

Required Reserves as a Credit Policy Tool*

Yasin Mimir[†]

University of Maryland

Enes Sunel[‡]

Central Bank of Turkey

Temel Taşkın[§]

Central Bank of Turkey

October, 2012

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 shocks are the only source 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 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

*The authors would like to thank Erdem Başçı, Mehmet Yörükoğlu, Ayhan Köse, Pedro Gete, and seminar participants at the Central Bank of the Republic of Turkey, 2012 Midwest Macroeconomics Meetings, 16th Annual International Conference on Macroeconomic Analysis and International Finance, 3rd International Conference in Memory of Carlo Giannini held at the Bank of Italy, 2012 Spring Meeting of Young Economists, 2012 Annual Meeting of Swiss Society of Economics and Statistics, 2011 Annual CEE Meeting held at Bogazici University, and International Conference on Financial and Macroeconomic Stability: Challenges Ahead. The views expressed in this paper are those of the authors and do not necessarily reflect the official views or the policies of the Central Bank of the Republic of Turkey. The usual disclaimer applies.

[†]mimir@econ.umd.edu; www.econ.umd.edu/~mimir

[‡]Research and Monetary Policy Department; enes.sunel@tcmb.gov.tr; sites.google.com/site/enessunel/

[§]Research and Monetary Policy Department; temel.taskin@tcmb.gov.tr; temeltaskin.weebly.com/

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 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 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

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

²At 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.

value of banks must be larger than or equal to the amount of diverted funds. As 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 modelled via a cash-in-advance constraint. Additional to the cash in advance demand of consumers, bankers demand required reserves. Consequently, the central bank meets the summation of cash and reserves demand of workers and bankers by supplying the monetary base. The resulting money market clearing condition creates room for fluctuations in reserve requirements to induce fluctuations in inflation, which feeds back into the cash in advance constraint of workers and has real effects.

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 2011 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 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

³We 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.

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 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.

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 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 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 savers (households) to 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 react 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 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 ,

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

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

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

⁴This 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 a lump-sum transfer 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):

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

Solution of the utility maximization problem of households leads to the optimality conditions below,

$$u_c(t) = \beta E_t \left\{ R_{t+1} u_c(t+1) \right\} \quad (4)$$

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

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). The key ingredients are as follows. We denote the period t balance sheet of a bank j as,

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

The right hand side of the balance sheet denotes the resources of bank j , namely, net worth, n_{jt} and deposits, b_{jt+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' physical capital demand 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 reserves ratio (RRR) set by the central bank as we describe below. Next period's net worth, n_{jt+1} will be determined by the return earned on assets and the cost of liabilities. Therefore,

$$n_{jt+1} = R_{kt+1} q_t s_{jt} - R_{t+1} b_{jt+1} + rr_t b_{jt+1} \quad (7)$$

where R_{kt+1} is the gross real return earned from purchased firm equity and R_{t+1} is the risk-free cost of borrowing from worker $i \neq j$. Since required reserves do not pay any real return, reserve balances are multiplied by one.⁵ Solving for b_{jt+1} in equation (7) and substituting it in the balance sheet of banker j , i.e. equation (6), we obtain the net worth evolution of a financial intermediary as,

$$n_{jt+1} = \left[R_{kt+1} - \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) \right] q_t s_{jt} + \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) n_{jt}. \quad (8)$$

Bankers have a finite life and survive to the next period with probability $0 < \theta < 1$.⁶ At the end of each period $1 - \theta$ measure of new bankers are born and are remitted $\frac{\epsilon}{1-\theta}$ fraction of the net worth owned by exiting bankers. Given this framework, 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 towards the ownership of non-financial firms' physical capital demand, s_{jt} . That is,

$$V_{jt} = \max_{s_{jt}} E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} \left\{ \left[R_{kt+1+i} - \left(\frac{R_{t+1+i} - rr_{t+i}}{1 - rr_{t+i}} \right) \right] q_{t+i} s_{jt+i} + \left(\frac{R_{t+1+i} - rr_{t+i}}{1 - rr_{t+i}} \right) n_{jt+i} \right\} \quad (9)$$

where $\beta^{i+1} \Lambda_{t,t+1+i} = \beta^{i+1} \frac{u_c(t+1+i)}{u_c(t)}$ is the $1 + i$ periods ahead stochastic discount factor of households.

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 initiate 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,

$$V_{jt} \geq \lambda q_t s_{jt} \quad (10)$$

to prevent liquidation by bank runs. This inequality suggests that the liquidation cost of bankers, V_{jt} , from diverting funds 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

⁵The zero real return earned from required reserves actually implies that the central bank is remunerating reserves with a nominal rate equal to the rate of inflation. This is indeed consistent with the experience of commercial banks in Turkey since their local currency denominated reserves have been remunerated with a nominal return in line with the rate of inflation in the period 2002:1-2010:3. For the remuneration rates, see www.tcmb.gov.tr/yeni/bgm/dim/TLzorunlukarsilikfaizorani.html.

⁶This assumption 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.

$$V_{jt}^* = \nu_t q_t s_{jt}^* + \eta_t n_{jt}^* \quad (11)$$

where the recursive objects,

$$\nu_t = E_t \left\{ (1 - \theta) \beta \Lambda_{t,t+1} \left[R_{kt+1} - \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) \right] + \theta \beta \Lambda_{t,t+1} \chi_t \nu_{t+1} \right\} \quad (12)$$

and

$$\eta_t = E_t \left\{ (1 - \theta) \beta \Lambda_{t,t+1} \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) + \theta \beta \Lambda_{t,t+1} \varrho_t \eta_{t+1} \right\} \quad (13)$$

represent the marginal values of making new loans and accumulating net worth for the bank respectively.⁷ $\chi_t = \frac{q_{t+1} s_{jt+1}}{q_t s_{jt}}$ and $\varrho_t = \frac{n_{jt+1}}{n_{jt}}$ represent growth rates of banks' loans and net worth respectively. As the spread between R_k and R gets larger, the marginal value of making loans to non-financial firms increases. On the other hand, since the risk free deposit rate is the opportunity cost of raising funds by borrowing from households, as R gets larger the marginal benefit of accumulating net worth increases. The ratio of required reserves, rr , decreases the marginal benefit of making loans, since it reduces the returns to making new loans, $\left[R_{kt+1} - \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) \right]$, and increases the marginal value of accumulating net worth, since it increases the return to accumulating net worth, $\left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right)$, *ceteris paribus*.

One can obtain the following by combining equations (10) and (11):

$$\nu_t q_t s_{jt} + \eta_t n_{jt} \geq \lambda q_t s_{jt}. \quad (14)$$

Our methodological approach is to linearly approximate the stochastic equilibrium around the deterministic steady state. Therefore we are interested with cases in which equation (14), an equilibrium condition of the model, is always binding. Given that $\eta_t n_{jt}$ is strictly greater than zero, $\nu_t \geq \lambda$ would imply a strict inequality in (14). Therefore $\nu_t < \lambda$ should hold for (14) to be an equality. This would be the case in which banks have made enough loans until the marginal value of increasing loans falls short of the fraction of these assets that they are willing to divert. Consequently, $\nu_t \geq \lambda$ corresponds to a case in which the amount of loans made are small enough that the marginal benefit of making new loans is greater than the fraction of diverted assets.

