ABSTRACT

Title of dissertation: ESSAYS ON FINANCIAL INTERMEDIARIES,
                             BUSINESS CYCLES AND
                             MACROPRUDENTIAL POLICIES

                             Yasin Mimir, Doctor of Philosophy, 2012

Dissertation directed by: Professor S. Boragan Aruoba
                             Department of Economics

This study conducts a quantitative analysis of the role of financial shocks and credit frictions affecting the banking sector in driving business cycles as well as the role of reserve requirements as a macroprudential policy tool. In the first chapter, I first empirically document three stylized business cycle facts of aggregate financial variables in the U.S. commercial banking sector for the period 1987-2010: (i) Bank credit, deposits and loan spread are less volatile than output, while net worth and leverage ratio are more volatile, (ii) bank credit and net worth are procyclical, while deposits, leverage ratio and loan spread are countercyclical, and (iii) financial variables lead the output fluctuations by one to three quarters. I then present an equilibrium business cycle model with a financial sector, featuring a moral hazard problem between banks and its depositors, which leads to endogenous capital constraints for banks in obtaining funds from households. Credit frictions in banking sector are modeled as in Gertler and Karadi (2011). The model incorporates empirically-disciplined shocks to bank net worth (i.e. "financial shocks") that al-

ter the ability of banks to borrow and to extend credit to non-financial businesses. The model is calibrated to U.S. data from 1987 to 2010. I show that the benchmark model driven by both standard productivity and financial shocks is able to deliver most of the stylized facts about real and financial variables simultaneously. Financial shocks and credit frictions in banking sector are important not only for explaining the dynamics of aggregate financial variables but also for the dynamics of standard macroeconomic variables. Financial shocks play a major role in driving real fluctuations due to their strong impact on the tightness of bank capital constraint and credit spread, which eventually affect the saving-investment nexus of the economy. Finally, the tightness of bank capital constraint given by the Lagrange multiplier in the theoretical model (which determines the banks' ability to extend credit to non-financial firms) tracks the index of tightening credit standards (which shows the adverse changes in banks' lending) constructed by the Federal Reserve Board quite well.

The second chapter (coauthored with Enes Sunel and Temel Taşkın) undertakes a quantitative investigation of the role of reserve requirements as a credit 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 mitigates 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) an operational 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.

ESSAYS ON FINANCIAL INTERMEDIARIES,
BUSINESS CYCLES AND MACROPRUDENTIAL POLICIES

by

Yasin Mimir

Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2012

Advisory Committee:

Professor S. Boragan Aruoba, Chair/Advisor
Professor Pablo D'Erasmo
Professor Anton Korinek
Professor Enrique G. Mendoza
Professor Phillip L. Swagel

Dedication

To my love, Meryem.

Acknowledgments

I owe my gratitude to my advisors Professor Boragan Aruoba and Professor Sanjay Chugh without whom this dissertation could not have been possible.

First and foremost, I would like to thank my committee chair, Boragan Aruoba, for his encouragement, endless support and guidance from the beginning of my research journey. Sanjay Chugh pushed me to delve in studying the question at hand. I cannot overstate my gratitude for his enlightening comments, confidence and continual support. They have always made themselves available for numerous meetings that took their valuable times.

I would also like to thank Professor Enrique Mendoza who honored me by being in my committee. My warm thanks are to due to my other advisors Professor Pablo D'Erasmo and Professor Anton Korinek for their guidance and inspiring advice. I am also grateful to Professor Phillip L. Swagel for agreeing to serve on my dissertation committee.

I am also thankful to the Board of Governors of the Federal Reserve System for financial support and for hosting me during part of my dissertation. My dissertation benefited greatly from their support.

I am grateful to my colleagues Enes Sunel and Salih Fendoglu who are also my great friends, for their help and support. Without their cordial companionship, it would be much more difficult to complete this dissertation. I am looking forward to working closely with them in the future research projects. Enes was also a wonderful roommate with whom I have interesting, enlightening, and entertaining

Table of Contents

List of Tables

List of Figures

List of Abbreviations

CBRT   Central Bank of the Republic of Turkey
FED   Board of Governors of the Federal Reserve System
RRR   Required Reserves Ratio
TFP   Total Factor Productivity

Chapter 1

Financial Intermediaries, Credit Shocks, and Business Cycles

1.1   Introduction

What are the cyclical properties of financial flows in the U.S. banking sector? How important are financial shocks relative to standard productivity shocks in driving real and financial business cycles in the U.S.? To address these questions, this study proposes an equilibrium real business cycle model with a financial sector, that is capable of matching both real and financial fluctuations observed in the U.S. data. Although the relevance of financial shocks together with an explicit modeling of frictions in financial sector has received attention recently, the behavior of aggregate financial variables in the U.S. banking sector and how they interact with real variables over the business cycle have not been fully explored in the literature.[1] Most previous studies have not tried to match fluctuations in both standard macro variables and aggregate financial variables *simultaneously*. In this chapter, I show that financial shocks to the banking sector contribute significantly to explaining the observed dynamics of real and financial variables. Financial shocks play a major role in driving real fluctuations due to their impact on the tightness of bank capital constraint and hence credit spread.

---

[1]See Christiano et. al. (2010), Dib (2010), Meh and Moran (2010), Gertler and Kiyotaki (2010), Gertler and Karadi (2011), Kollman et al. (2011).

I first systematically document the business cycle properties of aggregate financial variables, using the data on U.S. commercial banks from the Federal Reserve Board.[2] The following empirical facts emerge from the analysis: (i) Bank credit, deposits, and loan spread are less volatile than output, while net worth and leverage ratio are more volatile, (ii) bank assets and net worth are procyclical, while deposits, leverage ratio, and loan spread are countercyclical, and (iii) financial variables lead the output fluctuations by one to three quarters.

I then assess the quantitative performance of a theoretical model by its ability to match these empirical facts. In particular, there are two main departures from an otherwise standard real business cycle framework. The first departure is that I introduce an active banking sector with financial frictions into the model, which are modeled as in Gertler and Karadi (2011). Financial frictions require that banks borrow funds from households and their ability to borrow is limited due to a moral hazard (costly enforcement) problem, leading to an endogenous capital constraint for banks in obtaining deposits.[3] This departure is needed in order to have balance sheet fluctuations of financial sector matter for real fluctuations. The second departure is that the model incorporates shocks to bank net worth (i.e. "financial shocks") that alter the ability of banks to borrow and to extend credit to non-financial businesses.[4] In the context of the theoretical model, this shock can be interpreted as

---

[2]I also document the business cycle properties of aggregate financial variables of the whole U.S. financial sector from 1952 to 2009, using the Flow of Funds data. Interested readers may look at Appendix A.3.

[3]Hellmann, Murdock and Stiglitz (2000) argue that moral hazard in banking sector plays a crucial role in most of the U.S. economic downturns in the last century. Moreover, the presence of the agency problem makes the balance sheet structure of financial sector matter for real fluctuations, invalidating the application of Modigliani-Miller theorem to the model economy presented below.

[4]Hancock, Laing and Wilcox (1995), Peek and Rosengren (1997, 2000) empirically show that

a redistribution shock, which transfers some portion of the wealth from financial intermediaries to households.[5] However, because of the moral hazard problem between households and bankers, it distorts intermediaries' role of allocating resources between households and firms, inducing large real effects.

I construct the time series of financial shocks as the residuals from the law of motion for bank net worth, using empirical data for credit spread, leverage ratio, deposit rate and net worth. This approach is similar to the standard method for constructing productivity shocks as Solow residuals from the production function using empirical series for output, capital and labor.[6] The shock series show that U.S. economy is severely hit by negative financial shocks in the Great Recession. Finally, in order to elucidate the underlying mechanism as clearly as possible, I abstract from various real and nominal rigidities that are generally considered in medium scale DSGE models such as Christiano et. al.(2005) and Smets and Wouters (2007).

adverse shocks to bank capital contributed significantly to the U.S. economic downturns of the late 1980s and early 1990s. Theoretically, Meh and Moran (2010) consider shocks that originate within the banking sector and produce sudden shortages in bank capital. They suggest that these shocks reflect periods of financial distress and weakness in financial markets. Brunnermeier and Pedersen (2009) introduce shocks to bank capital and interpret them as independent shocks arising from other activities like investment banking. Curdia and Woodford (2010) introduce exogenous increases in the fraction of loans that are not repaid and exogenous increases in real financial intermediation costs, both of which reduce net worth of financial intermediaries exogenously. Mendoza and Quadrini (2010) study the effect of net worth shocks on asset prices and interpret these shocks as unexpected loan losses due to producers' default on their debt. A complete model of the determination of the fluctuations in net worth of banks is beyond the scope of this study, because my goal is to analyze the quantitative effects of movements in net worth of financial sector on business cycle fluctuations of real and financial variables.

