails the negative effects of adverse macroeconomic and financial shocks and the financial accelerator mechanism on real and financial variables. As a result, we conclude that RRRs might be used as a macroprudential policy tool in an economy that exhibits financial frictions. Second, in response to TFP and money growth shocks, countercyclical reserves policy reduces the volatilities of key variables such as output, consumption, investment, bank credit, credit spreads and asset prices in comparison with fixed reserves policy. This happens because the amplification effect of the financial sector is mitigated by time-varying reserve requirements. Third, a time-varying reserve requirement policy is welfare superior to a fixed reserve requirement policy.

The workings of the model might be elaborated in greater detail as follows: An adverse TFP shock reduces the demand of financial intermediaries for equity and drives down its price. The collapse in asset prices feeds back into the endogenous capital constraints of intermediaries and causes banks' net worth to decline. Accordingly, the shortage in loanable funds, which manifests itself as a rise in credit spreads, combined with the collapse in asset prices causes investment to

[3]We also conduct the analysis of a model economy with zero required reserves policy. However, since the dynamics of this case strongly resemble those of the fixed RRR economy, we don't include it in the paper in order to save space.

decline substantially. When the RRR is fixed, the dynamics of reserves resembles that of deposits.

When the countercyclical RRR policy is in place, the fall in bank credit led by the adverse TFP shock calls for a reduction in the RRR. This induces banks to substitute loans for reserves on the assets side of the balance sheet, because the cost of raising external finance is lower with a smaller RRR. Accordingly, larger supply of funds extended by banks mitigates the collapse in investment and asset prices, countervailing the financial accelerator mechanism. This also limits the rise in credit spreads, which is an intertemporal distortion created by financial frictions in the consumption-savings margin of workers. The downward response of RRR reduces the demand for monetary base and shoots up inflation on impact. Therefore, the credit policy mitigates the financial accelerator at the expense of higher inflation. However, since this immediate surge is transitory and driven by the reserves policy, the model implies an undershooting of inflation in the following periods. This implies a substitution of consumption for leisure on the part of forward looking households and labor supply increases in contrast with the fixed RRR economy. Increased labor supply combined with a stronger trajectory for capital mitigates the collapse in output significantly.

A positive money growth shock increases inflation and crowds out deposits and consumption for leisure in our cash-in-advance specification. Therefore, a positive money growth produces similar dynamics to that of TFP shocks in the model. Consequently, the counter-cyclical RRR policy rule stabilizes key financial and real variables in response to money growth shocks again at the expense of higher inflation.

Lastly, we run a financial crisis experiment in which we consider an exogenous decline in the net worth of financial intermediaries as in Hancock, Laing and Wilcox (1995), Meh and Moran (2010), Brunnermeier and Pedersen (2009), Curdia and Woodford (2010), Mendoza and Quadrini (2010), Iacoviello (2010), and Mimir (2011). This shock crudely captures loan losses, asset write-downs or asset revaluations that we observe in the recent financial crisis. Most importantly, it might be interpreted as an exogenous variation in the risk appetite of international investors, that may have destabilizing effects on the financial system of an economy such as Turkey.

Although the initial decline in banks' net worth led by the financial shock is exogenous, there will be second round effects that amplify the collapse in internal finance of banks. This would create a shortage of bank credit and would drive a drop in investment, and in the price of capital. Banks then increase their demand for external financing (i.e. increase their deposit demand) to compensate for the decline in bank net worth. This causes reserves to increase and drives down inflation, pointing out a difference from the case of TFP and money growth shocks on part of the nominal dynamics. Yet, since the shock is transitory, inflation overshoots in the period that follows the shock and workers' expectations regarding the hike in future inflation causes hours to decline substantially on impact. Therefore, output collapses together with investment.

Credit policy in response to financial shock calls for a reduction in the RRR and is again inflationary in the sense that the reduction in inflation on impact becomes substantially lower. Accordingly, overshooting in inflation becomes less as well, limiting the collapse in hours. In this manner, the analysis shows that the counter-cyclical RRR policy has a stabilizing effect in response to financial shocks in addition to TFP and money growth shocks and might be used by the central bank as a macroprudential policy tool.

Related Literature

Our work is mostly related to the studies by Glocker and Towbin (2012) and Montoro (2011) who analyze the role of reserve requirements as a macroprudential policy tool. Glocker and Towbin (2012) augment required reserves as an additional policy instrument and variations in loans as an additional target into an open-economy model with nominal rigidities and financial frictions. Their results imply that requirements are in favor of price stability objective only if financial frictions are non-trivial and are more effective if there is a financial stability objective and debt is denominated in foreign currency. In their work, due to the endogeneity of monetary base, an increase in the RRR increases loan-deposit spreads only if the remuneration of reserves is below the market rate. Since they obtain impact of policy change on consumption and investment, the overall effect on aggregate demand and inflation is ambiguous.

Montoro (2011) introduces counter-cyclical RRR policy tools in an otherwise standard New-Keynesian setting that introduce collateral and liquidity constraints as in Kiyotaki and Moore (2008) and maturity mismatch frictions as in Benes and Lees (2010). He finds that RRRs contain the procyclicality of the financial system in response to demand shocks but not under supply shocks. The main differences of our work with these papers is that we model financial frictions a-la' Gertler and Karadi (2011) that introduces an agency problem between depositors and bankers and that involves equity financing of non-financial firms. An important deviation from the former study is that we also explore the role of RRRs in response to financial shocks and from the latter study is that we find that RRRs might be stabilizing even under supply shocks. From an alternative perspective, our finding that credit policy implemented by RRRs is the most effective in response to financial shocks is in line with the finding of Glocker and Towbin (2012) that RRRs are mostly effective when financial frictions are relevant.

Another closely related paper to the current study is the work of Christensen et al. (2011) which explores the role of countercyclical bank capital regulations as a macroprudential policy tool. Similar to our experiment, they compare time-varying and constant bank capital regulations and find that the former regime reduces volatilities of real variables and bank lending. However, as they state in their paper, the type of financial friction that they introduce differs from that of Gertler and Karadi (2011) in that it is driven by asymmetric information between bankers and their creditors a la' Holmstrom and Tirole (1997), instead of limited commitment. While the macroprudential regulation in their work is focused on the *"size"* of the balance sheet, in our work it is focused on the *"composition of the assets side"* of the balance sheet.

Our work also has linkages to closed economy frameworks of Kashyap and Stein (2012) and Curdia and Woodford (2011) in which the remuneration of reserves has been studied. Yet, it is obvious that reserves policy studied in these papers are more related to the central bank balance sheet considerations of the Federal Reserve at the onset of the sub-prime financial crisis and do not have the focus of containing excessive credit growth in contrast with the focus of our work. From another perspective, the descriptive work of Gray (2011) on recent reserve requirement policy experiences and the work of Reinhart and Reinhart (1999) on the use of required reserves for stability of international capital flows relates to the current paper.

The rest of the paper is organized as follows. Section 2 describes the model economy and characterizes equilibrium. Section 3 undertakes the quantitative analysis regarding the dynamics introduced by macroeconomic and financial shocks and section 4 concludes.

2 The Model

The model economy is inhabited by households, banks, final goods producers, capital producers, and a government. Time is discrete. Two financial frictions characterize the economy. First, market segmentation ensures that households who are the ultimate savers in the economy cannot directly lend to non-financial firms. This assumption makes the banking sector essential for transferring funds from ultimate savers (households) to ultimate borrowers (final goods producers). Second, banking sector is characterized by credit frictions that are modelled *a la* Gertler and Karadi (2011). Households face a cash-in-advance constraint, which makes them hold real balances, leading to the existence of monetary equilibria. Finally, banks are subject to time-varying reserve requirements imposed by the central bank, which reacts countercyclically to expected credit expansion in the economy. Below is a detailed description of economic agents that reside in this model economy.

2.1 Households

The population consists of a continuum of infinitely-lived identical households. We assume that each household is composed of a worker and a banker who perfectly insure each other. Workers supply labor to the final goods producers and assumed to deposit their savings in the banks owned by the banker member of "*other*" households.[4]

A representative household maximizes the discounted lifetime utility earned from consumption, c_t and leisure, l_t,

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

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

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

[4]This assumption is useful in making the agency problem that we introduce in section 2.2 more realistic.

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 gross risk free deposits rate, Π_t is the profits remitted from the ownership of banks and capital producers and T_t is lump-sum transfers remitted by the government.