The existence of a well-behaved equilibrium also necessitates ν_t to be greater than zero for the banks to extend loans to non-financial firms at any date t . Therefore, we make sure that under reasonable values of parameters, $0 < \nu_t < \lambda$ always holds in our model. This modifies equation (14) into an endogenous borrowing constraint for banks as follows:

⁷Derivation of equations (11), (12), and (13) are available in the technical appendix.

$$q_t s_{jt} = \frac{\eta_t}{\lambda - \nu_t} n_{jt} = \kappa_t n_{jt}. \quad (15)$$

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 shall 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 (15) over j and obtain the following aggregate relationship:

$$q_t s_t = \kappa_t n_t \quad (16)$$

where $q_t s_t$ and n_t represent aggregate levels of banks' assets and net worth, respectively. Equation (16) 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 the 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}):

$$n_{t+1} = n_{et+1} + n_{nt+1}. \quad (17)$$

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

$$n_{nt+1} = \epsilon n_t. \quad (18)$$

Bankers' net worth evolution, (8), the capital constraint, (16), and the fact that θ fraction of bankers survive to the next period, yield a net worth evolution condition for surviving bankers as follows:

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

Finally, equations (18) and (19) can be summed up to obtain the evolution of net worth for the entire banking system:

$$n_{t+1} = \left\{ \theta \left(\left[R_{kt+1} - \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) \right] \kappa_t + \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) \right) + \epsilon \right\} n_t \quad (20)$$

Dividing both sides of equation (20) implies that the growth of aggregate net worth depends

positively on loan/deposit spreads, endogenous bank leverage, risk free deposits rate, survival probability and the fraction of start-up funds. On the hand, the impact of RRR on net worth accumulation depends on the two opposing effects discussed above: a higher rr_t *decreases* returns to making loans to non-financial firms, and *increases* returns to accumulating net worth, *ceteris paribus*. However, since bank leverage is greater than one, i.e. $\kappa > 1$, any change in the former is amplified as equation (20) suggests. Consequently, an increase in rr_t decreases the growth of aggregate net worth growth of the banking system.

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

$$y_t = \exp(z_t)F(k_t, h_t) \quad (21)$$

where

$$z_{t+1} = \rho_z z_t + \epsilon_{zt+1} \quad (22)$$

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,

$$q_t s_t = q_t k_{t+1} \quad (23)$$

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

$$R_{kt} = \frac{z_t F_k(k_t, h_t) + q_t(1 - \delta)}{q_{t-1}} \quad (24)$$

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

$$w_t = \exp(z_t)F_h(k_t, h_t) \quad (25)$$

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,

$$\max_{i_t} q_t k_{t+1} - q_t(1 - \delta)k_t - i_t \quad (26)$$

subject to the capital accumulation technology,

$$k_{t+1} = (1 - \delta)k_t + \Phi\left(\frac{i_t}{k_t}\right)k_t \quad (27)$$

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,

$$q_t = \left[\Phi'\left(\frac{i_t}{k_t}\right)\right]^{-1} \quad (28)$$

2.5 Government

The government is responsible for (i) meeting the cash in advance and required reserves demand of workers and bankers respectively, and (ii) setting the macroprudential credit policy rule. For the former, it controls the supply of monetary base M_{0t+1} and for the latter, it determines the required reserve ratio rr_t .

The monetary base grows at the constant rate μ , i.e.,

$$M_{0t+1} = \exp(\mu)M_{0t}. \quad (29)$$

The growth of the monetary base is remitted to households in the form of lump-sum transfers, T_t .⁸ Therefore, $T_t = (\exp(\mu) - 1)M_{0t}$.⁹

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, i.e.,

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

⁸We model monetary policy in a simplistic manner in order to isolate the impact of macroprudential required reserves policy described below. We also abstain from modeling disturbances to money growth because they produce implausible inflation dynamics in a cash in advance model of a flexible price environment.

⁹Perfect insurance within family members of households ensures that the increase in real balances and reserves demand is lumped into T_t , which does not alter the optimality conditions of the utility maximization problem.

where, \bar{r} is the steady-state value of the required reserves ratio and $\phi > 0$. Consequently, as discussed in section 2.2, the central bank increases the effective profit from extending new loans, i.e. reduces rr_t , when credit in the aggregate economy is expected to shrink, and vice versa. Stabilizing the stock of credit is expected to smooth fluctuations in credit spreads which emerge due to the existence of financial frictions. Since credit spreads are a measure of intertemporal distortions in this model, the overall economy's welfare level is expected to be higher when this macroprudential policy rule is in place as opposed to fixing $rr_t = \bar{r}$.

Money market clearing necessitates,

$$M_{0t+1} = M_{t+1} + P_t rr_t b_{t+1} \quad (31)$$

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. The dynamics of inflation driven by these fluctuations shall then feedback into the intertemporal consumption leisure margin and have real effects via the cash in advance constraint shown by equation (3).

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 $\widehat{m}_t = M_{t+1}/(\widehat{P}_t M_{0t+1})$ and solve the model locally around a deterministic steady state.

A competitive equilibrium of this model economy is defined by sequences of allocations $\{c_t, k_{t+1}, i_t, l_t, h_t, s_t, n_t, n_{et}, n_{nt}, b_{t+1}, \Lambda_{t,t+1}, \nu_t, \eta_t, \kappa_t, \rho_{t,t+1}, \chi_{t,t+1}, \widehat{m}_{t+1}, \pi_t\}_{t=0}^{\infty}$, prices $\{q_t, R_{kt+1}, R_{t+1}, w_t, \widehat{P}_t\}_{t=0}^{\infty}$, the shock process $\{z_t\}_{t=0}^{\infty}$, and the government policy $\{rr_t\}_{t=0}^{\infty}$ that satisfy the optimality conditions of utility maximization of workers, net worth maximization of bankers, profit maximization of firms and capital producers and the market clearing for the consumption good and money. A complete set of these conditions might be found in Appendix B.

3 Quantitative Analysis

The benchmark model is calibrated to Turkish economy, which is representative of using reserve requirements as a macroprudential policy instrument since the last quarter of 2010. This reduces to fixing the long-run value of RRR to its value preceding the macroprudential intervention of the CBRT and calibrating the response parameter in the credit policy rule, equation (30), in order to match the variation in RRR following the intervention. 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 a one standard deviation negative productivity shock and run a financial crisis experiment in environments that

Table 1: Parameter Values in the Benchmark Model

Description	Value	Target
<u>Preferences</u>		
Quarterly discount factor (β)	0.9885	Annualized real deposit rate (4.73%)
Relative risk aversion (γ)	2	Literature
Inverse of the Frisch elasticity (v)	2	Literature
Relative utility weight of leisure (ψ)	15.182	Hours worked (0.33)
<u>Production Technology</u>		
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 = 2.31
Depreciation rate of capital (δ)	0.037	Average annual ratio of investment to capital (14.8%)
<u>Government</u>		
Steady-state value of RRR ($\bar{r}\bar{r}$)	0.05	Pre-macroprudential policy period
Adjustment parameter in the RRR rule (ϕ)	5.925	Standard deviation of differences in RRR for 2009:Q4-2012:Q2 (1.73%)
Growth rate of monetary base (μ)	0.0446	Time series average for 2006:Q1-2011:Q4
<u>Financial Intermediaries</u>		
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
<u>TFP Shock Process</u>		
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	

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. Moreover, we analyze the welfare implications of alternative RRR policies. Finally, we conduct sensitivity analysis by changing key parameters of the benchmark model regarding financial sector in order to understand the effectiveness of reserve requirements as a credit policy tool in different economic structures.