[5]This interpretation is suggested by Iacoviello (2010). He argues that 1990-91 and 2007-09 recessions can be characterized by situations in which some borrowers pay less than contractually agreed upon and financial institutions that extend loans to these borrowers suffer from loan losses, resulting in some sort of a redistribution of wealth between borrowers (households and firms) and lenders (banks).

[6]I also consider some alternative measures of financial shocks, including the one constructed based on loan losses incurred by U.S. commercial banks (using the charge-off and delinquency rates data compiled by the Federal Reserve Board). The construction of these alternative measures and their simulation results can be found in Appendix A.4. The main results of the study do not change under these alternative measures.

The business cycle accounting exercise in this study is important in the sense that explaining the dynamics of balance sheet fluctuations in the U.S. banking sector can help us better understand, capture and predict the dynamics of standard macroeconomic variables as the financial flows in the U.S. banking sector are highly cyclical and lead the output fluctuations by one to three quarters. Therefore, the dynamics of financial variables in the U.S. banking sector may serve as additional state variables for explaining real fluctuations. This study is one of the first studies, which rigorously addressed this issue. It is also the first work that tried to match fluctuations in both standard macro variables and aggregate financial variables of U.S. banking sector simultaneously. Finally, in order to start thinking about how different policy tools can be implemented in an environment in which the financial sector is crucial for business cycle fluctuations and what the welfare implications of these policies are, we need a model capable of matching real and financial fluctuations simultaneously. It could be asserted that the model proposed in this study is quite successful in this dimension.

In the theoretical model, there are three main results. First, the benchmark model driven by both standard productivity and financial shocks is able to deliver most of the stylized cyclical facts about real and financial variables *simultaneously*. Second, financial shocks to banking sector are important not only for explaining the dynamics of financial variables but also for the dynamics of standard macroeconomic variables. In particular, the model simulations show that the benchmark model driven by both shocks has better predictions about investment, hours and output than the frictionless version of the model (which is standard RBC model with capital

4

adjustment costs) and than the model driven only by productivity shocks. The benchmark model also performs better than the model with only productivity shocks in terms of its predictions about aggregate financial variables.[7] Third, the tightness of bank capital constraint given by the Lagrange multiplier in the theoretical model (which determines the banks' ability to extend credit to non-financial firms) tracks the index of tightening credit standards (which shows the adverse changes in banks' lending) constructed by the Federal Reserve Board quite well.

The economic intuition for why financial shocks matter a lot for real fluctuations in the model lies in the effect of these shocks on the tightness of bank capital constraint and credit spread. When financial shocks move the economy around the steady state, they lead to large fluctuations in the tightness of bank capital constraint as evidenced by the big swings in the Lagrange multiplier of the constraint. Since credit spread is a function of this Lagrange multiplier, fluctuations in the latter translate into variations in the former. Credit spread appears as a positive wedge in the intertemporal Euler equation, which determines how households' deposits (savings in the economy) are transformed into bank credit to non-financial firms. Fluctuations in this wedge move the amount of deposits, therefore the amount of bank credit that can be extended to firms. Since productive firms finance their capital expenditures via bank credit, movements in the latter translate into the fluctuations in capital stock. Because hours worked is complementary to capital stock in a standard Cobb-Douglas production function, empirically-relevant fluctuations

---

[7]The RBC model with capital adjustment costs has no predictions about financial variables since balance sheets of banks in that model are indeterminate.

in capital stock lead to empirically-observed fluctuations in hours, which eventually generate observed fluctuations in output.

This study contributes to recently growing empirical and theoretical literature studying the role of financial sector on business cycle fluctuations. On the empirical side, Adrian and Shin (2008, 2009) provide evidence on the time series behavior of balance sheet items of some financial intermediaries using the Flow of Funds data.[8] However, they do not present standard business cycle statistics of financial flows.[9] On the theoretical side, the current work differs from the existing literature on financial accelerator effects on demand for credit, arising from the movements in the strength of borrowers' balance sheets.[10] I focus on fluctuations in supply of credit driven by movements in the strength of lenders' balance sheets. Meh and Moran (2010) investigate the role of bank capital in transmission of technology, bank capital and monetary policy shocks in a medium-scale New Keynesian, double moral hazard framework. Jermann and Quadrini (2010) study the importance of credit shocks in non-financial sector in explaining the cyclical properties of equity and debt payouts of U.S. *non-financial firms* in a model without a banking sector.

An independent study that is closely related and complementary to our work is Iacoviello (2011). In a DSGE framework with households, banks, and entrepreneurs each facing endogenous borrowing constraints, he studies how repayment shocks

---

[8]They argue that to the extent that balance sheet fluctuations affect the supply of credit, they have the potential to explain real fluctuations, and they empirically show that bank equity has a significant forecasting power for GDP growth.

[9]The notion of "procyclical" in their papers is with respect to total assets of financial intermediaries, not with respect to GDP as in the current study. In that sense, this study undertakes a more standard business cycle accounting exercise.

[10]For example, see Kiyotaki and Moore (1997), Carlstrom and Fuerst (1998), Bernanke, Gertler, and Gilchrist (1999)

undermine the flow of funds between savers and borrowers in the recent recession. My work is different from his study in terms of both empirical and theoretical contributions. First, in terms of empirical work, I systemically document the business cycle properties of aggregate financial variables in the U.S. banking sector from 1987 to 2010, which I then use to judge the quantitative performance of the theoretical model, while his work particularly focuses on the 2007-09 recession. Second, in the theoretical model presented below, only the banking sector faces endogenous capital constraints, which gives me the ability to isolate the role of banks in the transmission of financial shocks from the role of household and production sectors. Finally, I employ a different methodology of constructing the series of financial shocks from the data. In terms of normative policy, Angeloni and Faia (2010) examine the role of banks in the interaction between monetary policy and macroprudential regulations in a New Keynesian model with bank runs, while Gertler and Kiyotaki (2010), and Gertler and Karadi (2011) investigate the effects of central bank's credit policy aimed at troubled banks.[11] Finally, in an open-economy framework, Kollmann (2011) studies how a bank capital constraint affects the international business cycles driven by productivity and loan default shocks in a two-country RBC model with a global bank.

The rest of the chapter is structured as follows: In Section 1.2, I document evidence on the real and financial fluctuations in U.S. data. Section 1.3 describes the theoretical model. Section 1.4 presents the model parametrization and calibration together with the quantitative results of the model. Section 1.5 concludes.

---

[11]The latter also features the interbank market.

1.2 Real and Financial Fluctuations in the U.S. economy

This section documents some key empirical features of financial cycles in the U.S. economy. The upper left panel of Figure 1 displays quarterly time series for loan losses of U.S. commercial banks from 1987 to 2010. The loan loss rates are expressed as annualized percentages of GDP. The figure shows that loan loss rates increased in last three recessions of the U.S. economy. The loss rates peaked in both 1990-91 and 2007-09 recessions, reaching its highest level of 5% in the latter. The upper right panel of Figure 1 plots daily time series for Dow Jones Bank Index from 1992 to 2010. The figure suggests that the market value of banks' shares declined substantially in the recent recession. Finally, the middle left panel of Figure 1 displays real net worth growth of U.S. commercial banks (year-on-year). The figure suggests that banks' net worth shrank in last three recessions of the U.S. economy, with a reduction of 40% in the 2007-09 recession. These three plots convey a common message: substantial loan losses incurred by banks together with the fall in their equity prices typically cause large declines in banks' net worth, which might lead to persistent and mounting pressures on bank balance sheets, worsening the aggregate credit conditions, and thus causing the observed decline in real economic activity, which is much more pronounced in the Great Recession.