Households face a cash-in-advance constraint which reflects the timing assumption that asset markets open first as in Cooley and Hansen (1989):

$$c_t \leq \frac{M_t}{P_t} + \frac{T_t}{P_t} + R_t b_t - b_{t+1} \tag{3}$$

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

$$u_c(t) = \beta R_{t+1} E_t u_c(t+1) \tag{4}$$

$$\frac{u_l(t)}{P_t w_t} = \beta E_t \left\{ \frac{u_c(t+1)}{P_{t+1}} \right\} \tag{5}$$

Condition (4) is a standard consumption-savings optimality condition, which equates marginal benefit of consumption to the expected discounted benefit of saving in deposits. Equation (5) on the other hand is a non-standard consumption-leisure optimality condition due to the existence of cash-in-advance friction which transforms the trade-off between the two into an inter-temporal one. Specifically, increasing leisure demand by 1 unit reduces savings in cash by $\frac{P}{P'} = \frac{1}{1+\pi'}$ future units because the yield of cash balances is deflated by inflation. Therefore, the utility cost of leisure is measured only in terms of future utility foregone by facing a tighter cash-in-advance constraint in the next period.

2.2 Banks

The modelling 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 bank j as,

$$q_t s_{jt} = (1 - rr_t) b_{jt+1} + n_{jt} \tag{6}$$

The right hand side of the balance sheet denotes the resources of bank j, namely, net worth, n_{jt} and deposits, b_{t+1} needed to finance its credit extension to non-financial firms, $q_t s_{jt}$. The loans to firms serve as state-contingent claims s_{jt} 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 central bank as we describe below. The balance sheet of banks described in equation (6) imply an evolution equation for net worth as follows:

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

It is evident in equation (7) that an increase in the required reserve ratio rr_t decreases the returns to assets and increases the returns to equity all else equal. That induces banks to substitute internal financing (n_t) for external financing (b_{t+1}).

Bankers have a finite life and survive to the next period with probability θ.[5] 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 exiting bankers. Bankers' objective is to maximize the present discounted value of the terminal net worth of their financial firm, V_{jt}, by choosing the amount of claims against the firm ownership, s_{jt}. That is,

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

The finite life of bankers, $\theta < 1$, ensures that bankers never accumulate enough net worth to finance all their equity purchases of non-financial firms via internal funds so that they have to borrow from households in the form of deposits.

The key feature of the financial sector unfolds around a moral hazard problem 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 $q_t s_{jt}$ 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_{jt} at any date t should satisfy an incentive compatibility constraint,

$$V_{jt} \geq \lambda q_t s_{jt} \tag{9}$$

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

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

$$V_{jt}^* = \nu_t q_t s_{jt}^* + \eta_t n_{jt}^* \tag{10}$$

where the recursive objects,[6]

[5]This assumption ensures that bankers do not reach to a point in which they only self-finance.

[6]Proofs of equations (10), (11), and (12) are available in technical appendix upon request.

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

and

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

represent the marginal values of relaxing credit and accumulating net worth for the bank respectively. The growth rates of assets and net worth of banks are denoted with $\chi_t = \frac{q_{t+1}s_{jt+1}}{q_t s_{jt}}$ and $\varrho_t = \frac{n_{jt+1}}{n_{jt}}$.

One can obtain the following by combining equations (9) and (10):

$$\nu_t q_t s_{jt} + \eta_t n_{jt} \geq \lambda q_t s_{jt} \tag{13}$$

Given that $\eta_t n_{jt}$ is strictly greater than zero, $\nu_t \geq \lambda$ would imply a strict inequality in (13). Therefore $\nu_t < \lambda$ should hold for (13) to be an equality. Moreover, ν_t must be greater than zero for the banks to increase loans until the above incentive compatibility constraint binds. This is always the case under reasonable values of parameters in our model $\nu_t < \lambda$, which in turn produces the endogenous borrowing constraint for the bank as follows:

$$q_t s_{jt} = \frac{\eta_t}{\lambda - \nu_t} n_{jt} = \kappa_t n_{jt}. \tag{14}$$

This is the case in which the loss of bankers in the event of liquidation is just equal to the amount of loans that they can divert. 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.

We confine our interest to equilibria in which all households behave symmetrically so that we can aggregate equation (14) over j and obtain the following aggregate relationship:

$$q_t s_t = \kappa_t n_t \tag{15}$$

where s_t and n_t represent aggregate levels of banks' assets and net worth, respectively. Equation (15) shows that aggregate credit in this economy can only be up to an endogenous multiple of aggregate bank capital. Also, fluctuations in asset prices (q_t) will feedback into fluctuations in bank capital via this relationship. This will be the source of financial accelerator mechanism in our model.

The evolution of aggregate net worth depends on that of the surviving bankers (n_{et+1}) and the start-up funds of the new entrants (n_{nt+1}):

$$n_{t+1} = n_{et+1} + n_{nt+1}. \tag{16}$$

The start-up funds for new entrants are equal to $\frac{\epsilon}{1-\theta}$ fraction of exiting banks' net worth, $(1-\theta)n_t$. [7] Therefore,

$$n_{nt+1} = \epsilon n_t \tag{17}$$

The fact that θ fraction of banks survive over next period equates the net worth of surviving banks to the following:

$$n_{et+1} = \theta \left\{ \left[R_{kt+1} - \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) \right] \kappa_t + \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) \right\} n_t \tag{18}$$

One can sum up equations (17) and (18) to obtain the evolution of net worth for the entire set of banks:

$$n_{t+1} = \left\{ \theta \left(\left[R_{kt+1} - \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) \right] \kappa_t + \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) \right) + \epsilon \right\} n_t \tag{19}$$

Equation (19) shows that the evolution of net worth depends on effective spread and leverage ratio of banks.

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

$$y_t = exp(z_t)F(k_t, h_t) \tag{20}$$

where

$$z_{t+1} = \rho_z z_t + \epsilon_{zt+1} \tag{21}$$

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

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

$$q_t s_t = q_t k_{t+1} \tag{22}$$

[7] This assumption is slightly different from that in Gertler and Karadi (2011). They assume that the net worth of newly entering bankers is a fraction of banks' total assets rather than its net worth. Since the fraction is small, it does not change the main results of the paper significantly.

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

$$R_{kt} = \frac{z_t F_k(k_t, h_t) + q_t(1-\delta)}{q_{t-1}} \tag{23}$$

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

$$w_t = exp(z_t) F_h(k_t, h_t) \tag{24}$$

which equates marginal product of labor to the marginal cost of it.

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 reads,

$$\max_{i_t} q_t k_{t+1} - q_t(1-\delta)k_t - i_t \tag{25}$$

subject to the capital accumulation technology,

$$k_{t+1} = (1-\delta)k_t + \Phi\Big(\frac{i_t}{k_t}\Big)k_t \tag{26}$$

where the function $\Phi(\cdot)$ 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,

$$q_t = \Big[\Phi'\Big(\frac{i_t}{k_t}\Big)\Big]^{-1} \tag{27}$$

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 μ_t,

$$M_{0t+1} = exp(\mu_t) M_{0t} \tag{28}$$

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

$$\mu_{t+1} = (1-\rho_\mu)\bar{\mu} + \rho_\mu \mu_t + \epsilon_{\mu t+1} \tag{29}$$

In order to contain the financial accelerator mechanism, the government uses required reserves as a macroprudential rule. Specifically, the required reserves ratio is assumed to follow a rule that reacts to the expected growth rate of bank credit at date $t+1$ compared to its level in the current period.

$$rr_t = \bar{rr} + \phi E_t \left[\log(q_{t+1}s_{t+1}) - \log(q_t s_t)\right] \tag{30}$$

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

$$M_{0t+1} = M_{t+1} + P_t rr_t b_{t+1} \tag{31}$$

where P_t is the general price level of the consumption good. Since the left hand side is exogenously determined by the central bank, equilibrium in the money market might call for adjustments in price level in response to fluctuations in reserves.

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 (1989), 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 $\{c_t, k_{t+1}, i_t, l_t, h_t, s_t, n_t, n_{et}, n_{nt}, b_{t+1}, \Lambda_{t,t+1}, \nu_t, \eta_t, \kappa_t, \rho_{t,t+1}, \chi_{t,t+1}, \hat{m}_{t+1}, \pi_t\}_{t=0}^{\infty}$, 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:

$$\Lambda_{t,t+1} = \frac{u_c(t+1)}{u_c(t)} \tag{32}$$

$$1 = \beta E_t R_{t+1} \Lambda_{t,t+1} \tag{33}$$

$$c_t = \frac{exp(\mu_t) - 1 + \hat{m}_t \hat{P}_t}{\hat{P}_t exp(\mu_t)} + R_t b_t - b_{t+1} \tag{34}$$

$$\frac{u_l(t)}{w_t \hat{P}_t} = \beta E_t \left\{ \frac{u_c(t+1)}{\hat{P}_{t+1} exp(\mu_{t+1})} \right\} \tag{35}$$

$$\kappa_t = \frac{\eta_t}{\lambda - \nu_t} \tag{36}$$

$$q_t s_t = \kappa_t n_t \tag{37}$$

$$q_t s_t = (1 - rr_t) b_{t+1} + n_t \tag{38}$$

$$\varrho_{t,t+1} = \Big(R_{kt+1} - \frac{R_{t+1} - rr_t}{1 - rr_t}\Big)\kappa_t + \frac{R_{t+1} - rr_t}{1 - rr_t} \tag{39}$$