3.1 Calibration of the Benchmark Model

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 relative risk aversion, γ , and inverse of the Frisch elasticity, 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, \bar{h} , at 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 the 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.¹⁰ 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 (30) which does not alter the steady state of the model but affects the dynamics around it. The level of weighted RRR preceding the macroprudential intervention by the CBRT is 5% (see figure 1). Therefore, we calibrate the long-run value of RRR to 0.05 in the baseline model. The value of the response parameter of the credit policy rule, ϕ , is calibrated to 5.925 in order to match the standard deviation of the differences in RRR of 1.73% for the Turkish economy in the period 2009:Q4-2012:Q2.¹¹ The time series average of the growth rate of monetary base for the period 2006:Q1-2011:Q4 is 4.46%. Therefore we set $\mu = 0.0446$.

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, $\sigma_z = 0.0183$.

3.2 Functional Forms

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

$$u(c_t, l_t) = \frac{c_t^{1-\gamma}}{1-\gamma} - \psi \frac{(1-l_t)^{1+\nu}}{1+\nu} \quad (32)$$

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

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

$$\exp(z_t)F(k_t, h_t) = \exp(z_t)k_t^\alpha h_t^{1-\alpha} \quad (33)$$

with $0 < \alpha < 1$.

¹⁰The 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.

¹¹This is the period in which the CBRT changed the RRR for macroprudential purposes.

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

$$\Phi\left(\frac{i_t}{k_t}\right) = \frac{\varphi}{2} \left[\frac{i_t}{k_t} - \delta\right]^2 \quad (34)$$

3.3 Impact of Reserve Requirements on Banks' Incentives

The dynamics of RRR affect bankers' financing decision as follows. First, as illustrated in section 2.2, RRR reduces the growth of aggregate net worth. Furthermore, an increase in rr_t would potentially induce banks to demand more deposits in order to make up for the required reserves, which do not pay any real return. These two effects shall induce bankers to substitute external financing, b_{t+1} , for internal financing, n_t , when RRR is higher. A higher leverage ratio, i.e. $\frac{b_{t+1}}{n_t}$, for the banking system would then increase its exposure to external financing and cause financial frictions to become more severe and would potentially result in higher loan/deposit spreads.

On the assets side of the balance sheet, an increase in RRR is expected to induce banks to substitute required reserves for bank loans for the reasons that (i) they are obliged to increase reserves, and (ii) the return to making new loans to non-financial firms gets smaller. This would result in a reduction in investment since the intermediated funds to the real sector shrink.

Figure 2 plots key real and financial variables' steady state values as a function of different long run values of RRR and verifies our conjectures regarding the impact of RRR on banks' incentives.

3.4 Amplifying Effect of Financial Frictions

The dashed and straight plots in figure 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. The figure shows that the collapse in output, investment, price of capital and loan-deposit spreads, in response to a one-standard deviation negative TFP shock, 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 in a collapse in the value of funds provided to them. As a result, firms acquire less capital and investment declines more.

We now analyze the implications of the RRR policy on the dynamics of real, financial, and monetary variables. In figure 4, we compare the dynamics of these variables in response to one standard deviation negative TFP shocks. In figure 5 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 the recent literature.¹²

In figures 4 and 5, 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.

3.5 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 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 (16). 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

¹²Hancock, 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).

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

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 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.

Table 2: Volatilities of Real and Financial Variables

Variable	Fixed Reserves	Credit Policy ($\phi = 5.925$)
Real Variables		
Output	2.77	1.66
Consumption	1.21	1.09
Investment	7.76	3.83
Hours	2.79	2.36
Financial Variables		
Credit	1.24	0.72
Deposits	1.53	1.57
Net Worth	12.30	6.42
Leverage Ratio	11.38	6.30
Credit Spread	0.45	0.26
Asset Prices	0.80	0.39
Monetary Variables		
Inflation	0.19	0.27

3.6 Effects of Time-Varying Reserve Requirement Policy on Volatilities

Table 2 displays the volatilities of real and financial variables when TFP shocks are realized over sufficiently long simulations of the model economy with three different regimes: (i) fixed RRR, (ii) a moderate required reserve policy ($\phi = 5.925$), 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. Another noteworthy finding on volatilities is that reduced volatilities in key macroeconomic real and financial variables come at the expense of much higher volatility in inflation. Considering the money market equilibrium condition represented by equation (31), higher volatility in reserves, led by the credit policy rule, induces higher volatility in inflation to restore equilibrium in the money market. Volatility of hours in turn increases when the credit policy is in place, since inflation feeds back into the intertemporal consumption leisure optimality condition, (5).

Since volatilities of key real variables 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.

3.7 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:

$$V_0^{trp} = E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^{trp}, l_t^{trp}) \quad (35)$$

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

$$V_0^{frp} = E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^{frp}, l_t^{frp}), \quad (36)$$

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

$$V_0^{trp} = E_0 \sum_{t=0}^{\infty} \beta^t U\left((1 + \lambda^c)c_t^{frp}, l_t^{frp}\right) \quad (37)$$

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 :

$$V_{0,t} = U(c_t, l_t) + \beta E_t V_{0,t+1}. \quad (38)$$

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

$$V_{0,t} = \bar{V}_0 + \frac{1}{2} \Delta(V_0) \quad (39)$$

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 (39) 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 ($\phi = 5.925$), *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 0.05% in consumption-equivalent welfare terms. Moreover, the welfare gain of the central bank following *atrp* rather than *frp* is 0.13% 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.

3.8 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 5 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 5). 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 5). 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 5).

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.

4 Sensitivity Analysis

In this section we explore the impact of important model parameters on the credit policy. For that matter we first analyze the role of policy intensity by changing the response parameter of the time-varying required reserves rule, ϕ . Next, we run credit policy for alternative values of fraction of diverted funds, λ , (which is used to target the long-run value of credit spreads) and survival probability, θ , (which is used to target the long-run value of bank leverage). Lastly, we tweak the capital adjustment cost parameter, φ , which affects the transmission of shocks to the real sector via fluctuations in asset prices which are propagated by endogenous capital constraints of financial intermediaries. The comparisons are based on the implied volatilities of key model variables under fixed and time-varying reserve requirement policy regimes and are reported in table 3. The first two columns of the top panel of table 3 reproduces the columns in table 2 which report findings regarding the benchmark model. In the following columns of table 3, we change one parameter at a time and leave the other parameters same as in the benchmark model. If the steady state levels of bank leverage and credit spreads differ from the benchmark case for an alternative parameter level, we report the new values of these variables below the parameter value.

Policy intensity, ϕ : The third and fourth columns in the top panel of table 3 report the implications of credit policy on volatilities of model variables when the response parameter of RRR rule is decreased to 1 and increased to 10, respectively. The numbers indicate that as the credit policy gets more aggressive, volatility of key macroeconomic and financial variables gets smaller. In accordance with the explanation in section 3.4, inflation volatility gets larger when the credit policy is more aggressive.