The middle left panel of Figure 1 plots commercial and industrial loan spreads over federal funds rate (annualized). The figure shows that bank lending spreads sky-rocketed in the recent crisis, reaching a 3.2% per annum towards the end of the recession and they keep rising although the recession was officially announced
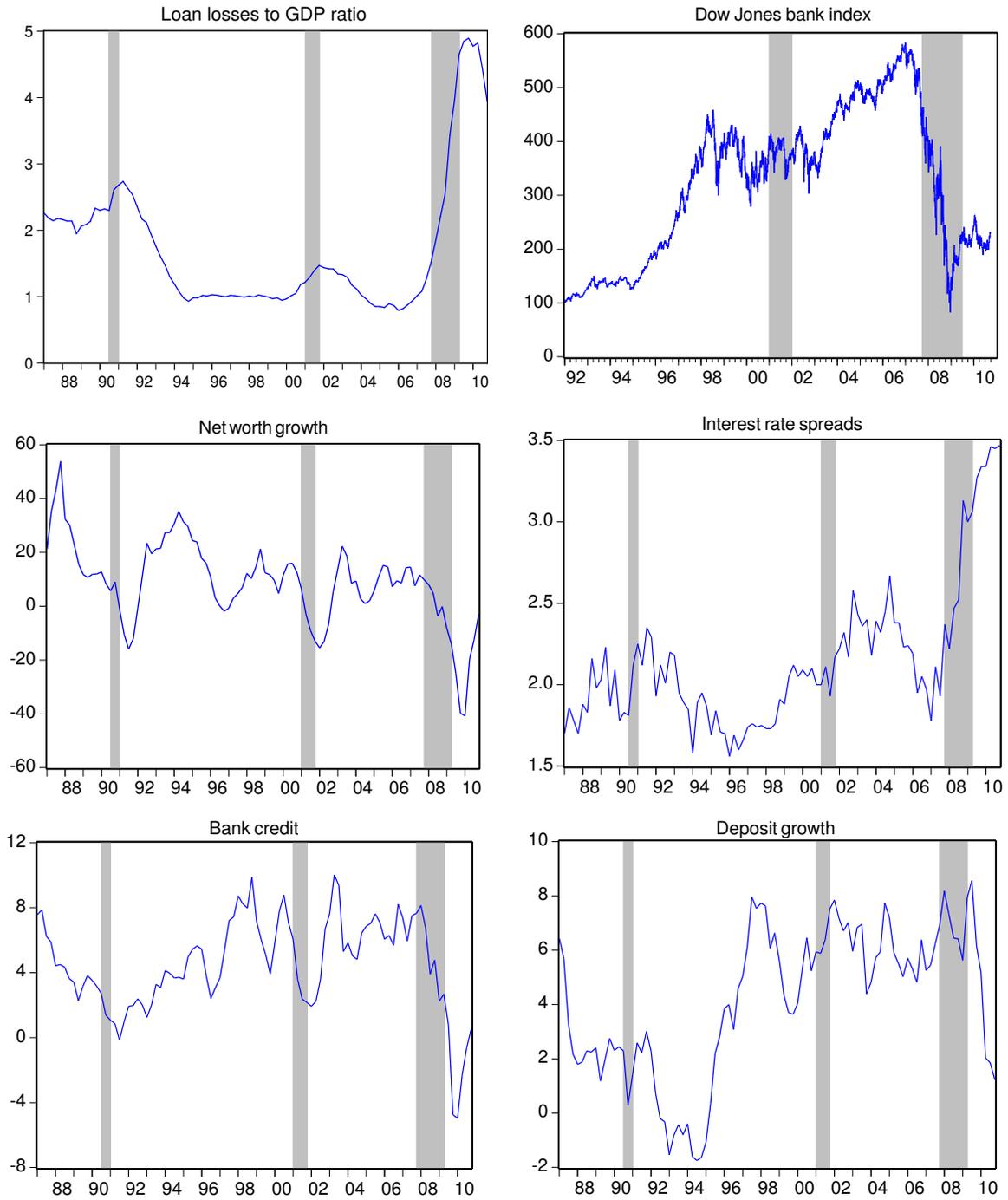
Figure 1.1: Financial Flows in the U.S. Economy

to be over. The bottom left panel displays real bank credit growth rates (year-on-year). The figure indicates that bank credit growth fell significantly in the recent economic downturn. Taken together, these figures suggest that the U.S. economy has experienced a significant deterioration in aggregate credit conditions as total bank lending to non-financial sector declined sharply and the cost of funds for non-financial firms increased substantially. Finally, the bottom right panel of Figure 1 plots real deposit growth rates (year-on-year). The figure shows that growth rate of deposits began to fall substantially right after the recent recession.

Table 1.1: Business Cycle Properties of Real and Financial Variables, Quarterly U.S. Data, 1987- 2010

	Standard Deviation	x_{t-4}	x_{t-3}	x_{t-2}	x_{t-1}	x_t	x_{t+1}	x_{t+2}	x_{t+3}	x_{t+4}
Real Variables										
Output	1.80	0.15	0.39	0.66	0.87	1.00	0.87	0.66	0.39	0.15
Consumption	0.45	-0.20	0.06	0.37	0.66	**0.82**	0.80	0.67	0.46	0.25
Investment	2.73	0.27	0.49	0.71	0.87	**0.97**	0.82	0.59	0.33	0.09
Hours	0.91	-0.01	0.19	0.43	0.65	0.83	**0.89**	0.83	0.68	0.44
Financial Variables										
Bank credit	0.93	-0.20	-0.11	0.02	0.14	0.30	0.47	0.63	**0.68**	0.63
Deposits	0.69	-0.02	-0.08	-0.18	-0.30	-0.39	**-0.42**	-0.34	-0.22	-0.07
Net Worth	5.17	-0.15	-0.03	0.14	0.32	0.52	0.70	**0.80**	0.76	0.63
Leverage Ratio	5.61	0.16	0.05	-0.12	-0.30	-0.49	-0.66	**-0.74**	-0.70	-0.55
Loan Spread	0.08	0.05	0.04	-0.08	-0.21	-0.39	-0.42	**-0.43**	-0.32	-0.18

[a] Business cycle statistics in the table are based on HP-filtered cyclical components of quarterly empirical time series (smoothing parameter:1600).
[b] The standard deviation of output is expressed in percent; standard deviations of the remaining variables are normalized by the standard deviation of output (std(x)/std(GDP)).
[c] The correlation coefficients in bold font are the maximum ones in their respective rows.
[d] Data sources are provided in Appendix A.1.

I will assess the performance of the model below by its ability to match empirical cyclical properties of real and financial variables in the U.S data. Table 1 presents

the business cycle properties of aggregate financial variables in U.S. commercial banking sector together with standard macro aggregates for the period 1987-2010.[12] The standard deviations of real and financial variables except GDP are relative to the standard deviation of GDP. The correlation coefficients in bold font are the maximum ones in their respective rows, which indicate the lead-lag relationship of variables with output. The aggregate financial variables I consider are U.S. commercial banks' assets (bank credit), liabilities (deposits), net worth, leverage ratio and loan spread.[13] Quarterly seasonally-adjusted financial data are taken from the Federal Reserve Board. Quarterly real data are taken from Federal Reserve Economic Data (FRED) of St. Louis FED. Financial data at the FED Board is nominal. GDP deflator from NIPA accounts is used to deflate the financial time series. See the data appendix for a more detailed description.

Table 1.1 gives us the following empirical facts about real and financial variables. Consumption and hours are less volatile than output, while investment is more volatile; and consumption, investment, and hours are all strongly procyclical with respect to output. These are standard business-cycle facts; for example, see King and Rebelo (1999). Bank credit, deposits, and loan spread are less volatile than output, while net worth and leverage ratio are nearly 5 times more volatile. Bank

---

[12]I focus on the period that begins in 1987 for two reasons. First, U.S. banking sector witnessed a significant transformation starting from 1987 such as deregulation of deposit rates, increases in financial flexibility. Second, it also corresponds to a structural break in the volatility of many standard macro variables, which is so-called Great Moderation.

[13]I also conducted the same empirical exercise for total assets and total liabilities in addition to the narrow definitions of these items here. The business cycle statistics are qualitatively very similar although there are some negligible quantitative differences. The reason might be the fact that bank credit constitutes a substantial part of total assets of a typical commercial bank and deposits constitute a big portion of its total liabilities.

assets and net worth are procyclical, while deposits, leverage ratio, and loan spread are countercyclical. Finally, all financial variables lead the output fluctuations by one to three quarters.[14]

Table 1.2: The Sequence of Events in a Given Time Period

1. Productivity z_t and recovery rate ω_t are realized.
2. Firms hire labor H_t and use capital K_t they purchased in period $t-1$, which are used for production, Y_t.
3. Firms make their wage payments $w_t H_t$ and dividend payments to shareholders (banks) from period t-1.
4. Banks make their interest payments on deposits of households from period t-1 and bankers exit with prob. (1-θ).
5. Households make their consumption and saving decisions and deposit their resources at banks.
6. Firms sell their depreciated capital to capital producers who make investment and produce new capital K_{t+1}.
7. Firms issue shares $[s_t = K_{t+1}]$ and sell these shares to banks to finance their capital expenditures.
8. Banks purchase firms' shares and their incentive constraints bind.
9. Firms purchase capital K_{t+1} from capital producers at the price of q_t with borrowed funds.