$$\chi_{t,t+1} = \varrho_{t,t+1} \frac{\kappa_{t+1}}{\kappa_t} \tag{40}$$

$$n_{et} = \theta \varrho_{t-1,t} n_{t-1} \tag{41}$$

$$n_{nt} = \epsilon n_{t-1} \tag{42}$$

$$n_t = n_{et} + n_{nt} \tag{43}$$

$$\nu_t = E_t \left\{ (1-\theta)\beta\Lambda_{t,t+1} \left(R_{kt+1} - \frac{R_{t+1} - rr_t}{1 - rr_t} \right) + \beta\Lambda_{t,t+1}\theta\chi_{t,t+1}\nu_{t+1} \right\} \tag{44}$$

$$\eta_t = E_t \left\{ (1-\theta)\beta\Lambda_{t,t+1} \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) + \beta\Lambda_{t,t+1}\theta\varrho_{t,t+1}\eta_{t+1} \right\} \tag{45}$$

$$w_t = exp(z_t) F_h(k_t, h_t) \tag{46}$$

$$R_{kt} = \frac{exp(z_t) F_k(k_t, h_t) + q_t(1 - \delta)}{q_{t-1}} \tag{47}$$

$$k_{t+1} = (1 - \delta) k_t + \Phi\Big(\frac{i_t}{k_t}\Big) k_t \tag{48}$$

$$q_t = \Big[\Phi'\Big(\frac{i_t}{k_t}\Big)\Big]^{-1} \tag{49}$$

$$exp(z_t) F(k_t, h_t) = c_t + i_t \tag{50}$$

$$s_t = k_{t+1} \tag{51}$$

$$1 = l_t + h_t \tag{52}$$

$$exp(\pi_t) = exp(\mu_t)\frac{\widehat{P_t}}{\widehat{P_{t-1}}} \tag{53}$$

$$z_{t+1} = \rho_z z_t + \epsilon_{zt+1} \tag{54}$$

$$\mu_{t+1} = (1-\rho_\mu)\bar{\mu} + \rho_\mu \mu_t + \epsilon_{\mu t+1} \tag{55}$$

$$rr_t = \bar{rr} + \phi E_t\left[\log(q_{t+1}s_{t+1}) - \log(q_t s_t)\right] \tag{56}$$

$$\frac{1}{\widehat{\widehat{P_t}}} = \hat{m}_{t+1} + rr_t b_{t+1} \tag{57}$$

3 Quantitative Analysis

3.1 Functional Forms

Preferences: We use a standard CRRA utility function and separable utility for leisure:

$$u(c_t, l_t) = \frac{c_t^{1-\gamma}}{1-\gamma} - \psi\frac{(1-l_t)^{1+\nu}}{1+\nu} \tag{58}$$

with $\gamma > 1$, $\psi, \nu > 0$.

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

$$exp(z_t)F(k_t, h_t) = exp(z_t)k_t^\alpha h_t^{1-\alpha} \tag{59}$$

with $0 < \alpha < 1$.

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

$$\Phi\Big(\frac{i_t}{k_t}\Big) = \frac{\varphi}{2}\Big[\frac{i_t}{k_t} - \delta\Big]^2 \tag{60}$$

The parameter values used in the quantitative analysis are reported in table 1. The preference and production parameters are standard in business cycle literature. The share of capital in the production function is set to 0.4, and the capital adjustment cost parameter is 2.75. We borrow the standard values of γ and v from literature as 2 and 2, respectively. We take the quarterly discount factor, β, as 0.9885 to match the 2006-2011 average annualized real deposit rate, 4.73%, in Turkey. We pick the relative utility weight of labor, ψ, to fix hours worked in steady state, $\overline{h}$, at

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 risk aversion (γ)	2	
Inverse of the Frisch elasticity (v)	2	Literature
Relative utility weight of leisure (ψ)	15.182	Hours worked (0.33)
Production Technology		
Share of capital in output (α)	0.4	Labor share of output (0.64)
Capital adjustment cost parameter (φ)	2.75	Relative volatility of investment = 2.25
Depreciation rate of capital (δ)	0.037	Average annual ratio of investment to capital (14.8%)
Government		
Steady-state value of RRR ($\bar{rr}$)	0.05	Pre macroprudential policy period
Adjustment parameter in the RRR rule (ϕ)	5.15	Standard deviation of differences in RRR for 2009:4-2012:2 (1.73%)
Financial Intermediaries		
Fraction of diverted loans (λ)	0.5	Annual commercial & industrial loan spread (1.96%)
Prop. transfer to the entering bankers (ϵ)	0.001	5.71% of aggregate net worth
Survival probability of the bankers (θ)	0.962	Capital adequacy ratio of 16% 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)	0.5702	Estimated from $\log \Delta M1_t = (1-\rho_\mu)\bar{\mu} + \rho_\mu \log \Delta M1_{t-1} + \epsilon_{\mu t}$
Std. deviation of money growth shocks (σ_μ)	0.0275	

one third of the available time. The quarterly depreciation rate of capital is set to 3.7% to match the 1987-2011 average annual investment to capital ratio of 14.8% in Turkey.

Parameters related to the financial sector are calibrated to match financial statistics of the Turkish economy in the period 2006-2011. We set ϵ to 0.001 so that the proportional transfer to newly entering bankers is 5.71% of aggregate net worth. We pick the fraction of diverted funds, λ, and the survival probability, θ, simultaneously to match the following two targets: an average interest rate spread of 48 basis points, which is the historical average of the difference between the quarterly commercial and industrial loan rates and the quarterly deposit rate from 2006:Q1 to 2011:Q4, and an average capital adequacy ratio of 16%, which is the historical average of Turkish commercial banks' capital adequacy ratio for the same period.[8] The resulting values for λ and θ are 0.5 and 0.962, respectively. The benchmark model involves a macroprudential policy rule illustrated in equation (28) which does not alter the steady state of the model but affects the dynamics around it. We calibrate the value of the response parameter of the RRR rule, ϕ, to

[8] The legal target of risk-weighted capital adequacy ratio set by the Banking Regulation and Supervision Agency in Turkey is 8%, however, commercial banks in Turkey maintain 16% for this ratio in practice.

5.15 in order to match the standard deviation of the differences in RRR of 1.73% for the Turkish economy in the period 2009:4-2012:2.[9]

We estimate an AR(1) process for the log of TFP for the period 1988:Q2-2011:Q2 and find a persistence of, $\rho_z = 0.9821$, and a standard deviation of innovations to TFP, $\sigma_z = 0.0183$. The money growth process on the other hand is estimated for the period 2003:Q1-2011:Q4.[10] Estimation results implied a persistence of, $\rho_z = 0.5702$, and a standard deviation of innovations to money growth shocks, $\sigma_\mu = 0.0275$.

With the parameterized economy, we first illustrate the role of financial accelerator driven by credit frictions in the banking sector. We then study the dynamics of the model by focusing on impulse responses to one standard deviation negative productivity and positive money growth shocks in environments that involve alternative required reserves policies. We also document implications of using a time-varying required reserves ratio in terms of its effect on the volatilities of real and financial variables in order to understand its effectiveness as a macroprudential policy tool. Finally, we analyze the welfare implications of alternative RRR policies.

3.2 Findings

In the following subsections, we first display the role of financial accelerator by comparing the usual cash-in-advance model with the model described in section 2. We then compare the dynamics of negative TFP and positive money growth shocks under two model economies with time-varying and fixed RRR policies. Lastly, we run a financial crisis experiment, in which the net worth of banks are hit by a one-time exogenous shock, and compare the implications of the two reserve requirement regimes.[11]

3.2.1 Amplifying Effect of Financial Frictions

The dashed and straight plots in figures 2 and 3 represent the economy described in section 2 and the standard cash-in-advance model with no financial frictions, respectively. Required reserves ratio in the former economy is set to zero to isolate the impact of financial frictions.

Figure 2 below illustrates that the collapse in output, investment, price of capital and loan-deposit spreads is amplified when financial frictions are in place. We especially want to highlight the almost tripling increase in the reduction of investment and asset prices and 250 basis points of increase in the credit spreads in annualized terms. The last one is even more striking because in the economy with no financial frictions, there is no-arbitrage between return to capital and return to deposits. The evident amplification owes to the reduced demand of banks for deposits in case of lower productivity. This stems from the decline in the return to state-contingent equity issued by firms when productivity is lower. This depresses the price of equity issued by firms and results

[9] This is the period in which the Central Bank of the Republic of Turkey changed the RRR for macroprudential purposes.

[10] The choice of estimation period reflects the structural disinflation that the Turkish economy has experienced, see Sunel (2011).