Fraction of Diverted Funds, λ : An increase in the fraction of diverted funds corresponds to an economy in which financial frictions are more severe, because the moral hazard problem between banks and households becomes more intense. This is reflected as a smaller long run value for bank leverage and a larger long run value for credit spreads compared to the benchmark model. A smaller bank leverage is due to tighter endogenous capital constraints faced by banks. Accordingly, tighter credit constraints result in higher credit spreads faced by non-financial firms. The comparison of the last four columns in the top panel of table 3 reveals that when λ is larger, credit policy (with the same response parameter as in the benchmark model) is more effective in reducing the volatilities of output, consumption, investment, bank credit and asset prices. Therefore, the importance of

Table 3: Sensitivity of Credit Policy to Model Parameters

	$\phi = 0^*$	$\phi = 5.925^*$	$\phi = 1$	$\phi = 10$	$\lambda = 0.25$	$\lambda = 0.25$	$\lambda = 0.75$	$\lambda = 0.75$
	$(\bar{\kappa} = 6.25)$ $(\overline{R_k - \bar{R}} = 48 \text{ bs. pt.})$				$(\bar{\kappa} = 12.51)$ $(\overline{R_k - \bar{R}} = 27 \text{ bs. pt.})$		$(\bar{\kappa} = 4.17)$ $(\overline{R_k - \bar{R}} = 69 \text{ bs. pt.})$	
Variable	Fixed Reserves	Credit Policy	Credit Policy	Credit Policy	Fixed Reserves	Credit Policy	Fixed Reserves	Credit Policy
Real Variables								
Output	2.77	1.66	2.22	1.50	2.37	1.59	3.25	1.73
Consumption	1.21	1.09	1.21	1.06	1.23	1.13	1.22	1.07
Investment	7.76	3.83	5.49	3.40	5.63	3.30	10.01	4.37
Hours	2.79	2.36	2.50	2.42	1.48	2.29	3.99	2.41
Financial Variables								
Credit	1.24	0.72	0.91	0.66	0.94	0.63	1.54	0.83
Deposits	1.53	1.57	1.10	2.07	0.94	1.36	2.39	1.92
Net Worth	12.30	6.42	6.25	6.46	13.33	6.09	11.88	6.66
Leverage	11.38	6.30	6.00	6.38	12.76	6.13	10.65	6.41
Credit Spread	0.45	0.26	0.33	0.25	0.73	0.34	0.33	0.22
Asset Prices	0.80	0.39	0.57	0.35	0.58	0.34	1.03	0.45
Monetary Variables								
Inflation	0.19	0.27	0.18	0.34	0.10	0.27	0.27	0.27
	$\theta = 0.955$	$\theta = 0.955$	$\theta = 0.975$	$\theta = 0.975$	$\varphi = 0.275$	$\varphi = 0.275$	$\varphi = 13.75$	$\varphi = 13.75$
	$(\bar{\kappa} = 7.46)$ $(\overline{R_k - \bar{R}} = 51 \text{ bs. pt.})$		$(\bar{\kappa} = 4.06)$ $(\overline{R_k - \bar{R}} = 37 \text{ bs. pt.})$		$(\bar{\kappa} = 6.25)$ $(\overline{R_k - \bar{R}} = 48 \text{ bs. pt.})$			
Variable	Fixed Reserves	Credit Policy	Fixed Reserves	Credit Policy	Fixed Reserves	Credit Policy	Fixed Reserves	Credit Policy
Real Variables								
Output	2.61	1.64	3.43	1.74	2.86	1.94	2.53	1.27
Consumption	1.22	1.09	1.23	1.10	1.13	1.06	1.57	1.19
Investment	7.05	3.71	10.31	4.27	8.48	5.02	5.69	1.97
Hours	2.33	2.34	4.38	2.46	2.90	2.16	2.49	2.58
Financial Variables								
Credit	1.14	0.70	1.58	0.80	0.88	0.67	3.10	1.09
Deposits	1.31	1.52	2.50	1.89	1.28	1.34	2.39	2.31
Net Worth	12.36	6.31	12.12	6.69	7.79	6.23	26.46	6.72
Leverage	11.56	6.23	10.84	6.43	7.36	6.17	23.72	6.40
Credit Spread	0.40	0.23	0.65	0.42	0.30	0.28	0.87	0.24
Asset Prices	0.73	0.38	1.06	0.44	0.09	0.05	2.93	1.01
Monetary Variables								
Inflation	0.16	0.27	0.30	0.27	0.20	0.23	0.16	0.34

reserve requirement policies are enhanced when financial frictions get more severe.

Survival Probability, θ : A larger value for survival probability reduces the long run value of bank leverage because bankers can accumulate more net worth during their finite life. Consequently, stronger internal financing results in lower credit spreads in the long run. Coming to simulation results, the effectiveness of credit policy in reducing the volatilities of output, consumption, investment, bank credit and asset prices is enhanced when steady state bank leverage is smaller as a result of higher survival probability.

Capital Adjustment Cost Parameter, φ : The value of capital adjustment cost parameter is especially important because it affects the transmission of the financial accelerator mechanism to the asset prices without changing the steady state of the model. Specifically, when $\varphi = 0$, asset prices do not fluctuate at all and the second round effects of the financial accelerator do not operate via banks' capital constraints. As a result $\varphi = 0$ stops the propagation of the financial accelerator in the model. The comparison of the last four columns of the bottom panel of table 3 shows that credit policy is much more effective in reducing the volatilities all macroeconomic and financial variables when asset prices are more responsive to volatilities in bank capital, i.e. when φ is larger. This explanation is consistent with the impulse responses as well. Figure 6 reproduces the impulse responses of model variables led by a one-standard deviation negative TFP shock in the fixed reserves (straight plots) and time-varying reserves (dashed plots) economies when $\varphi = 0$. The comparison of figure 6 with figure 4 reveals two facts: (i) The straight plots in the former display less response in bank net worth, leverage, bank credit and credit spreads and no response in asset prices at all to the negative TFP shock, and (ii) the dashed plots again in the former illustrate that credit policy operates much less effectively in stabilizing financial variables when the propagation of the financial accelerator is shut down.¹⁴

5 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) they might be used as a tax that affects the loan/deposit spreads on the banking system in order to alter the cost of making loans if loan growth is a policy concern. On the other hand, among some drawbacks of using reserve requirements are, (i) they put depository institutions at a competitive disadvantage compared to unregulated financial institutions, and (ii) they might be

¹⁴Investment is more volatile when $\varphi = 0$ precisely because none of the adjustment to the adverse TFP shock comes through asset price changes.

circumvented by the banking sector to an extent that alternative ways of extending credit such as syndicated loans and currency swaps, which are not subject to reserve requirements are used. Other regulatory tools such as loan provisioning (which are outside the scope of this paper) might also prove to be more effective than reserve requirements in boosting the cost of extending credit.

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 suggest 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 two different types of shocks: productivity, 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 spreads 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 reserve requirement ratios as a macroprudential 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.

This study illustrates that when financial frictions are important, monetary policy that adopts reserve requirement ratios as a macroprudential instrument might have real effects even if there are no nominal or real rigidities. 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.