1.3 A Business Cycle Model with Financial Sector

The model is an otherwise standard real business cycle model with a financial sector. Market segmentation ensures that households cannot directly lend to final good firms, which makes the financial sector essential for transferring funds from households to non-financial firms. Credit frictions in financial sector are modeled as in Gertler and Karadi (2011). I introduce shocks to bank net worth on top of the standard productivity shocks. The model economy consists of four types of agents: households, financial intermediaries, firms, and capital producers. The ability of financial intermediaries to borrow from households is limited due to a moral hazard (costly enforcement) problem, which will be described below. Firms acquire capital in each period by selling shares to financial intermediaries. Finally, capital producers

---

[14]I also reproduce Table 1.1 for the period 1987:Q1-2007:Q1 in order to see whether the empirical results are driven or at least substantially affected by the recent economic events starting at 2007:Q3 or not. The results show that the key stylized facts about real and financial variables described above are robust to the sample period taken. The reproduced table can be found in Appendix A.1.

are incorporated into the model in order to introduce capital adjustment costs in a tractable way. Table 1.2 shows the sequence of events in a given time period in the theoretical model described below. The section below will clarify this timeline.

1.3.1 Households

There is a continuum of identical households of measure unity. Households are infinitely-lived with preferences over consumption (c_t) and leisure $(1 - L_t)$ given by

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, 1 - L_t) \tag{1.1}$$

Each household consumes and supplies labor to firms at the market clearing real wage w_t. In addition, they save by holding deposits at a riskless real return r_t at competitive financial intermediaries.

There are two types of members within each household: workers and bankers. Workers supply labor and return the wages they earn to the household while each banker administers a financial intermediary and transfers any earnings back to the household. Hence, the household owns the financial intermediaries that its bankers administer. However, the deposits that the household holds are put in financial intermediaries that it doesn't own.[15] Moreover, there is perfect consumption insurance within each household.

At any point in time the fraction $1 - \zeta$ of the household members are workers

---

[15]This assumption ensures independent decision-making. Depositors are not the owners of the bank, so the bankers don't maximize the depositors' utility, but the expected terminal net worth of the banks that they own.

and the remaining fraction ζ are bankers. An individual household member can switch randomly between these two jobs over time. A banker this period remains a banker next period with probability θ, which is independent of the banker's history. Therefore, the average survival time for a banker in any given period is $1/(1-\theta)$. The bankers are not infinitely-lived in order to make sure that they don't reach a point where they can finance all equity investment from their own net worth.[16] Hence, every period $(1-\theta)\zeta$ bankers exit and become workers while the same mass of workers randomly become bankers, keeping the relative proportion of workers and bankers constant. Period t bankers learn about survival and exit at the beginning of period $t+1$. Bankers who exit from the financial sector transfer their accumulated earnings to their respective household. Furthermore, the household provides its new bankers with some start-up funds.[17]

The household budget constraint is given by

$$c_t + b_{t+1} = w_t L_t + (1 + r_t)b_t + \Pi_t \tag{1.2}$$

The household's subjective discount factor is $\beta \in (0,1)$, c_t denotes the household's consumption, b_{t+1} is the total amount of deposits that the household holds at the financial intermediary, r_t is the non-contingent real return on the deposits from $t-1$ to t, w_t is the real wage rate, and Π_t is the profits to the household from owning capital producers and banks net of the transfer that it gives to its new bankers plus

---

[16]This assumption ensures that the bankers have to borrow from households to finance their equity purchases.

[17]This assumption ensures that banks don't have zero net worth in any period and is similar to the one about the entrepreneurial wage in Carlstrom and Fuerst (1998), and Bernanke, Gertler, and Gilchrist (1999).

(minus) the amount of wealth redistributed from banks (households) to households (banks) induced by the net worth shock.

The household chooses c_t, L_t, and b_{t+1} to maximize (1.1) subject to the sequence of flow budget constraints in (1.2). The resulting first order conditions for labor supply and deposit holdings are given by

$$\frac{U_l(t)}{U_c(t)} = w_t \tag{1.3}$$

$$U_c(t) = \beta(1 + r_{t+1})E_t U_c(t+1) \tag{1.4}$$

The condition (1.3) states that the marginal rate of substitution between consumption and leisure is equal to the wage rate. The condition (1.4) is the standard consumption-savings Euler equation, which equates the marginal cost of not consuming and saving today to the expected discounted marginal benefit of consuming tomorrow.

1.3.2 Financial Intermediaries

1.3.2.1 Balance Sheets

Financial intermediaries transfer the funds that they obtain from households to firms. They acquire firm shares and finance these assets with household deposits and their own equity. At the beginning of period t, before banks collect deposits, an aggregate net worth shock hits banks' balance sheets. Let's denote ω_t as the

time-varying recovery rate of loans as a percentage of bank net worth. Innovations to ω_t are shocks to bank net worth. Therefore, $\omega_t \tilde{n}_{jt}$ is the effective net worth of the financial intermediary. For notational convenience, I denote $\omega_t \tilde{n}_{jt}$ by n_{jt}. Hence, n_{jt} is the net worth of financial firm j at the beginning of period t after the net worth shock hits. The balance sheet identity of financial intermediary j is then given by

$$q_t s_{jt} = b_{jt+1} + n_{jt} \tag{1.5}$$

where q_t is the price of a representative firm's shares and s_{jt} is the quantity of these shares owned by bank j, b_{jt+1} is the amount of deposits that intermediary j obtains from the households, n_{jt} is the net worth of financial firm j at the beginning of period t after the net worth shock hits.[18] Banks undertake equity investment and firms finance their capital expenditures by issuing shares. Therefore, the financial contract between the intermediary and the firm is an equity contract (or equivalently a state-dependent debt contract).

The households put their deposits into the financial intermediary at time t and obtain the non-contingent real return r_{t+1} at $t+1$. Therefore, b_{jt+1} is the liabilities of the financial intermediary and n_{jt} is its equity or capital. The financial intermediaries receive ex-post state-contingent return, r_{kt+1} for their equity investment. The fact that r_{kt+1} is potentially greater than r_{t+1} creates an incentive for bankers to engage in financial intermediation.

The financial intermediary's net worth at the beginning of period $t+1$ (before

---

[18]In U.S. financial data, household deposits constitute 70% of total liabilities of banks. Boyd (2007) also suggests that demand (checking) deposits form a substantial portion of bank liabilities.

the time $t+1$ net worth shock hits) is given by the difference between the earnings on equity investment in firms (assets of financial intermediary) and interest payments on deposits obtained from the households (liabilities of financial intermediary). Thus the law of motion for bank net worth is given by

$$\tilde{n}_{jt+1} = (1 + r_{kt+1})q_t s_{jt} - (1 + r_{t+1})b_{jt+1} \tag{1.6}$$

Using the balance sheet of the financial firm given by (1.5), we can re-write (1.6) as follows:

$$\tilde{n}_{jt+1} = (r_{kt+1} - r_{t+1})q_t s_{jt} + (1 + r_{t+1})n_{jt} \tag{1.7}$$

The financial intermediary's net worth at time $t+1$ depends on the premium $(r_{kt+1} - r_{t+1})$ that it earns on shares purchased as well as the total value of these shares, $q_t s_{jt}$.

1.3.2.2   Profit Maximization

This section describes banks' profit maximization. The financial intermediary j maximizes its expected discounted terminal net worth, V_{jt}, by choosing the amount of firm shares, s_{jt}, it purchases, given by

$$V_{jt} = \max_{s_{jt}} E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i}[(r_{kt+1+i} - r_{t+1+i})q_{t+i}s_{jt+i}] + (1+r_{t+1+i})n_{jt+i}] \tag{1.8}$$

Since the expected discounted risk premium is positive in any period, the financial intermediary will always have an incentive to buy firms' shares. Obtaining additional funds (deposits) from the households is the only way to achieve this. However, an agency problem described below introduces an endogenous borrowing constraint for banks, thus a limit on the size of the financial intermediaries: At the end of the period, the financial intermediary may choose to divert λ fraction of available funds from its shares of firms with no legal ramification and give them to the household of which the banker is a member. If the financial intermediary diverts the funds, the assumed legal structure ensures that depositors are able to force the intermediary to go bankrupt and they may recover the remaining fraction $1 - \lambda$ of the assets. They are not able to get the remaining fraction λ of the funds since, by assumption, the cost of recovering these funds is too high.[19] Therefore, for the banks not to have an incentive to divert the funds, the following incentive compatibility constraint must be satisfied at the end of period t:

$$V_{jt} \geq \lambda q_t s_{jt} \tag{1.9}$$

The left-hand side of (1.9) is the value of operating for the bank (or equivalently cost of diverting funds) while the right-hand side is the gain from diverting λ

---

[19] As Christiano (2010) suggests, diverting funds is meant to say that bankers might not manage funds in the interest of depositors or they might invest funds into risky projects which do not earn a high return for depositors but a high excess return for bankers themselves (Bankers might invest λ fraction of funds into very risky projects, which could potentially go bankrupt and reduce equilibrium return to depositors). Taking this into consideration, depositors put their money at banks up to a threshold level beyond which if bankers make risky investments, they do this at their own risk. This threshold level of deposits can be thought as if deposits expand beyond that level, banks would have an incentive to default. The market discipline prevents deposits from expanding beyond the default threshold level and interest rate spreads reflect this fear of default although defaults are not observed in equilibrium.

fraction of assets. The intuition for this constraint is that in order for the financial intermediary not to divert the funds and for the households to put their deposits into the bank, the value of operating in financial sector must be greater than or equal to the gain from diverting assets and going bankrupt.[20]

A financial intermediary's objective is to maximize the expected return to its portfolio consisting of firms' shares and its capital subject to the incentive compatibility constraint. Then its demand for shares is fully determined by its net worth position, since as long as the expected return from the portfolio is strictly positive, it will expand its lending (its size) until the incentive compatibility constraint binds.