[11] We also analyzed the case with zero reserve requirements policy. Since the dynamics are quite similar to a fixed RRR regime, we do not report those results, which are available upon request.

in a collapse in the value of funds provided to them. As a result, firms acquire less capital and investment declines more.

Figure 3 illustrates the dynamics in response to a positive money growth shock. An important feature of this cash-in-advance economy is that as equations (3) (with equality) and (5) suggest, investment and leisure act as cash and credit goods in our model, respectively. Therefore, when inflation rises following a positive money growth shock, labor supply and investment decreases causing a decline in output. We again obtain amplified responses of investment, asset prices, output and credit spreads on impact following the shock. Yet, the trajectory of all variables except the last appears to be similar to the economy with no financial frictions. The amplified response of investment is coupled with larger degree of declines in asset prices and credit spreads as in the case of TFP shocks. We also note that the quantitative impact of monetary shocks are much smaller compared to TFP shocks, which is a typical property of CIA models.

We now analyze the implications of the RRR policy on the dynamics of real, financial, and monetary variables. In figures 4 and 5, we compare the dynamics of these variables in response to one standard deviation negative TFP and positive money growth shocks. In figure 6 we explore the implications of RRR policy in a financial crisis scenario. The specific financial disruption is a balance sheet shock that bankers face as in mostly recent literature.[12]

In figures 4 to 6, the dashed plots correspond to the benchmark economy with the countercyclical RRR rule and the straight plots correspond to an economy with fixed RRR. The dynamics of the economy with no reserves closely resemble those with a fixed RRR. Therefore for space considerations, we do not discuss them here and only present the comparison of fixed RRR economy with the benchmark economy that displays a countercyclical RRR.[13] Unless otherwise is stated, the numbers in the y-axes correspond to percentage deviations of variables from their long-run values. For the case of inflation and RRR, we plot percentage *"point changes"* and for the case of credit spreads we plot *"basis point changes"* in annualized terms. In addition, we explore the impact of implementing aggressive credit policy rules by increasing the response parameter ϕ. In these experiments, as anticipated, the impact of the time-varying RRR rule is enhanced when ϕ is larger. Therefore, we do not include charts regarding policy intensity experiments here, and they are available from authors upon request.

3.2.2 Impulse Responses to TFP Shocks

The general observation that emerges from figure 4 is that the time-varying RRR policy dampens the impact of the financial accelerator on key macroeconomic real and financial variables at the expense of higher inflation in response to TFP shocks.

In the economy with fixed RRR, as expected, households reduce their demand for consumption and supply of deposits in response to the adverse TFP shock since output and the profits that accrue from the ownership of banks and capital producers are lower. On the banks' side, the

[12]Hancock, Laing and Wilcox (1995), Meh and Moran (2010), Brunnermeier and Pedersen (2009), Curdia and Woodford (2010), Mendoza and Quadrini (2010), Iacoviello (2010), and Mimir (2011).

[13]The dynamics of the economy with no reserves are available upon request.

reduced TFP highlights the reduction in the profitability of equity loans to firms, inducing them to reduce their demand for deposits.

Under fixed RRR economy, as figure 4 shows, the net worth of banks collapse by 4% reflecting the feedback effect of a 0.6% decline in asset prices through the endogenous capital constraint of banks, represented by equation (15). The decline in net worth in accordance with the decline in deposits downsizes the total financing for non-financial firms (see figure 4). However, since the decline in bank capital is larger than that of the value of bank assets, the model implies a countercyclical bank leverage, which increases by 3.5%. On the other hand, the scarcity of funds for firms shoots up loan-deposits spreads by about 250 basis points in annualized terms (see the middle panel of figure 4). The reduction in the quantity of equities traded and the collapse in asset prices trigger a downsizing in bank credit of about 0.75%. As a combined outcome of these dynamics, investment falls by 3.75% and output declines by about 1.75%.

The nominal price level increases (the bottom panel of figure 4) because the economy is now less productive in generating output. Hence, inflation increases by 0.2 percentage points causing the real balances demand to decline and consumption velocity of monetary base to increase by about 1%.

Now, we explain how the credit policy defined by a countercyclical RRR rule mitigates the impact of the financial accelerator on key macroeconomic real and financial variables (see the dashed plots in figure 4). Since bank credit declines in response to the adverse TFP shock, the policy rule implies a reduction in the RRR by about 1 percentage point, which can be seen in the bottom panel of the figure. This reduces the cost of extending credit for banks and induces a substitution from reserves balances to loans in the asset side of their balance sheet. Consequently, the stronger demand for firm equity stabilizes the price of it on impact, and the peak of decline in equity price is about 0.2% less than how much it is in the fixed RRR economy. The substitution in the balance sheet of banks combined with the better outlook of asset prices reduce the collapse in bank credit from 0.8% to 0.2%. Accordingly, output and investment decline by 1.3% and 3.5% less than how much they decline in the fixed RRR economy.

The support of the central bank via lower reserve requirements cause credit spreads to rise by about 150 basis points less compared to the fixed RRR economy over 5 quarters. We emphasize this finding because credit spreads introduce an intertemporal wedge to the savings decision of the aggregate economy and are created by financial frictions. The relatively muted response of spreads stems from the reduced decline in return to firm equity. The stronger outlook of the economy reflects into the balance sheet of banks and bank capital declines by 4% less compared to the fixed RRR economy and even increases above its long-run level for 20 quarters, since RRR is lower than its long-run value for about 30 quarters. The immediate implication of stronger trajectory of net worth is a rise of virtually zero in bank leverage on impact (against a 3.25% hike with fixed RRR) and even implies a decline of it up to 2% caused by the increase in bank capital.

The substantial collapse in reserves demand (about 20%) drives down the price of money and amplifies the upwards response of inflation obtained in the fixed RRR economy (see bottom panel of figure 4). However, since this immediate surge is transitory and driven by the reserves policy, the model implies an undershooting of inflation in the coming 7 quarters. This implies a substitution of consumption for leisure on the part of forward looking households and labor supply increases by 2% more in comparison with the fixed RRR economy. Hence, we obtain the stabilizing impact of the countercyclical RRR rule on the dynamics of output displayed in the top panel of figure 4. Consistent with these findings, demand for real balances collapses on impact but outweighs its steady state level along the transition and consumption velocity increases by 11% more than the fixed RRR economy.

To sum up, the countercyclical RRR policy mitigates the impact of financial accelerator triggered by TFP shocks on real and financial variables at the expense of higher inflation. Now, we explore the dynamics driven by money growth shocks.

3.2.3 Impulse Responses to Money Growth Shocks

In this section, we analyze the dynamics of our model economies in response to a one-standard deviation positive money growth shock. Figure 5 displays the impulse responses. Although the impact of a money growth shock on those variables is an order of magnitude smaller than that of a productivity shock, these figures deliver the same message as in the previous section that the time-varying RRR policy mitigates the adverse effects of money growth shocks on real and financial variables driven by the financial accelerator mechanism while creating higher inflation rates compared to fixed RRR policy.

We should firstly note that the dynamics of the model with fixed required reserves ratio policy strongly resemble the properties of a standard stochastic cash-in-advance economy by Stockman (1981) and Cooley and Hansen (1989). In this sense, we follow the timing assumption of Cooley and Hansen (1989) that asset markets open first for workers, but with the difference that b_{t+1} is not necessarily (and actually never) equal to zero, and higher rates of inflation discourage household savings in the form of deposits. In the end, the general mechanism in this basic model is broadly summarized by the idea that an expansionary shock to the growth rate of money supply raises inflation rate and induces households to substitute credit goods for cash goods. The reflection of that mechanism to the current model is that consumption and deposit savings decline and leisure demand increases as implied by equations (3) and (5). Since deposit savings are intermediated to non-financial firms' equity financing, investment declines in response to a positive money growth shock. Lower investment and the decline in labor supply then reduce output and consumption.

In the fixed RRR economy, inflation rate increases by about 0.2% percentage points on impact. This reduces hours worked by 0.25% since consumption and deposits are the cash goods and leisure is the credit good. The fall in household deposits leads to a reduction in bank credit in the form of equity purchases. As the demand for non-financial firms' shares decline, the price of equity falls by 0.07%. The decline in equity prices causes bank net worth to shrink by 0.4% on impact, leading to a rise in credit spreads by about 20 annualized basis points. Since the cost of financing capital expenditures is now higher for non-financial firms, investment and output drop by 0.4% and 0.15%, respectively. In terms of monetary variables, as inflation rate rises, real money balances decrease and consumption velocity surges by 0.4%.