References

- [1] Benes, J. and Lees, K., 2010. "Multi-Period Fixed Rate Loans, Housing and Monetary Policy in Small Open Economies." *International Journal of Central Banking*, Forthcoming.
- [2] Brunnermeier, M.K. and Pedersen, L.H., 2009. "Market Liquidity and Funding Liquidity." *The Review of Financial Studies* Vol. 22 (6), pp. 2201-2238.
- [3] Christensen, I., Meh C. and Moran, K., 2011. "Bank Leverage Regulation and Macroeconomic Dynamics." *Bank of Canada Working Paper*, No. 2011-32.
- [4] Christiano, L.J., Eichenbaum M. and Evans, C.L., 2005. "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy." *Journal of Political Economy* Vol. 113 (1), pp. 1-45.
- [5] Cooley, T. and Hansen, G., 1989. "The Inflation Tax in a Real Business Cycle Model." *American Economic Review* Vol. 79 (4), pp. 733-748.
- [6] Gertler, M. and Karadi, P., 2011. "A Model of Unconventional Monetary Policy." *Journal of Monetary Economics* Vol. 58, pp. 17-34.
- [7] Glocker, C. and Towbin, P., 2012. "Reserve Requirements for Price and Financial Stability: When Are They Effective." *International Journal of Central Banking* Vol. 8 (1), pp. 65-113.
- [8] Gray, S., 2011. "Central Bank Balances and Reserve Requirements." *IMF Working Paper*, No.11/36.
- [9] Hancock, D., Laing, A.J. and Wilcox, J.A., 1995. "Bank Capital Shocks: Dynamics Effects on Securities, Loans and Capital." *Journal of Banking & Finance* Vol. 19 (3-4), pp. 661-677.
- [10] Holmstrom B. and Tirole, J., 1997. "Financial Intermediation, Loanable Funds and the Real Sector." *Quarterly Journal of Economics*, Vol.112, pp. 663-691.
- [11] Iacoviello, M., 2010. "Financial Business Cycles." *Unpublished manuscript*, Federal Reserve Board.
- [12] Kashyap, A.K. and Stein, J.C., 2012. "The Optimal Conduct of Monetary Policy with Interest on Reserves." *American Economic Journal: Macroeconomics*, Vol. 4(1), pp. 266-282.
- [13] Kiyotaki, N. and Moore, J., 2008. "Liquidity, Business Cycles, and Monetary Policy.", mimeo.
- [14] Meh, C., Moran, K., 2010. "The Role of Bank Capital in the Propagation of Shocks." *Journal of Economic Dynamics and Control*, Vol.34, pp. 555-576.
- [15] Mendoza, E.G., Quadrini, V., 2010. "Financial Globalization, Financial Crises and Contagion." *Journal of Monetary Economics*, Vol.57, pp. 24-39.
- [16] Mimir, Y., 2011. "Financial Intermediaries, Credit Shocks, and Business Cycles." *Unpublished manuscript*, University of Maryland.
- [17] Montoro, C., 2011. "Assessing the Role of Reserve Requirements under Financial Frictions." *Unpublished manuscript*, Bank for International Settlements.
- [18] Montoro, C. and Moreno, R., 2011. "The Use of Reserve Requirements as a Policy Instrument in Latin America." *BIS Quarterly Review*, March 2011, pp. 53-65.

- [19] Reinhart, C. and Reinhart, V., 1999. "On the Use of Reserve Requirements in Dealing with Capital Flow Problems." *International Journal of Finance & Economics*, Vol.4 (1), pp. 27-54.
- [20] Smets, F. and Wouters, R., 2007. "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach." *American Economic Review*, Vol.97 (3), pp. 586-606.
- [21] Sunel, Enes, 2011. "Essays on the Distributional and Welfare Consequences of Disinflation in Emerging Economies." *Ph.D. Dissertation*, Department of Economics, University of Maryland.
- [22] Woodford, M., Curdia, V., 2010. "Credit Spreads and Monetary Policy." *Journal of Money, Credit and Banking*, Vol. 58, pp. 54-79.

Appendix A: Banks' Profit Maximization Problem

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

$$V_{jt} = \nu_t q_t s_{jt} + \eta_t n_t \quad (40)$$

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

$$\nu_t q_t s_{jt} = E_t \sum_{i=0}^{\infty} (1-\theta) \theta^i \beta^{i+1} \Lambda_{t,t+1+i} \left[R_{kt+1+i} - \left(\frac{R_{t+1+i} - rr_{t+i}}{1 - rr_{t+i}} \right) \right] q_{t+i} s_{jt+i} \quad (41)$$

$$\eta_t n_{jt} = E_t \sum_{i=0}^{\infty} (1-\theta) \theta^i \beta^{i+1} \Lambda_{t,t+1+i} \left[\frac{R_{t+1+i} - rr_{t+i}}{1 - rr_{t+i}} \right] n_{jt+i} \quad (42)$$

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,

$$\nu_t q_t s_{jt} = E_t \sum_{i=0}^{\infty} (1-\theta) \theta^i \beta^{i+1} \Lambda_{t,t+1+i} ESP_{t+i} q_{t+i} s_{jt+i} \quad (43)$$

$$\eta_t n_{jt} = E_t \sum_{i=0}^{\infty} (1-\theta) \theta^i \beta^{i+1} \Lambda_{t,t+1+i} RR_{t+i} n_{jt+i} \quad (44)$$

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.

$$\nu_t = \sum_{i=0}^{\infty} (1-\theta) \theta^i \beta^{i+1} \Lambda_{t,t+1+i} ESP_{t+i} x_{t,t+i} \quad (45)$$

where $x_{t,t+i} = \frac{q_{t+i} s_{jt+i}}{q_t s_{jt}}$. Let's separate (45) into two parts.

$$\nu_t = (1-\theta) \beta \Lambda_{t,t+1} ESP_t + \sum_{i=1}^{\infty} (1-\theta) \theta^i \beta^{i+1} \Lambda_{t,t+1+i} ESP_{t+i} x_{t,t+i} \quad (46)$$

Rearrange the second term at the right-hand side of the expression (46),

$$\nu_t = (1-\theta) \beta \Lambda_{t,t+1} ESP_t + \beta \Lambda_{t,t+1} \theta x_{t,t+1} \sum_{i=0}^{\infty} (1-\theta) \theta^{i+1} \beta^{i+1} \Lambda_{t+1,t+2+i} ESP_{t+1+i} x_{t+1,t+1+i} \quad (47)$$

The infinite sum at the right-hand side of equation (47) is one period updated version of equation (45), given by

$$\nu_{t+1} = \sum_{i=0}^{\infty} (1-\theta) \theta^{i+1} \beta^{i+1} \Lambda_{t+1,t+2+i} ESP_{t+1+i} x_{t+1,t+1+i} \quad (48)$$

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 (47) with the expectations as follows:

$$\nu_t = E_t [(1-\theta) \beta \Lambda_{t,t+1} ESP_t + \beta \Lambda_{t,t+1} \theta x_{t,t+1} \nu_{t+1}] \quad (49)$$

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

$$\eta_t = \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} R R_{t+i} z_{t,t+i} \quad (50)$$

where $z_{t,t+i} = \frac{n_{jt+i}}{n_{jt}}$. Let's separate (50) into two parts.

$$\eta_t = (1-\theta)\beta \Lambda_{t,t+1} R R_t + \sum_{i=1}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} R R_{t+i} z_{t,t+i} \quad (51)$$

Rearrange the second term at the right-hand size of the expression (51),

$$\eta_t = (1-\theta)\beta \Lambda_{t,t+1} R R_t + \beta \Lambda_{t,t+1} \theta z_{t,t+1} \sum_{i=0}^{\infty} (1-\theta)\theta^{i+1} \beta^{i+1} \Lambda_{t+1,t+2+i} R R_{t+1+i} z_{t+1,t+1+i} \quad (52)$$

The infinite sum at the right-hand size of equation (51) is one period updated version of equation (49), given by

$$\eta_{t+1} = \sum_{i=1}^{\infty} (1-\theta)\theta^{i+1} \beta^{i+1} \Lambda_{t+1,t+2+i} R R_{t+1+i} z_{t+1,t+1+i} \quad (53)$$

where $z_{t+1,t+1+i} = \frac{n_{jt+1+i}}{n_{jt+1}}$.