1.3.2.3   Leverage Ratio and Net Worth Evolution

Proposition 1 *The expected discounted terminal net worth of a bank can be expressed as the sum of expected discounted total return to its equity investment into firms and expected discounted total return to its existing net worth.*

Proof: See Appendix A.2.1.

Proposition 1 states that that V_{jt} can be expressed as follows:

$$V_{jt} = \nu_t q_t s_{jt} + \eta_t n_{jt} \tag{1.10}$$

where

---

[20]In equilibrium, given the incentive compatibility constraint binds, the banker is indifferent between diverting funds and not diverting them. Here we focus on the equilibrium where banker chooses to operate in the financial sector rather than diverting money and going bankrupt. Therefore, we analyze the equilibrium where there are no defaults of banks and the amount of funds that the bankers can collect from households endogenously depends on bankers' own net worth.

$$\nu_t = E_t[(1-\theta)\beta\Lambda_{t,t+1}(r_{kt+1} - r_{t+1}) + \beta\Lambda_{t,t+1}\theta\frac{q_{t+1}s_{jt+1}}{q_t s_{jt}}\nu_{t+1}] \qquad (1.11)$$

$$\eta_t = E_t[(1-\theta)\beta\Lambda_{t,t+1}(1 + r_{t+1}) + \beta\Lambda_{t,t+1}\theta\frac{n_{jt+1}}{n_{jt}}\eta_{t+1}] \qquad (1.12)$$

ν_t can be interpreted as the expected discounted marginal gain to the bank of buying one more unit of firms' shares, holding its net worth n_{jt} constant. The first term is the discounted value of the net return on shares to the bank if it exits the financial sector tomorrow. The second term is the continuation value of its increased assets if it survives. Meanwhile, η_t can be interpreted as the expected discounted marginal benefit of having one more unit of net worth, holding $q_t s_{jt}$ constant. The first term is the discounted value of the return on net worth to the bank if it exits the financial sector tomorrow. The second term is the continuation value of its increased net worth if it survives.

Therefore, we can write the incentive compatibility constraint as follows:

$$\nu_t q_t s_{jt} + \eta_t n_{jt} \geq \lambda q_t s_{jt} \qquad (1.13)$$

The incentive compatibility constraint above binds as long as $0 < \nu_t < \lambda$. The intuition is as follows: Assume that $\nu_t \geq \lambda$. Then the left-hand side of (1.13) is always greater than the right-hand side of (1.13) since $\eta_t n_{jt} > 0$ as can be seen from (1.12). The franchise value of the bank is always higher than the gain from diverting funds. Therefore, the constraint is always slack. Moreover, assume that

$\nu_t \leq 0$. Since ν_t is the expected discounted marginal gain to the bank of increasing its assets, the intermediary does not have the incentive to expand its assets when $\nu_t \leq 0$. In this case, the constraint does not bind because the intermediary does not collect any deposits from households.

The profits of the financial intermediary will be affected by the premium $r_{kt+1} - r_{t+1}$. That is, the banker will not have any incentive to buy firms' shares if the discounted return on these shares is less than the discounted cost of deposits. Thus the financial firm will continue to operate in period $t + i$ if the following inequality is satisfied:

$$E_{t+i}\beta\Lambda_{t,t+1+i}(r_{kt+1+i} - r_{t+1+i}) \geq 0 \quad \forall i \geq 0 \tag{1.14}$$

where $\beta\Lambda_{t,t+1+i}$ is the stochastic discount factor that the financial firm applies to its earnings at $t + 1 + i$. The moral hazard problem between households and banks described above limits banks' ability to obtain deposits from the households, leading to a positive premium. The following proposition establishes this fact.

Proposition 2 *Risk premium is positive as long as the incentive compatibility constraint binds.*

Proof: See Appendix A.2.2.

When this constraint binds, the financial intermediary's assets are limited by its net worth. That is, if this constraint binds, the funds that the intermediary can obtain from households will depend positively on its equity capital:

$$q_t s_{jt} = \frac{\eta_t}{\lambda - \nu_t} n_{jt} \tag{1.15}$$

The constraint (1.15) limits the leverage of the financial intermediary to the point where its incentive to divert funds is exactly balanced by its loss from doing so. Thus, the costly enforcement problem leads to an endogenous borrowing constraint on the bank's ability to acquire assets. When bank's leverage ratio and/or bank equity is high, it can extend more credit to non-financial firms. Conversely, deleveraging or the deterioration in net worth in bad times will limit the bank's ability to extend credit. Note that by manipulating this expression using the balance sheet, I can obtain the bank's leverage ratio as follows:

$$\frac{b_{jt+1}}{n_{jt}} = \frac{\eta_t}{\lambda - \nu_t} - 1 \tag{1.16}$$

The leverage ratio increases in the expected marginal benefit of buying one more unit of firm share, and in the expected marginal gain of having one more unit of net worth. Intuitively, increases in η_t or ν_t mean that financial intermediation is expected to be more lucrative going forward, which makes it less attractive to divert funds today and thus increases the amount of funds depositors are willing to entrust to the financial intermediary.[21]

---

[21]The amount of deposits at banks does directly depend on banks' net worth. In good times banks' net worth is relatively high and depositors believe that bankers do not misbehave in terms of managing their funds properly. In these times, credit spreads can be fully explained by observed bankruptcies and intermediation costs. However, in bad times, banks experience substantial declines in their net worth and depositors are hesitant about putting their money in banks. In these times, the financial sector operates at a less efficient level and a smaller number of investment projects are funded. Large credit spread observed in these times can be explained by the above factors plus the inefficiency in the banking system.

Using (1.15), I can re-write the law of motion for the banker's net worth as follows:

$$\widetilde{n}_{jt+1} = [(r_{kt+1} - r_{t+1})\frac{\eta_t}{\lambda - \nu_t} + (1 + r_{t+1})]n_{jt} \tag{1.17}$$

The sensitivity of net worth of the financial intermediary j at $t + 1$ to the ex-post realization of the premium $r_{kt+1} - r_{t+1}$ increases in the leverage ratio.

Proposition 3 *Banks have an identical leverage ratio as none of its components depends on bank-specific factors.*

Proof: From (1.17), one can obtain the following:

$$\frac{\widetilde{n}_{jt+1}}{n_{jt}} = [(r_{kt+1} - r_{t+1})\frac{\eta_t}{\lambda - \nu_t} + (1 + r_{t+1})] \tag{1.18}$$

$$\frac{q_{t+1}s_{jt+1}}{q_t s_{jt}} = \frac{\frac{\eta_{t+1}}{\lambda - \nu_{t+1}}}{\frac{\eta_t}{\lambda - \nu_t}} \frac{\widetilde{n}_{jt+1}}{n_{jt}} \tag{1.19}$$

The expressions above show that banks have identical expected growth rates of assets and net worth, thus have identical leverage ratios.[22]

By using Proposition 4, we can sum demand for assets across j to obtain the total intermediary demand for assets:

$$q_t s_t = \frac{\eta_t}{\lambda - \nu_t} n_t \tag{1.20}$$

---

[22]This immediately implies that η_t and ν_t are independent of j. In Appendix A.2.1, I use this result in explicit derivation of η_t and ν_t.

where s_t is the aggregate amount of assets held by financial intermediaries and n_t is the aggregate intermediary net worth. In the equilibrium of the model, movements in the leverage ratio of financial firms and/or in their net worth will generate fluctuations in total intermediary assets.