When the central bank puts the credit policy to work, RRR declines about 0.06 percentage points as bank credit falls in response to a positive money growth shock. There is an immediate decline of 1.25% in the reserves, and deposit demand by banks. The reduced cost of extending credit induces banks to substitute away their assets from reserves to firm equity, and accordingly the initial decline in bank credit is 0.07% smaller. As equity purchases by banks are larger, the decline in the price of equity on impact is totally eliminated in comparison to the fixed RRR policy. This is reflected into the balance sheet of banks and intermediary capital does not decline at all compared to a reduction of 0.45% in the fixed RRR economy. Furthermore, the rise in credit spreads are about 15 annualized basis points lower and the stronger trajectory of bank net worth causes leverage to decline by 0.05% over 5 quarters instead of an increase of about 0.4%. Since credit spreads are the main source of intertemporal distortion caused by the credit frictions in financial sector, the central bank effectively mitigates the adverse impact of this distortion on the economy via implementing a lower reserve requirement policy. As another favorable result of these dynamics, investment falls by 0.3% less in the case of time-varying reserve requirements.

The initial fall in reserves by 1.2% creates an excess supply of monetary base in the economy and raises the inflation rate by 0.25% percentage points to restore equilibrium in the money market (see figure 5). Therefore the trade-off between price and financial stability is still evident under money growth shocks. This causes the real money demand to decline and consumption velocity of monetary base to rise by 0.6% more. Lastly, we again obtain the undershooting of inflation following the first period as opposed to the case with fixed RRR. This feeds back into the consumption-leisure margin of workers and hours decline by about 0.2% less compared to the fixed RRR economy. This results in stabilizing output on impact and obtaining 0.1% less decline in it over 5 quarters when the rule is in place.

3.2.4 Financial Crisis Experiment and Credit Policy

The previous two sections illustrated that the macroprudential reserves policy stabilizes key macroeconomic and financial variables in response to conventional shocks along the business cycle. In this section, we explore how countercyclical reserve requirements perform during a financial crisis. The specific experiment is to consider an exogenous decline in the net worth of financial intermediaries. This shock crudely captures loan losses, asset write-downs or asset revaluations that we observe in the recent financial crisis. As stated in the section 1, it might be thought of as a sharp reversal in the risk appetite of international investors, which is an exogenous factor that threatens the financial stability of a country such as Turkey.

Although the initial decline in banks' net worth that we introduce is exogenous, there will be second round effects that endogenously trigger an adverse financial accelerator mechanism. The initial fall in the net worth reduces the amount of bank credit that can be extended to non-financial firms as banks are not able to compensate the decline in their internal financing with households' deposits. Since non-financial firms finance their capital expenditures via bank credit, there will be a drop in investment, and hence in the price of capital. The value of intermediary capital depends on asset prices. The endogenous decline in asset prices leads to a further deterioration in banks' net worth, creating an adverse feedback loop of falling aggregate demand, declining asset prices, and deteriorating intermediary balance sheets.

Specifically, we consider an initiating disturbance of a 5% decline in the net worth of financial intermediaries. This disturbance will be a one-time shock and we want to think of it as a rare event. We analyze the effects of this shock in the model economy with fixed RRR policy and then illustrate the mitigating effects of time-varying RRR policy on real, financial and monetary variables. Figure 6 shows the impulse responses of real, financial and monetary variables under different policy regimes.

In the economy with fixed RRR, the negative net worth shock immediately reduces bank capital by 11% on impact (see the middle panel of figure 6). Although deposits rise due to banks' increased demand for deposits to compensate the decline in their internal financing, the deterioration of bank capital causes total financing by financial intermediaries to shrink. This translates into a reduction in bank credit in the form of equity purchases to firms by 1.2% on impact. As the demand for firms' shares is lower, the price of equity falls by 1%. This amplifies the exogenous impact of the financial shock via endogenous capital constraint of banks and explains the substantial decline of 11% in the net worth. The decline in bank capital rises their leverage by 10% on impact. Induced by the shortage in credit and collapse in asset prices, credit spreads rise by 450 basis points in annualized terms. This in turn causes firms to cut back their investment severely (by about 6%) due to lower bank credit and higher cost of financing.

The increase in bank deposits driven by banks' effort to compensate for the net worth loss increases reserves balances by 1% in the fixed RRR economy. This creates an excess demand for monetary base and inflation declines on impact by 0.6 percentage points (see the bottom panel of figure 6). However, since the shock is transitory, inflation overshoots by 0.7 percentage points in the period that follows the shock and workers' expectations regarding the hike in future inflation causes hours to decline by 2.75% on impact. Therefore, output shrinks by 1.6% as shown in the top panel of the figure. The dynamics of real balances demand and consumption velocity of monetary base resemble the expected implication of the dynamics of inflation.

In the model economy with credit policy, the time-varying rule induces a fall in the RRR of about 0.6 percentage points since bank credit declines in response to the negative financial shock. Reserves immediately drop by 11% and eliminate the collapse in inflation almost completely. Most importantly, the dynamics of reserves moves inflation in such a way to induce hours and accordingly output to increase on impact (see the bottom and top panels of figure 6).

Following the reduced cost of making equity loans to firms, banks substitute away their assets from reserves to firm equity, therefore the initial decline in bank credit is 1% smaller. As the demand for firm equity is higher in the model with credit policy, the 1% reduction in the price of equity is in the model economy with fixed RRR policy is almost totally eliminated. This reinforces the intermediary capital via the leverage constraint and reduces the collapse in bank net worth by 5%. We emphasize this finding that the macroprudential policy reduces the amplified impact of the financial shock on bank capital by 50%. Accordingly, the rise in credit spreads are 200 basis points lower in annualized terms and bank leverage increases by 5% instead of 10%. As another favorable outcome, investment falls by 5% less than the decline in the fixed RRR economy over 5 quarters. To sum up, we obtain the result that a macroprudential reserve requirements policy that has a first order impact on the balance sheet of financial intermediaries is the most effective in the event of a financial turmoil.

For all shocks, the higher the intensity of required reserves policy, which is measured by a larger ϕ parameter, the lower is the contraction in real macroeconomic and financial variables. Most importantly, the adverse hike in credit spreads, which is the indicator of financial frictions in this model economy are eliminated to substantial degrees as the credit policy is implemented more aggressively. Additionally, as expected, the inflationary cost of macroprudential intervention is also magnified as the policy becomes more intense.

Now we proceed to the next section in which we report the impact of countercyclical reserve requirement policy on the volatilities of key macroeconomic real and financial variables.

3.2.5 Effects of Time-Varying Reserve Requirement Policy on Volatilities

Table 2 displays the volatilities of real and financial variables when TFP and money growth shocks are realized over sufficiently long simulations of the model economy with three different regimes: (i) fixed RRR, (ii) a moderate required reserve policy ($\phi = 5.15$), and (iii) an aggressive required reserve policy ($\phi = 10$). As indicated in the table, the economy with a moderate credit policy features lower volatilities in real variables such as output, consumption, investment as well as in financial variables such as bank credit, loan-deposit spread, and asset prices, compared to the economy with a fixed RRR policy. Column 4 of the table shows that as the required reserve policy gets more aggressive, the volatilities of output, consumption, investment, bank credit, loan-deposit spread, and asset prices are even lower. We especially want to highlight the 50% decline in the volatilities of credit spreads and leverage ratio, the 22% decline in the volatilities of investment and asset prices, and 77% decline in the volatility of bank net worth when the moderate credit policy is in place. Since volatilities over the business cycle are lower under credit policy, we consider exploring welfare implications of it worthwhile. Accordingly, in the following section, we carry out welfare comparisons of different reserve requirement policies. Finally, we emphasize that as the time-varying RRR policy gets

3.2.6 Credit Policy and Welfare

We define the welfare associated with the time-invariant equilibrium given by the countercyclical reserve requirement policy conditional on a particular state of the economy in period 0 as:

$$V_0^{trp} = E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^{trp}, l_t^{trp}) \tag{61}$$

Table 2: Volatilities of Real and Financial Variables

Variable	Fixed Reserves	Credit Policy ($\phi = 5.15$)	Credit Policy ($\phi = 10$)
Real Variables			
Output	2.77	2.26	2.07
Consumption	1.59	1.47	1.41
Investment	6.01	4.70	4.22
Hours	0.35	2.44	2.62
Financial Variables			
Credit	1.08	0.89	0.82
Deposits	1.22	1.76	2.57
Net Worth	4.35	1.24	1.31
Leverage Ratio	4.04	2.01	2.04
Credit Spread	0.28	0.14	0.12
Asset Prices	0.62	0.48	0.43
Monetary Variables			
Inflation	0.18	0.27	0.37

where E_0 denotes conditional expectation over the initial state, and c_t^{trp} and l_t^{trp} stand for the contingent plans for consumption and leisure under the time-varying reserve requirement policy. Similarly, the welfare associated with the time-invariant equilibrium given by the fixed reserve requirement policy conditional on a particular state of the economy in period 0 as

$$V_0^{frp} = E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^{frp}, l_t^{frp}), \tag{62}$$

where c_t^{frp} and l_t^{frp} stand for the contingent plans for consumption and leisure under the fixed reserve requirement policy.