Hence, we can re-write equation (51) with the expectations as follows:

$$\eta_t = E_t[(1-\theta)\beta \Lambda_{t,t+1} R R_t + \beta \Lambda_{t,t+1} \theta z_{t,t+1} \eta_{t+1}] \quad (54)$$

The profit maximization problem by a representative bank is given by

$$V_{jt} = \max_{s_{jt}} E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} E S P_{t+i} q_{t+i} s_{jt+i} + R R_{t+i} n_{jt+i} \quad (55)$$

$$s.t. \quad V_{jt} \geq \lambda q_t s_{jt} \quad (\mu_t) \quad (56)$$

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,

$$L = \nu_t q_t s_{jt} + \eta_t n_{jt} + \mu_t [\nu_t q_t s_{jt} + \eta_t n_{jt} - \lambda q_t s_{jt}] \quad (57)$$

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

$$(1 + \mu_t)\nu_t q_t = \mu_t \lambda q_t \quad (58)$$

$$V_{jt} - \lambda q_t s_{jt} = 0 \quad (59)$$

Rearranging (58) gives us the following expression,

$$\nu_t = \frac{\mu_t \lambda}{(1 + \mu_t)} \quad (60)$$

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.

Appendix B: Competitive Equilibrium Conditions

Below are the optimality and market clearing conditions that are satisfied in a competitive equilibrium as defined in section 2.6.

$$\Lambda_{t,t+1} = \frac{u_c(t+1)}{u_c(t)} \quad (61)$$

$$1 = \beta E_t R_{t+1} \Lambda_{t,t+1} \quad (62)$$

$$c_t = \frac{\exp(\mu) - 1 + \hat{m}_t \hat{P}_t}{\hat{P}_t \exp(\mu)} + R_t b_t - b_{t+1} \quad (63)$$

$$\frac{u_l(t)}{w_t \hat{P}_t} = \beta E_t \left\{ \frac{u_c(t+1)}{\hat{P}_{t+1} \exp(\mu)} \right\} \quad (64)$$

$$\kappa_t = \frac{\eta_t}{\lambda - \nu_t} \quad (65)$$

$$q_t s_t = \kappa_t n_t \quad (66)$$

$$q_t s_t = (1 - rr_t) b_{t+1} + n_t \quad (67)$$

$$\varrho_{t,t+1} = \left(R_{kt+1} - \frac{R_{t+1} - rr_t}{1 - rr_t} \right) \kappa_t + \frac{R_{t+1} - rr_t}{1 - rr_t} \quad (68)$$

$$\chi_{t,t+1} = \varrho_{t,t+1} \frac{\kappa_{t+1}}{\kappa_t} \quad (69)$$

$$n_{et} = \theta \varrho_{t-1,t} n_{t-1} \quad (70)$$

$$n_{nt} = \epsilon n_{t-1} \quad (71)$$

$$n_t = n_{et} + n_{nt} \quad (72)$$

$$\nu_t = E_t \left\{ (1 - \theta) \beta \Lambda_{t,t+1} \left(R_{kt+1} - \frac{R_{t+1} - rr_t}{1 - rr_t} \right) + \beta \Lambda_{t,t+1} \theta \chi_{t,t+1} \nu_{t+1} \right\} \quad (73)$$

$$\eta_t = E_t \left\{ (1 - \theta) \beta \Lambda_{t,t+1} \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) + \beta \Lambda_{t,t+1} \theta \varrho_{t,t+1} \eta_{t+1} \right\} \quad (74)$$

$$w_t = \exp(z_t) F_h(k_t, h_t) \quad (75)$$

$$R_{kt} = \frac{\exp(z_t) F_k(k_t, h_t) + q_t (1 - \delta)}{q_{t-1}} \quad (76)$$

$$k_{t+1} = (1 - \delta)k_t + \Phi\left(\frac{i_t}{k_t}\right)k_t \quad (77)$$

$$q_t = \left[\Phi'\left(\frac{i_t}{k_t}\right)\right]^{-1} \quad (78)$$

$$\exp(z_t)F(k_t, h_t) = c_t + i_t \quad (79)$$

$$s_t = k_{t+1} \quad (80)$$

$$1 = l_t + h_t \quad (81)$$

$$\exp(\pi_t) = \exp(\mu) \frac{\widehat{P}_t}{\widehat{P}_{t-1}} \quad (82)$$

$$z_{t+1} = \rho_z z_t + \epsilon_{zt+1} \quad (83)$$

$$rr_t = \bar{r} + \phi E_t \left[\log(q_{t+1}s_{t+1}) - \log(q_t s_t) \right] \quad (84)$$

$$\frac{1}{\widehat{P}_t} = \hat{m}_{t+1} + rr_t b_{t+1} \quad (85)$$

Figure 1: Evolution of Required Reserve Ratios in Turkey

TL Required Reserve Ratios (RRR) (%)