The aggregate intermediary net worth at the beginning of period $t+1$ (before the net worth shock hits but after exit and entry), $\tilde{n}_{t+1}$, is the sum of the net worth of surviving financial intermediaries from the previous period, $\tilde{n}_{et+1}$, and the net worth of entering financial intermediaries, $\tilde{n}_{nt+1}$. Thus, we have

$$\tilde{n}_{t+1} = \tilde{n}_{et+1} + \tilde{n}_{nt+1} \tag{1.21}$$

Since the fraction θ of the financial intermediaries at time t will survive until time $t+1$, their net worth, $\tilde{n}_{et+1}$, is given by

$$\tilde{n}_{et+1} = \theta[(r_{kt+1} - r_{t+1})\frac{\eta_t}{\lambda - \nu_t} + (1 + r_{t+1})]n_t \tag{1.22}$$

Newly entering financial intermediaries receive start-up funds from their respective households. The start-up funds are assumed to be a transfer equal to a fraction of the net worth of exiting bankers.[23] The total final period net worth of exiting bankers at time t is equal to $(1-\theta)n_t$. The household is assumed to transfer the fraction $\frac{\epsilon}{(1-\theta)}$ of the total final period net worth to its newly entering financial intermediaries. Therefore, we have

---

[23]This assumption is slightly different from that in Gertler&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 study significantly.

$$\tilde{n}_{nt+1} = \epsilon n_t \tag{1.23}$$

Using (1.21), (1.22), and (1.23), we obtain the following law of motion for $\tilde{n}_{t+1}$:

$$\tilde{n}_{t+1} = \theta[(r_{kt+1} - r_{t+1})\frac{\eta_t}{\lambda - \nu_t} + (1 + r_{t+1})]n_t + \epsilon n_t \tag{1.24}$$

1.3.3 Firms

There is a continuum of unit mass of firms that produce the final output in the economy. The production technology at time t is described by a constant returns to scale Cobb-Douglas production function:

$$Y_t = z_t F(K_t, H_t) = z_t K_t^\alpha H_t^{1-\alpha} \tag{1.25}$$

where K_t is the firm's capital stock, H_t is the firm's hiring of labor and z_t is an aggregate TFP realization.

Firms acquire capital K_{t+1} at the end of period t to produce the final output in the next period. After producing at time $t + 1$, the firm can sell the capital on the open market.

Firms finance their capital expenditures in each period by issuing equities and selling them to financial intermediaries. Firms issue s_t units of state-contingent claims (equity), which is equal to the number of units of capital acquired K_{t+1}. The financial contract between a financial intermediary and a firm is an equity contract (or equivalently, a state contingent debt contract). The firm pays a state-contingent

interest rate equal to the ex-post return on capital r_{kt+1} to the financial intermediary. The firms set their capital demand K_{t+1} taking this stochastic repayment into consideration. At the beginning of period $t+1$ (after shocks are realized), when output becomes available, firms obtain resources Y_{t+1} and use them to make repayments to shareholders (or financial intermediaries). The firm prices each financial claim at the price of a unit of capital, q_t. Thus, we have

$$q_t s_t = q_t K_{t+1} \qquad (1.26)$$

There are no frictions for firms in obtaining funds from financial intermediaries. The bank has perfect information about the firm and there is perfect enforcement. Therefore, in the current model, only banks face endogenous borrowing constraints in obtaining funds. These constraints directly affect the supply of funds to the firms. Firms choose the labor demand at time t as follows:

$$w_t = z_t F_H(K_t, H_t) \qquad (1.27)$$

Then firms pay out the ex-post return to capital to the banks given that they earn zero profit state by state. Therefore, ex-post return to capital is given by

$$r_{kt+1} = \frac{z_{t+1} F_K(K_{t+1}, H_{t+1}) + q_{t+1}(1-\delta)}{q_t} - 1 \qquad (1.28)$$

Labor demand condition (1.27) simply states that the wage rate is equal to the marginal product of labor. Moreover, condition (1.28) states that the ex-post

26

real rate of return on capital is equal to the marginal product of capital plus the capital gain from changed asset prices.

1.3.4 Capital Producers

Following the literature on financial accelerator, I incorporate capital producers into the model in order to introduce capital adjustment costs in a tractable way. Capital adjustment costs are needed to introduce variation in the price of capital; otherwise the price of capital will not respond to the changes in capital stock and will always be equal to 1.[24]

I assume that households own capital producers and receive any profits. At the end of period t, competitive capital producers buy capital from firms to repair the depreciated capital and to build new capital. Then they sell both the new and repaired capital. The cost of replacing the depreciated capital is unity; thus the price of a unit of new capital or repaired capital is q_t. The profit maximization problem of the capital producers is given by:

$$\max_{I_t} q_t K_{t+1} - q_t(1-\delta)K_t - I_t \tag{1.29}$$

$$s.t. \ K_{t+1} = (1-\delta)K_t + \Phi\left(\frac{I_t}{K_t}\right)K_t \tag{1.30}$$

where I_t) is the total investment by capital producing firms and $\Phi\left(\frac{I_t}{K_t}\right)$ is the capital

---

[24]There will be no financial accelerator between households and banks if there is no variation in the price of capital.

adjustment cost function. The resulting optimality condition gives the following "Q"

relation for investment:

$$q_t = \left[\Phi'\left(\frac{I_t}{K_t}\right)\right]^{-1} \tag{1.31}$$

where $\Phi'\left(\frac{I_t}{K_t}\right)$ is the partial derivative of the capital adjustment cost function with

respect to investment-capital ratio at time t. The fluctuations in investment expen-

ditures will create variation in the price of capital. A fall in investment at time t

(ceteris paribus) will reduce the price of capital in the same period.

1.3.5 Competitive Equilibrium

A competitive equilibrium of this model economy consists of sequences of allo-

cations $\{c_t, L_t, K_{t+1}, s_t, n_t, \tilde{n}_t, I_t, \eta_t, \nu_t, H_t\}_{t=0}^{\infty}$, of prices $\{w_t, r_{kt+1}, r_{t+1}, q_t\}_{t=0}^{\infty}$ and of

exogenous processes $\{z_t, \omega_t\}_{t=0}^{\infty}$ such that (i) the allocations solve the household's,

the financial intermediary's, the firm's and the capital producer's problems at the

equilibrium prices and (ii) markets for factor inputs clear. The following equilibrium

conditions must be satisfied:

$$\frac{U_l(t)}{U_c(t)} = w_t \tag{1.32}$$

$$U_c(t) = \beta(1 + r_{t+1})E_t U_c(t+1) \tag{1.33}$$

$$r_{kt+1} = \frac{z_{t+1}F_K(K_{t+1}, H_{t+1}) + q_{t+1}(1-\delta)}{q_t} - 1 \tag{1.34}$$

$$w_t = z_t F_H(K_t, H_t) \tag{1.35}$$

$$n_t = \omega_t \tilde{n}_t \tag{1.36}$$

$$q_t s_t = \frac{\eta_t}{\lambda - \nu_t} n_t \tag{1.37}$$

$$\nu_t = E_t[(1-\theta)\beta\Lambda_{t,t+1}(r_{kt+1} - r_{t+1}) + \beta\Lambda_{t,t+1}\theta\frac{q_{t+1}s_{t+1}}{q_t s_t}\nu_{t+1}] \tag{1.38}$$

$$\eta_t = E_t[(1-\theta)\beta\Lambda_{t,t+1}(1 + r_{t+1}) + \beta\Lambda_{t,t+1}\theta\frac{n_{t+1}}{n_t}\eta_{t+1}] \tag{1.39}$$

$$\tilde{n}_{t+1} = \theta[(r_{kt+1} - r_{t+1})\frac{\eta_t}{\lambda - \nu_t} + (1 + r_{t+1})]n_t + \epsilon n_t \tag{1.40}$$

$$q_t s_t = q_t K_{t+1} \tag{1.41}$$

$$K_{t+1} = (1-\delta)K_t + \Phi\left(\frac{I_t}{K_t}\right)K_t \tag{1.42}$$

$$q_t = \left[\Phi' \left(\frac{I_t}{K_t} \right) \right]^{-1} \tag{1.43}$$

$$L_t = H_t \tag{1.44}$$

$$C_t + I_t = z_t F(K_t, H_t) \tag{1.45}$$

$$log(z_{t+1}) = \rho_z log(z_t) + \epsilon_{t+1}^z \tag{1.46}$$

$$log(\omega_{t+1}) = \rho_\omega log(\omega_t) + \epsilon_{t+1}^\omega \tag{1.47}$$

1.4   Quantitative Analysis

This section studies the quantitative predictions of the model by examining the results of numerical simulations of an economy calibrated to quarterly U.S. data. In order to investigate the dynamics of the model, I compute a second-order approximation to the equilibrium conditions using Dynare.

1.4.1 Functional Forms, Parametrization and Calibration

The quantitative analysis uses the following functional forms for preferences, production technology and capital adjustment costs:[25]

$$U(c, 1 - L) = log(c) + \upsilon log(1 - L) \tag{1.48}$$

$$F(K, H) = K^\alpha H^{1-\alpha} \tag{1.49}$$

$$\Phi\left(\frac{I}{K}\right) = \frac{I}{K} - \frac{\varphi}{2}\left[\frac{I}{K} - \delta\right]^2 \tag{1.50}$$

Table 1.3 lists the parameter values for the model economy. The preference and production parameters are standard in business cycle literature. I take the quarterly discount factor, β as 0.9942 to match the 2.37% average annualized real deposit rate in the U.S. for the period 1987.Q1-2010.Q4. I pick the relative utility weight of labor υ as 1.72 to fix hours worked in steady state, $\overline{L}$, at one third of the available time. The share of capital in the production function is set to 0.36 to match the labor share of income in the U.S. data. The capital adjustment cost parameter is taken so as to match the relative volatility of price of investment goods with respect to output in the U.S. data.[26] The quarterly depreciation rate of capital is set to 2.25% to match the average annual investment to capital ratio.