We then compute consumption-based welfare gains for each alternative time-varying reserve requirement policy (moderate or aggressive). Let λ^c stand for the welfare gain of adopting time-varying reserve requirement policy instead of the fixed one conditional on a particular state in period 0. We define λ^c as the proportional increase of regime *frp*'s consumption plan that a household must demand to be as well off under policy regime *trp*. Therefore, λ^c is implicitly defined by

$$V_0^{trp} = E_0 \sum_{t=0}^{\infty} \beta^t U\left((1 + \lambda^c)c_t^{frp}, l_t^{frp}\right) \tag{63}$$

Hence, a positive value for λ^c implies that the time-varying reserve requirement policy is welfare superior to the fixed reserve requirement policy.

In order to obtain accurate welfare rankings, we perform a second-order approximation to the policy functions and the welfare given by V_0. It is very well-known that welfare levels would be equal to each other under alternative policy regimes if we conduct a first-order approximation to the policy functions since the expected value of endogenous variables would be equal to their non-stochastic steady state levels across all alternative reserve policies. We then define welfare in the following recursive form to conduct a second-order approximation to V_0:

$$V_{0,t} = U(c_t, l_t) + \beta E_t V_{0,t+1}. \tag{64}$$

Schmitt-Grohe and Uribe (2006) show that V_0 can also be represented as

$$V_{0,t} = \overline{V_0} + \frac{1}{2}\Delta(V_0) \tag{65}$$

where $\overline{V_0}$ is the level of welfare evaluated at the non-stochastic steady-state, and $\Delta(V_0)$ is the constant correction term, denoting the second-order derivative of the policy function for $V_{0,t}$ with respect to the variance of shock processes. Therefore, equation (65) is an approximation to the welfare $V_{0,t}$, capturing the fluctuations of endogenous variables at the stochastic steady state.

We compare three different policy regimes in terms of their welfare gains: (i) a fixed reserve requirement policy, *frp*, (ii) a moderate time-varying reserve requirement policy ($\phi = 5.15$), *mtrp* and (iii) an aggressive time-varying reserve requirement policy ($\phi = 10$), *atrp*. We find that the welfare gain of the central bank following *mtrp* rather than *frp* is 0.06% in consumption-equivalent welfare terms. Moreover, the welfare gain of the central bank following *atrp* rather than *frp* is 0.22% in consumption-equivalent welfare terms. These results indicate that following an operational time-varying reserve requirement policy is always welfare improving compared to an inactive reserve policy. Additionally, on quantitative grounds, these welfare gains are non-trivial as far as closed economy models are concerned.

4 Discussion and Conclusion

There are certain advantages and drawbacks of using reserve requirements to achieve financial stability. The main advantages are (i) it is one of the two main policy tools that most central banks can use, (ii) the central bank does not directly face any costs since reserve requirements effectively alter the financial sector's own balance sheet in order to provide liquidity to the system, and (iii) the central bank can employ reserve requirements without requiring banks to have low-risk assets as collateral, which is unlike the re-discount window. On the other hand, there are some drawbacks of using reserve requirements, including (i) their role as a tax on the banking sector, putting depository institutions at a competitive disadvantage compared to unregulated financial institutions, and (ii) they may lead to rise in the credit spreads as they put additional costs on financial intermediation. One can assess the effectiveness of reserve requirements as a financial stability tool through their effects on credit spreads and bank credit to non-financial sector. Other things being equal, we expect countercyclical implementation of reserve requirement ratios to mitigate the decline in credit growth and accordingly moderate the rise in credit spreads in economic downturns, and curb excessive credit growth in boom periods.

To that purpose, we build a quantitative monetary DSGE model with a banking sector that is subject to time-varying reserve requirements imposed by the central bank and endogenous capital constraints due to an agency problem. We model reserve requirements as an exogenous policy rule that countercyclically responds to credit growth in the financial sector in a forward looking sense. We consider the effects of three different types of shocks: productivity, money growth and financial shocks. For each type of shock, we find that the time-varying required reserve ratio rule mitigates the negative effects of adverse shocks amplified by the financial accelerator mechanism on real and financial variables. In each case, it reduces the intertemporal distortions created by the credit spread at the expense of generating higher inflation, pointing out the clear trade-off between price stability and financial stability faced by many central banks nowadays. It also reduces the volatilities of key variables such as output, consumption, investment, bank credit, loan spread and asset prices, indicating the role of reserve requirements as a macroprudential policy instrument. Finally, we find that a time-varying reserve requirement policy achieves a higher welfare than a fixed reserve requirement policy.

This study illustrates that when financial frictions are important, monetary policy that adopts macroprudential reserve requirement ratios as an instrument might have real effects even if there are no nominal or real rigidities. Our work is also timely in the sense that academicians and policy makers are expressing their doubts about inflation targeting contemporaneously, and accordingly, quantity of money has emerged as an explicit policy instrument.

There are several further research avenues: one can introduce liquidity shocks in order to bring a microfoundation to holding reserves in order to rationalize the optimality of positive reserve requirements. It might also be interesting to focus on the tradeoff between price stability and financial stability in a framework in which an interest rate feedback rule is introduced under nominal rigidities such as Christiano et al. (2005) and Smets and Wouters (2007). Lastly, it might also be worthwhile to study an open economy model to explicitly consider the effects of international capital flows in the design of required reserves policies.

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Appendix: Banks' Profit Maximization Problem

Let's conjecture that the bank's franchise value is given by

$$V_{jt} = \nu_t q_t s_{jt} + \eta_t n_t \tag{66}$$

Comparing the conjectured solution for V_{jt} to the expected discounted terminal net worth yields the following expressions,

$$\nu_t q_t s_{jt} = E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} \left[R_{kt+1+i} - \left(\frac{R_{t+1+i} - rr_{t+i}}{1 - rr_{t+i}} \right) \right] q_{t+i} s_{jt+i} \tag{67}$$

$$\eta_t n_{jt} = E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} \left[\frac{R_{t+1+i} - rr_{t+i}}{1 - rr_{t+i}} \right] n_{jt+i} \tag{68}$$

Let's ESP_{t+i} stand for $\left[R_{kt+1+i} - \left(\frac{R_{t+1+i} - rr_{t+i}}{1-rr_{t+i}} \right) \right]$ and let's RR_{t+i} stand for $\left[\frac{R_{t+1+i} - rr_{t+i}}{1-rr_{t+i}} \right]$. Therefore,

$$\nu_t q_t s_{jt} = E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} ESP_{t+i} q_{t+i} s_{jt+i} \tag{69}$$

$$\eta_t n_{jt} = E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} RR_{t+i} n_{jt+i} \tag{70}$$

We write ν_t and η_t recursively using the expressions above. Let's begin with ν_t. To ease the notation, let's drop expectations for now.

$$\nu_t = \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} ESP_{t+i} x_{t,t+i} \tag{71}$$

where $x_{t,t+i} = \frac{q_{t+i} s_{jt+i}}{q_t s_{jt}}$. Let's separate (71) into two parts.

$$\nu_t = (1-\theta)\beta \Lambda_{t,t+1} ESP_t + \sum_{i=1}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} ESP_{t+i} x_{t,t+i} \tag{72}$$

Rearrange the second term at the right-hand size of the expression (72),

$$\nu_t = (1-\theta)\beta \Lambda_{t,t+1} ESP_t + \beta \Lambda_{t,t+1} \theta x_{t,t+1} \sum_{i=0}^{\infty} (1-\theta)\theta^{i+1} \beta^{i+1} \Lambda_{t+1,t+2+i} ESP_{t+1+i} x_{t+1,t+1+i} \tag{73}$$

The infinite sum at the right-hand side of equation (73) is one period updated version of equation (71), given by

$$\nu_{t+1} = \sum_{i=0}^{\infty} (1-\theta)\theta^{i+1} \beta^{i+1} \Lambda_{t+1,t+2+i} ESP_{t+1+i} x_{t+1,t+1+i} \tag{74}$$

where $x_{t+1,t+1+i} = \frac{q_{t+1+i} s_{jt+1+i}}{q_{t+1} s_{jt+1}}$.
Hence, we can re-write (73) with the expectations as follows:

$$\nu_t = E_t[(1-\theta)\beta \Lambda_{t,t+1} ESP_t + \beta \Lambda_{t,t+1} \theta x_{t,t+1} \nu_{t+1}] \tag{75}$$

Let's continue with η_t. To ease the notation, let's drop expectations for now.

$$\eta_t = \sum_{i=0}^{\infty}(1-\theta)\theta^i\beta^{i+1}\Lambda_{t,t+1+i}RR_{t+i}z_{t,t+i} \tag{76}$$

where $z_{t,t+i} = \frac{n_{jt+i}}{n_{jt}}$. Let's separate (76) into two parts.