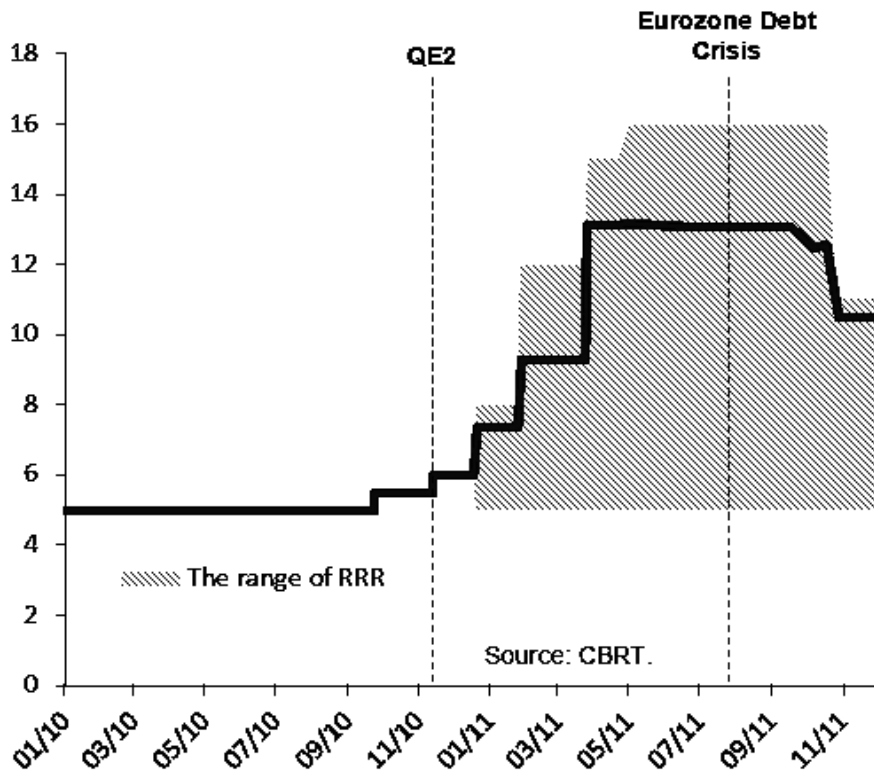


Figure 2: Steady State Implications of Reserve Requirement Ratio

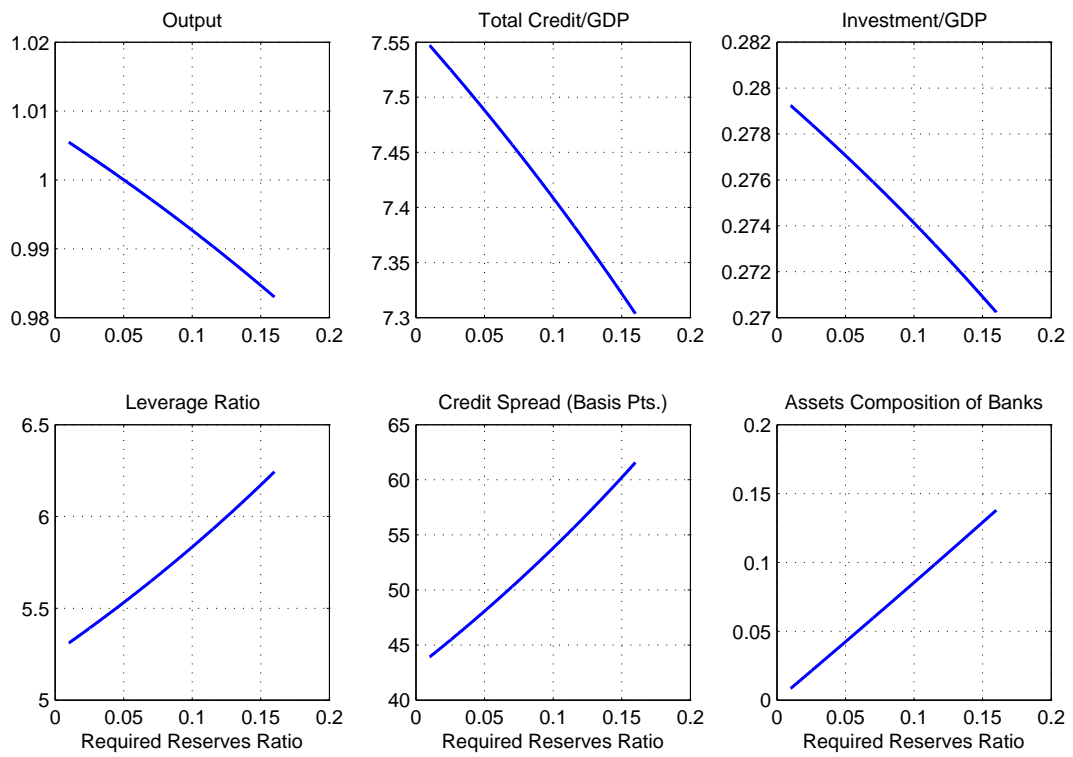


Figure 3: 1- σ Negative Productivity Shock

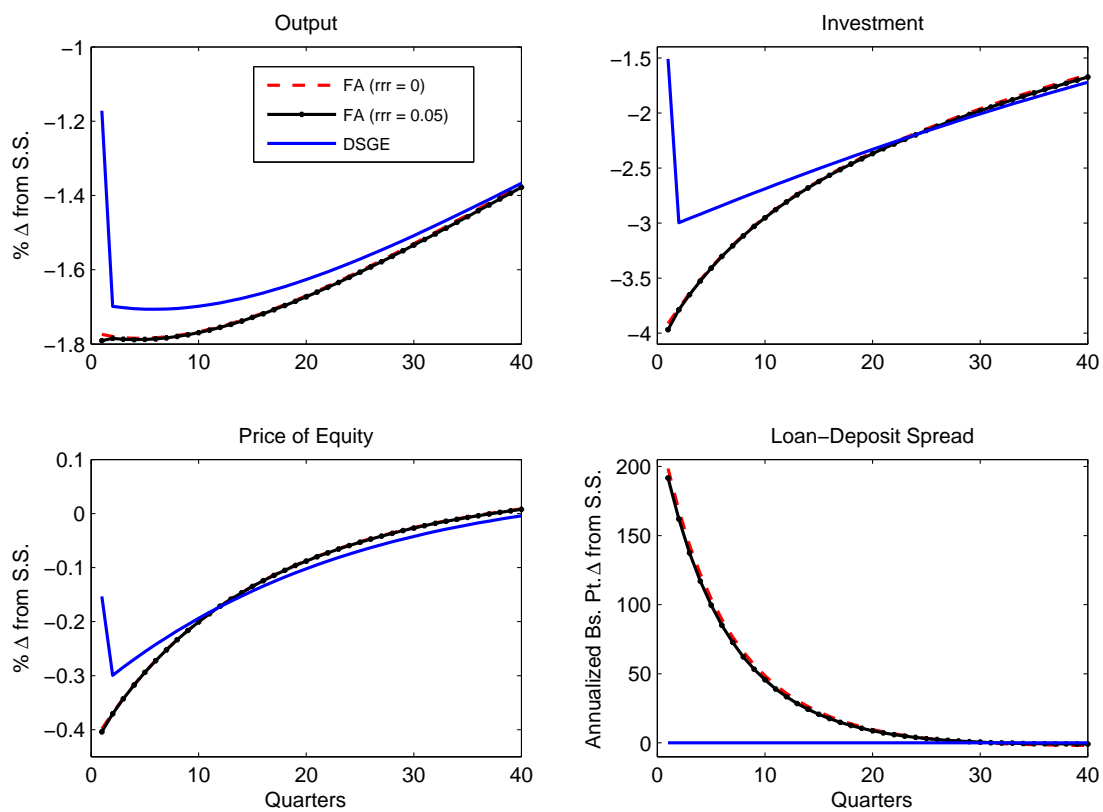


Figure 4: Impulse Responses Led by a $1\text{-}\sigma$ Adverse TFP Shock