---

[25]I choose the functional form of the capital adjustment cost following Bernanke, Gertler and Gilchrist (1999), Gertler, Gilchrist, and Natalucci (2007).

[26]The volatility of price of investment goods is taken from Gomme et al. (2011).

Table 1.3: Model Parameterization and Calibration

Description	Parameter	Value	Target	Data
Preferences				
Quarterly discount factor	β	0.9942	Annualized real deposit rate	2.37%
Relative utility weight of leisure	υ	1.7167	Hours worked	0.3333
Production Technology				
Share of capital in output	α	0.36	Labor share of output	0.64
Capital adjustment cost parameter	φ	3.6	Relative volatility of price of investment	0.37
Depreciation rate of capital	δ	0.025	Average annual ratio of investment to capital	10%
Steady-state total factor productivity	$\overline{z}$	1	Normalization	N/A
Financial Intermediaries				
Steady-state fraction of assets that can be diverted	λ	0.1548	Commercial and industrial loan spread	0.46%
Proportional transfer to the entering bankers	ϵ	0.001	0.1% of aggregate net worth	N/A
Survival probability of the bankers	θ	0.9685	Leverage ratio of commercial banks	4.62
Steady-state level of net worth shock	$\overline{\omega}$	1	Normalization	N/A
Shock Processes				
Persistence of TFP process	ρ_z	0.9315	Quarterly persistence of TFP process	0.9315
Standard deviation of productivity shock	σ_z	0.006424	Quarterly standard dev. of TFP shock	0.0064
Persistence of ω process	ρ_ω	0.3744	Quarterly persistence of ω process	0.3744
Standard deviation of net worth shock	σ_ω	0.0512	Quarterly standard dev. of net worth shock	0.0512

The non-standard parameters in our model are the financial sector parameters: the fraction of the revenues that can be diverted, λ, the proportional transfer to newly entering bankers, ϵ, and the survival probability of bankers, θ. I set ϵ to 0.001 so that the proportional transfer to newly entering bankers is 0.1% of aggregate net worth.[27] I pick other two parameters simultaneously to match the following two targets: an average interest rate spread of 46 basis points, which is the historical average of the difference between the quarterly commercial and industrial loan spread and the quarterly deposit rate from 1987.Q1 to 2010.Q4, and an average leverage ratio of 4.61, which is the historical average of U.S. commercial banks' leverage ratio for the same period. The resulting values for $\overline{\lambda}$ and θ are 0.155 and 0.968, respectively.

Finally, turning to the shock processes, I follow the standard Solow residuals approach to construct the series for productivity shocks.[28] Using the production

---

[27]I keep the proportional transfer to newly entering bankers small, so that it does not have significant impact on the results.

[28]I also perform model-based simulations of macro-financial shocks using utilization-adjusted TFP series constructed by Fernald (2009). The results can be found in Appendix A.5.

function, I obtain

$$z_t = \frac{y_t}{K_t^\alpha H_t^{1-\alpha}} \tag{1.51}$$

Using the empirical series for output, y_t, capital, K_t, and labor, H_t, I use equation (1.51) to obtain the z_t series. Then I construct the log-deviation of TFP series by linearly detrending the log of the z_t series over the period 1987.Q1-2010.Q4.

Similar to the construction of productivity shocks, ω_t series are constructed from the law of motion for bank net worth, which is given by

$$\omega_t = \frac{1}{\theta[(r_{kt+1} - r_{t+1})\frac{\eta_t}{\lambda - \nu_t} + (1 + r_{t+1})] + \epsilon} \frac{\tilde{n}_{t+1}}{\tilde{n}_t} \tag{1.52}$$

Using the empirical series for net worth, n_t, credit spread, $r_{kt+1} - r_{t+1}$, leverage, $\frac{\eta_t}{\lambda - \nu_t}$, and gross deposit rate $1 + r_{t+1}$, I use equation (1.52) obtain the ω_t series.[29] Then I construct the log-deviation of ω_t series by linearly detrending the log of these series over the period 1987.Q1-2010.Q4. The innovations to ω_t are net worth shocks.

After constructing the z_t and ω_t series over the period 1987.Q1-2010.Q4, I estimate two independent AR(1) processes for both series:[30]

$$log(z_{t+1}) = \rho_z log(z_t) + \epsilon_{t+1}^z \tag{1.53}$$

---

[29]I constructed two ω_t series by using the realized and the expected values of credit spread. I obtain the expected value of credit spread by regressing actual spread on real and financial variables (such as GDP, consumption, investment, hours, bank credit, deposits, net worth) and getting the predicted value of it. Both series of ω are very similar to each other (the correlation between the two series is 0.9934).

[30]For the stochastic processes, I also tried fitting a VAR(1), however, the cross-terms in VAR(1) are statistically insignificant at 5% significance level. I included the main results of the analysis under the VAR(1) representation into the Appendix A.4. The results are qualitatively very similar although there are some negligible quantitative differences.
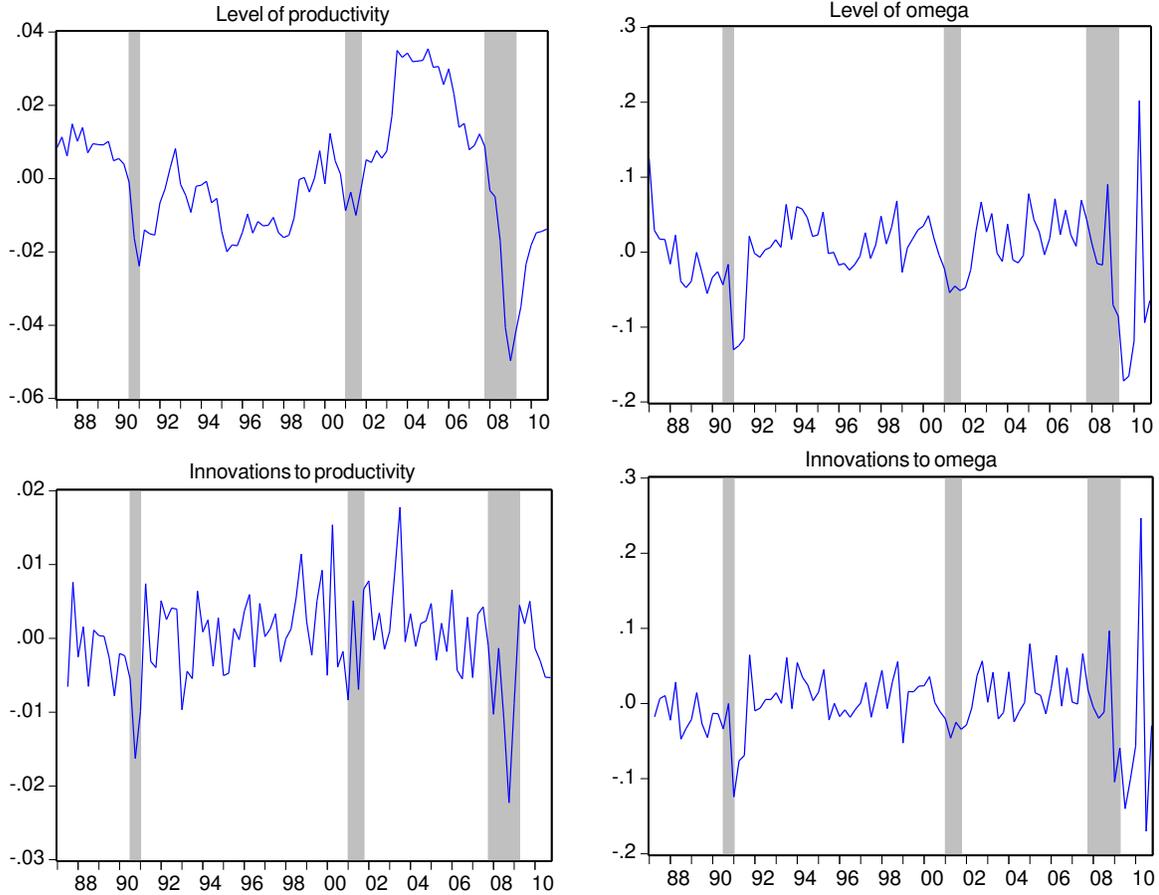
Figure 1.2: Time Series of Shocks to Productivity and Credit Conditions

$$log(\omega_{t+1}) = \rho_\omega log(\omega_t) + \epsilon_{t+1}^\omega \qquad (1.54)$$

where $\epsilon_{z,t+1}$ and $\epsilon_{\omega,t+1}$ are i.i.d. with standard deviations σ_z and σ_ω, respectively. The resulting parameters are $\rho_z = 0.93$, $\rho_\omega = 0.37$, $\sigma_z = 0.0064$, and $\sigma_\omega = 0.05$.