$$\eta_t = (1-\theta)\beta\Lambda_{t,t+1}RR_t + \sum_{i=1}^{\infty}(1-\theta)\theta^i\beta^{i+1}\Lambda_{t,t+1+i}RR_{t+i}z_{t,t+i} \tag{77}$$

Rearrange the second term at the right-hand size of the expression (77),

$$\eta_t = (1-\theta)\beta\Lambda_{t,t+1}RR_t + \beta\Lambda_{t,t+1}\theta z_{t,t+1}\sum_{i=0}^{\infty}(1-\theta)\theta^{i+1}\beta^{i+1}\Lambda_{t+1,t+2+i}RR_{t+1+i}z_{t+1,t+1+i} \tag{78}$$

The infinite sum at the right-hand size of equation (77) is one period updated version of equation (75), given by

$$\eta_{t+1} = \sum_{i=1}^{\infty}(1-\theta)\theta^{i+1}\beta^{i+1}\Lambda_{t+1,t+2+i}RR_{t+1+i}z_{t+1,t+1+i} \tag{79}$$

where $z_{t+1,t+1+i} = \frac{n_{jt+1+i}}{n_{jt+1}}$.
Hence, we can re-write equation (77) with the expectations as follows:

$$\eta_t = E_t[(1-\theta)\beta\Lambda_{t,t+1}RR_t + \beta\Lambda_{t,t+1}\theta z_{t,t+1}\eta_{t+1}] \tag{80}$$

The profit maximization problem by a representative bank is given by

$$V_{jt} = \max_{s_{jt}} E_t \sum_{i=0}^{\infty}(1-\theta)\theta^i\beta^{i+1}\Lambda_{t,t+1+i}ESP_{t+i}q_{t+i}s_{jt+i} + RR_{t+i}n_{jt+i}] \tag{81}$$

$$s.t. \quad V_{jt} \geq \lambda q_t s_{jt} \qquad (\mu_t) \tag{82}$$

where μ_t is the Lagrange multiplier associated with the incentive compatibility constraint. Using the conjectured solution for V_{jt} above, we can re-write the intermediary's maximization problem using the Lagrangian,

$$Ł = \nu_t q_t s_{jt} + \eta_t n_{jt} + \mu_t[\nu_t q_t s_{jt} + \eta_t n_{jt} - \lambda q_t s_{jt}] \tag{83}$$

The first order conditions w.r.t. s_{jt} and μ_t are given respectively by

$$(1+\mu_t)\nu_t q_t = \mu_t\lambda q_t \tag{84}$$

$$V_{jt} - \lambda q_t s_{jt} = 0 \tag{85}$$

Rearranging (84) gives us the following expression,

$$\nu_t = \frac{\mu_t\lambda}{(1+\mu_t)} \tag{86}$$

Therefore, we establish that the incentive compatibility constraint binds ($\mu_t > 0$) as long as expected discounted marginal gain of increasing bank assets is positive.