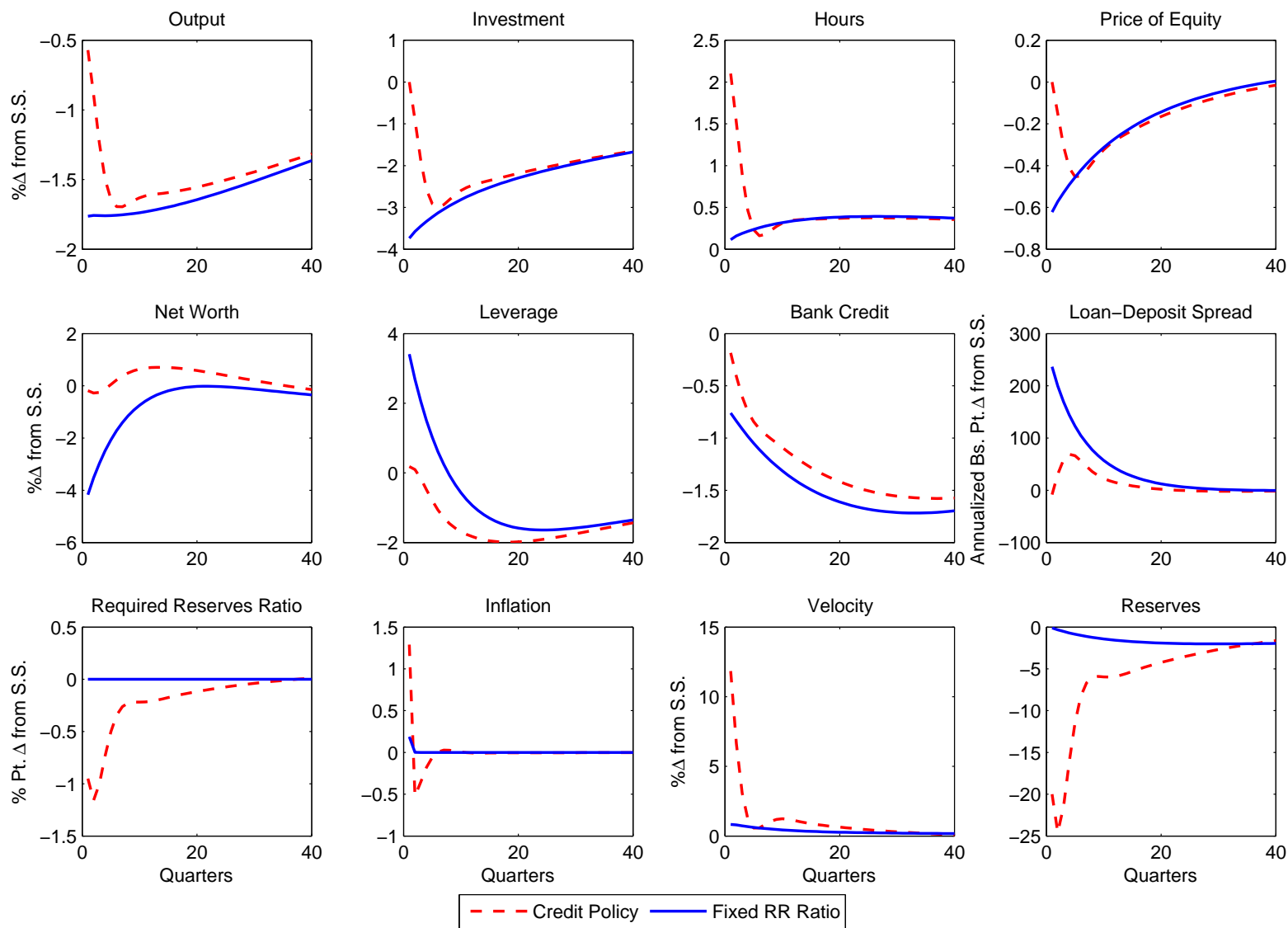


Figure 5: Impulse Responses Led by an Adverse Financial Shock

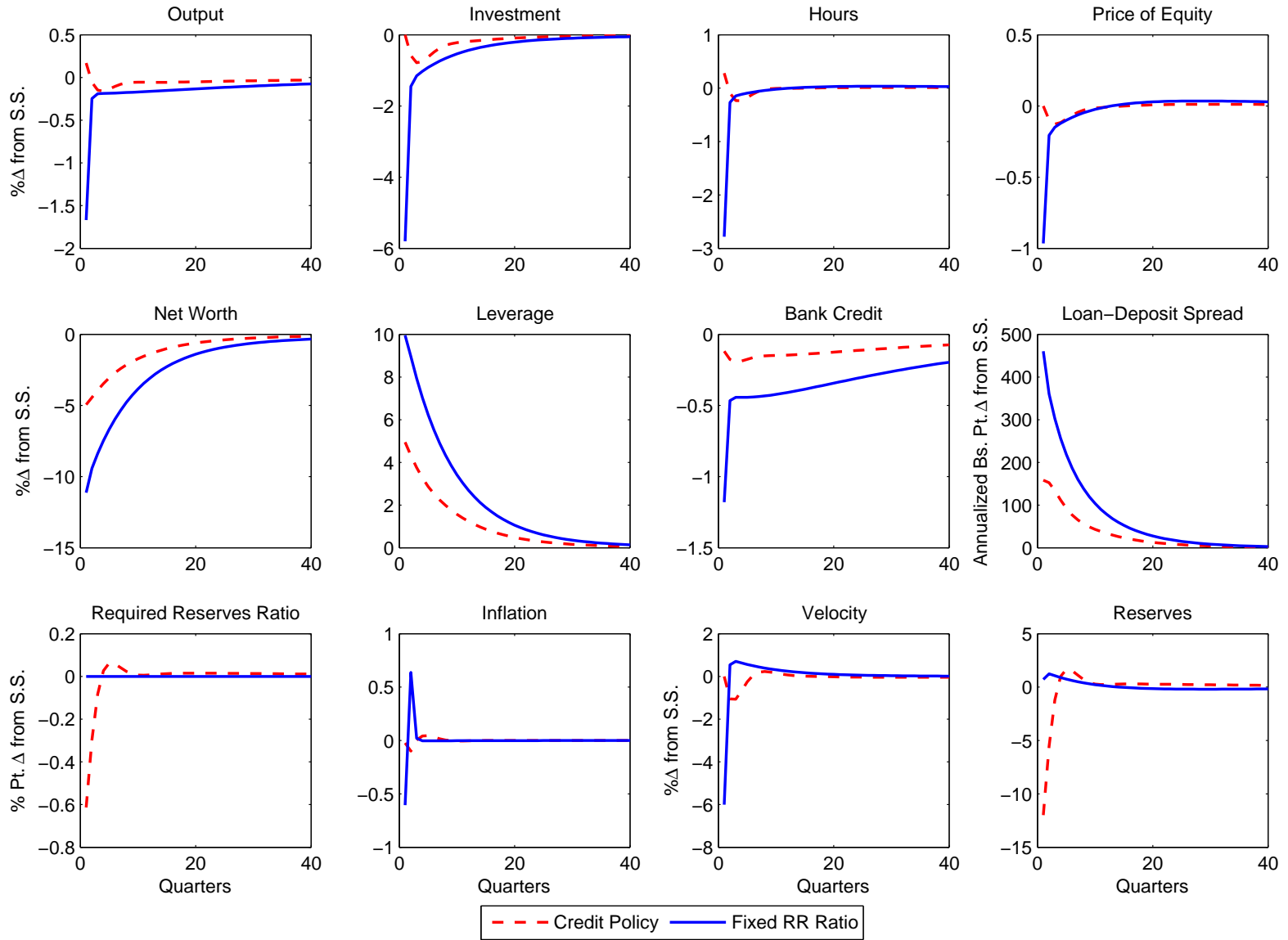


Figure 6: Impulse Responses Led by a $1\text{-}\sigma$ Adverse TFP Shock with $\varphi = 0$