Figure 1: Evolution of Required Reserve Ratios in Turkey

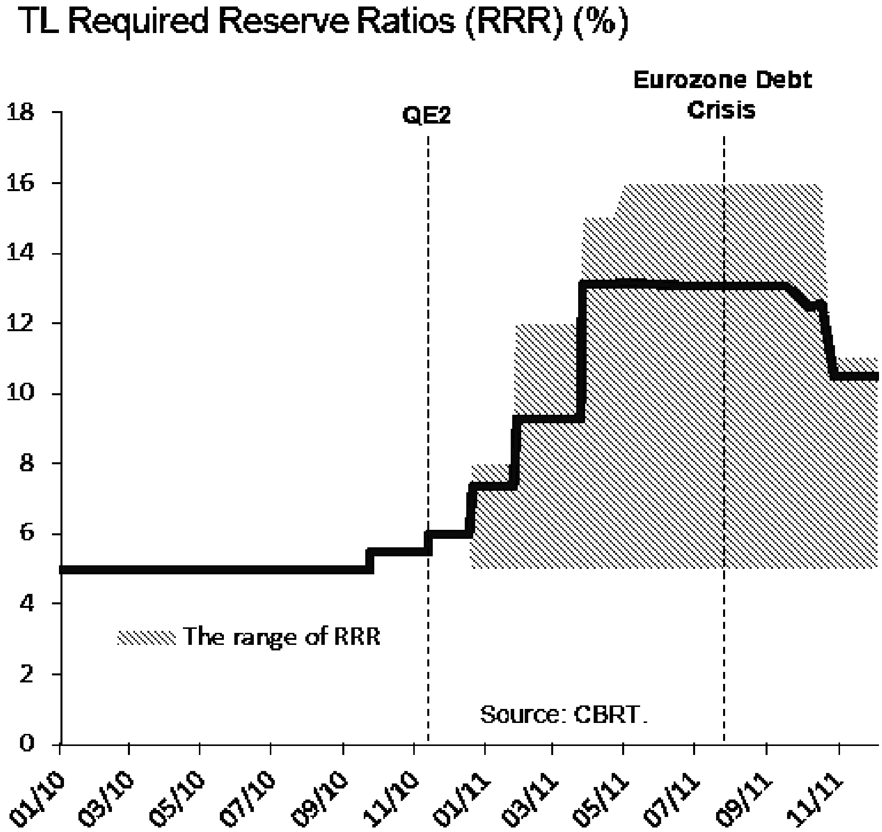

Figure 2: Negative Productivity Shocks

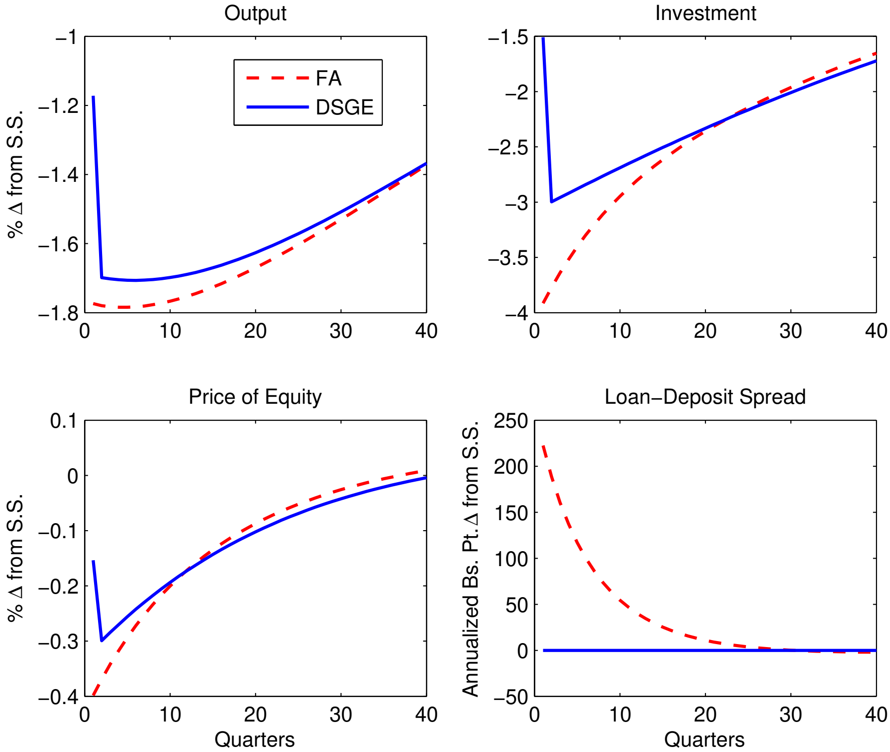

Figure 3: Positive Money Growth Shocks

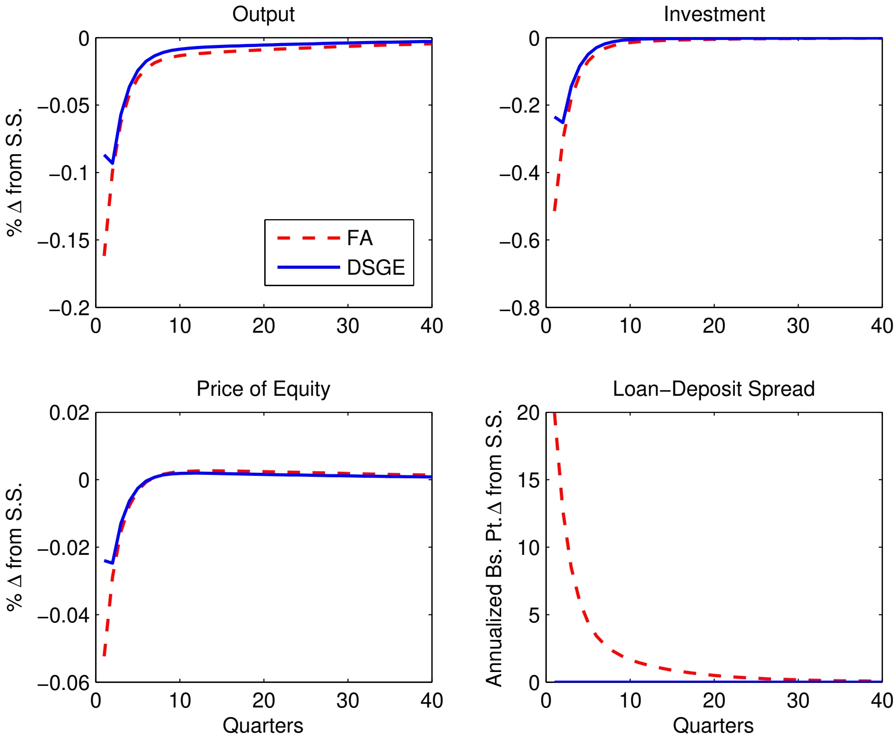

Figure 4: Impulse Responses Led by a 1-σ Adverse TFP Shock

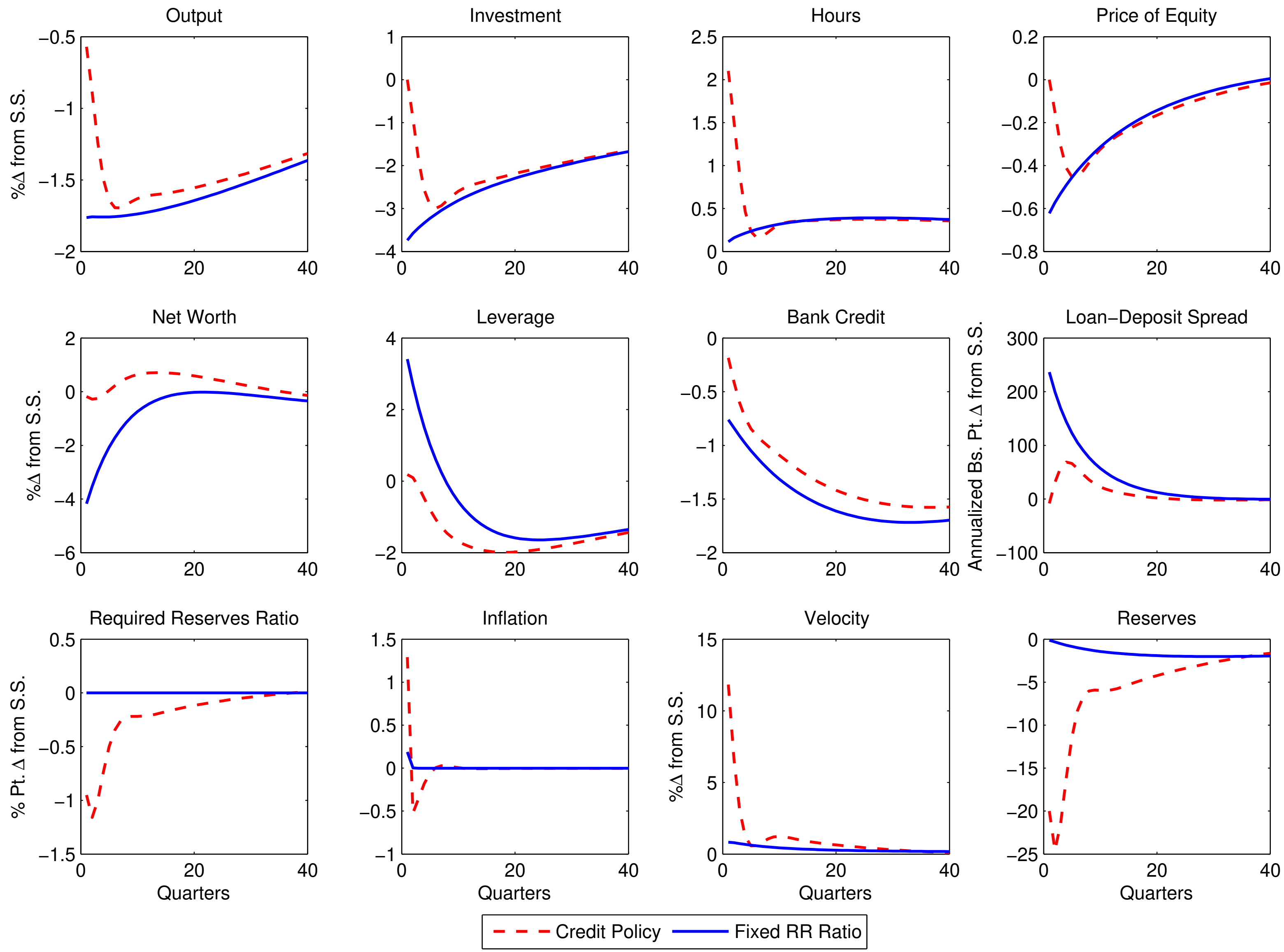

Figure 5: Impulse Responses Led by a 1-σ Adverse Money Growth Shock

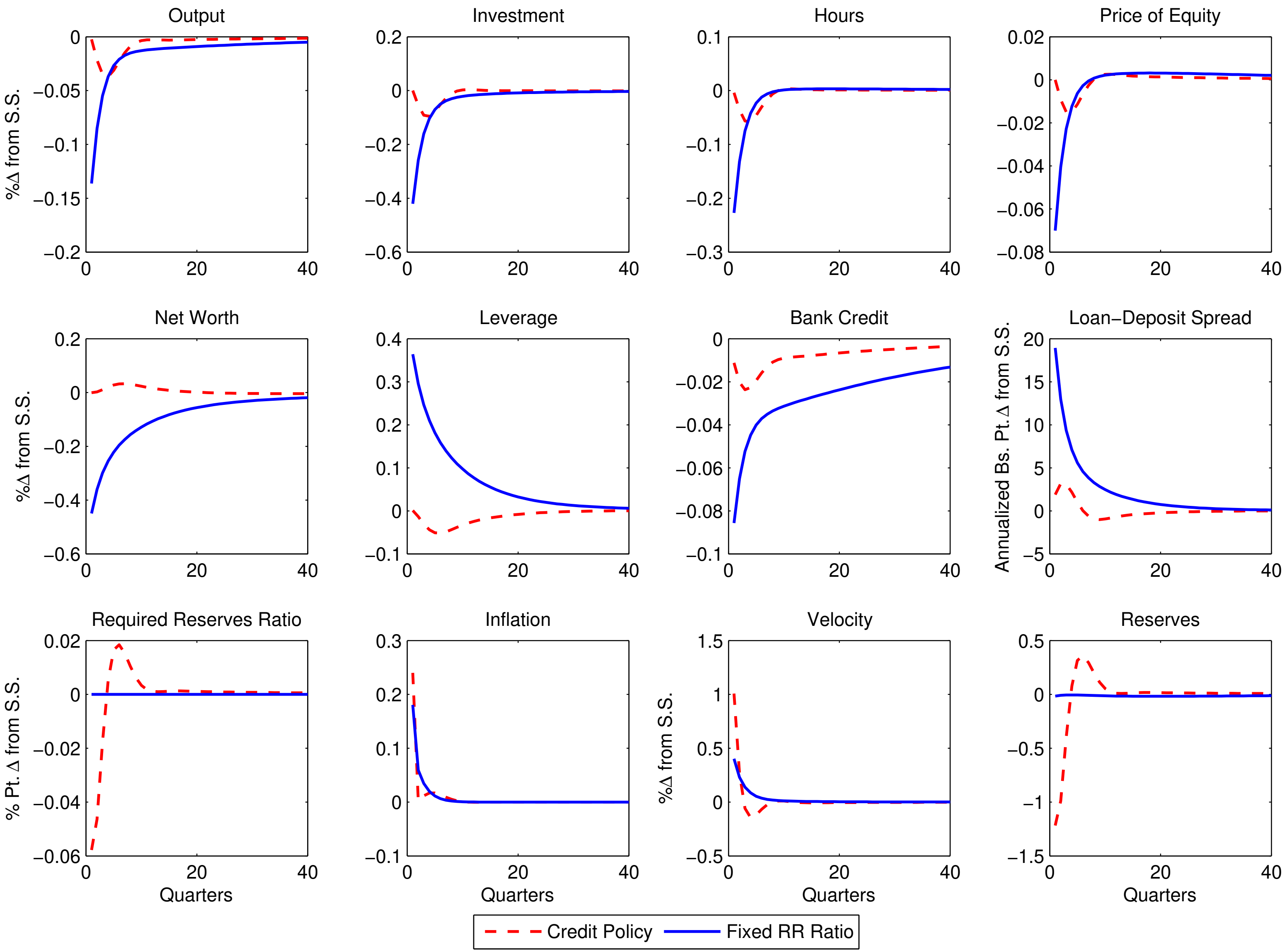

Figure 6: Impulse Responses Led by a 1-σ Adverse Financial Shock