The first two panels of Figure 1.2 plot the variables z_t and ω_t constructed using the procedures described above. The figures show that the levels of productivity and credit conditions fell sharply in the recent recession.[31] The bottom panels

---

[31]The level of ω_t started to decline before the recession officially began. However, we see a sharp increase in the level of ω_t in the middle of the recession period due to the fact that there are huge capital transfers from bank holding companies to their commercial banks and injection of capital from the FED with the capital purchase program. If we remove this spike due to the capital transfers, we see a decline in the level of ω_t before the recession starts.

plot the innovations $\epsilon_{z,t}$ and $\epsilon_{\omega,t}$. These innovations are unexpected changes in the levels of productivity and financial conditions. The plots suggest that the U.S. economy is severely hit by both negative productivity and financial shocks in the Great Recession.

1.4.2 Long-Run Equilibrium of the Model

This section presents the deterministic steady-state properties of the model economy. First, I will formally show how the tightness of bank capital constraint affects output. Imposing the steady-state on the competitive equilibrium conditions of the model economy yields the following analytical expression for output:

$$y = \left[\frac{\alpha}{\frac{(1-\beta\theta)\mu\lambda}{(1-\theta)\beta(1+\mu)} + \frac{(1-\beta)}{\beta} + \delta} \right]^{\frac{1}{(1-\alpha)}} \overline{L}^{2-\alpha} \tag{1.55}$$

where μ is the Lagrange multiplier of bank capital constraint. Taking the partial derivative of output w.r.t. μ, I obtain

$$\frac{\partial y}{\partial \mu} = -\frac{\alpha}{(1-\alpha)} \left[\frac{\alpha}{\frac{(1-\beta\theta)\mu\lambda}{(1-\theta)\beta(1+\mu)} + \frac{(1-\beta)}{\beta} + \delta} \right]^{\frac{\alpha}{(1-\alpha)}} \overline{L}^{2-\alpha} \left[\frac{(1-\theta)\beta(1-\beta\theta)\lambda}{[(1-\theta)\beta(1+\mu)]^2} \right]^{-2} < 0 \tag{1.56}$$

which unambiguously shows that the output will be lower the larger μ. The reason is simple. As the bank capital constraint gets tighter, the credit spread will be larger,

as can be seen from the following expression.

$$(r_k - r) = \frac{(1 - \beta\theta)\mu\lambda}{(1 - \theta)\beta(1 + \mu)} \tag{1.57}$$

The term at the right-hand side of equation (1.57) appears as a positive wedge in the intertemporal Euler equation, which determines how deposits (savings) are transformed into credit to firms in the economy. This positive wedge reduces the amount of savings that can be extended as credit to non-financial firms, lowering their physical capital accumulation, and thus leading to a lower steady-state output. The same mechanism is also at work when shocks move the economy around the steady-state as they tighten or relax the bank capital constraint.
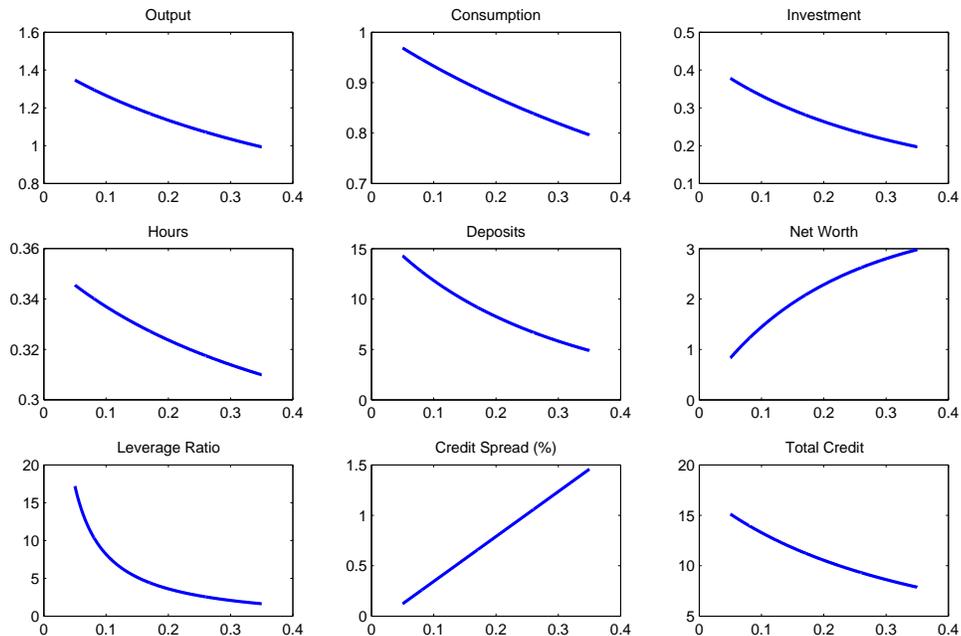
Figure 1.3: Long-run equilibrium as a function of fraction of diverted funds by bankers

Second, I analytically show how output is affected by the severity of credit frictions in banking sector, which is governed by the fraction of diverted funds by bankers, λ. Taking the partial derivative of output w.r.t. λ, I get

$$\frac{\partial y}{\partial \lambda} = -\frac{\alpha \overline{L}^{2-\alpha}}{(1-\alpha)} \left[\frac{\alpha \left[\frac{(1-\beta\theta)[(1-\epsilon)\beta-\theta]}{(1-\theta)\beta(1-\epsilon)\beta} \right]^{\frac{(1-\alpha)}{\alpha}}}{\frac{(1-\beta\theta)[(1-\epsilon)\beta-\theta]\lambda}{(1-\theta)\beta(1-\epsilon)\beta} + \frac{(1-\beta)+\beta\delta}{\beta}} \right]^{\frac{\alpha}{(1-\alpha)}} \left[\frac{(1-\beta\theta)[(1-\epsilon)\beta-\theta]\lambda}{(1-\theta)\beta(1-\epsilon)\beta} + \frac{(1-\beta)+\beta\delta}{\beta} \right]^{-2} < 0$$

(1.58)

which implies that the steady-state output will be lower the higher the intensity of financial frictions in banking sector. In order to get the intuition behind this result, I display long-run equilibria of real and financial variables as a function of the intensity of the credit friction in the financial sector given by fraction of diverted funds by bankers, λ. All other parameter values are set to those shown in Table 1.3. Figure 1.3 shows that the long-run dynamics of the model economy to changes in λ is monotonic and non-linear. As λ increases, households' incentive to make deposits into banks falls since the bankers' gain from diverting funds rises. Banks have to finance their equity investment by internal financing rather than external financing. Thus, deposits go down and net worth rises, leading to a fall in banks' leverage ratio. The decline in leverage ratio is sharper than the rise in net worth, inducing a drop in total credit to non-financial firms. Credit conditions tighten for firms and their cost of funds given by credit spread goes up. This leads to a reduction in investment and output falls.

1.4.3 Intermediary Capital and the Transmission of Shocks

I present the dynamics of the model in response to productivity and net worth shocks. In the figures below, credit spread, return to capital, and deposit rate are expressed in percentage points per annum. The responses of all other variables are expressed in percentage deviations from their respective steady state values.

1.4.3.1 Impulse Responses to TFP Shocks

Figure 1.4 presents the impulse responses to a one-time, one-standard deviation negative shock to TFP. The negative technology shock reduces the price of investment goods produced by capital producers by 0.3% on impact, lowering the value of firms' shares. This makes purchase of their shares less profitable for banks, which can also be observed from the 1.2% fall in the return to capital. Thus, banks have difficulty in obtaining deposits from households since their equity investment becomes less attractive. This reduces the return to deposits by 0.2%, inducing a countercyclical credit spread. The spread rises by 0.3% on impact. In order to compensate the fall in their external financing, banks need to finance a larger share of their purchases of equities from their net worth. However, bank net worth also falls by 4% due to lower asset prices. Since the decline in net worth is sharper than the fall in deposits on impact, banks' leverage ratio rises. Hence, the model with productivity shocks generates a countercyclical leverage ratio. Because banks cannot adjust their net worth immediately and the lower price of capital reduces the value of their net worth, their financing conditions tighten and bank lending in

the form of equity purchases falls dramatically (by about 4.6%), inducing aggregate investment to shrink by 0.9%. Finally, hours fall by 0.15%, and output declines by 1.2%.
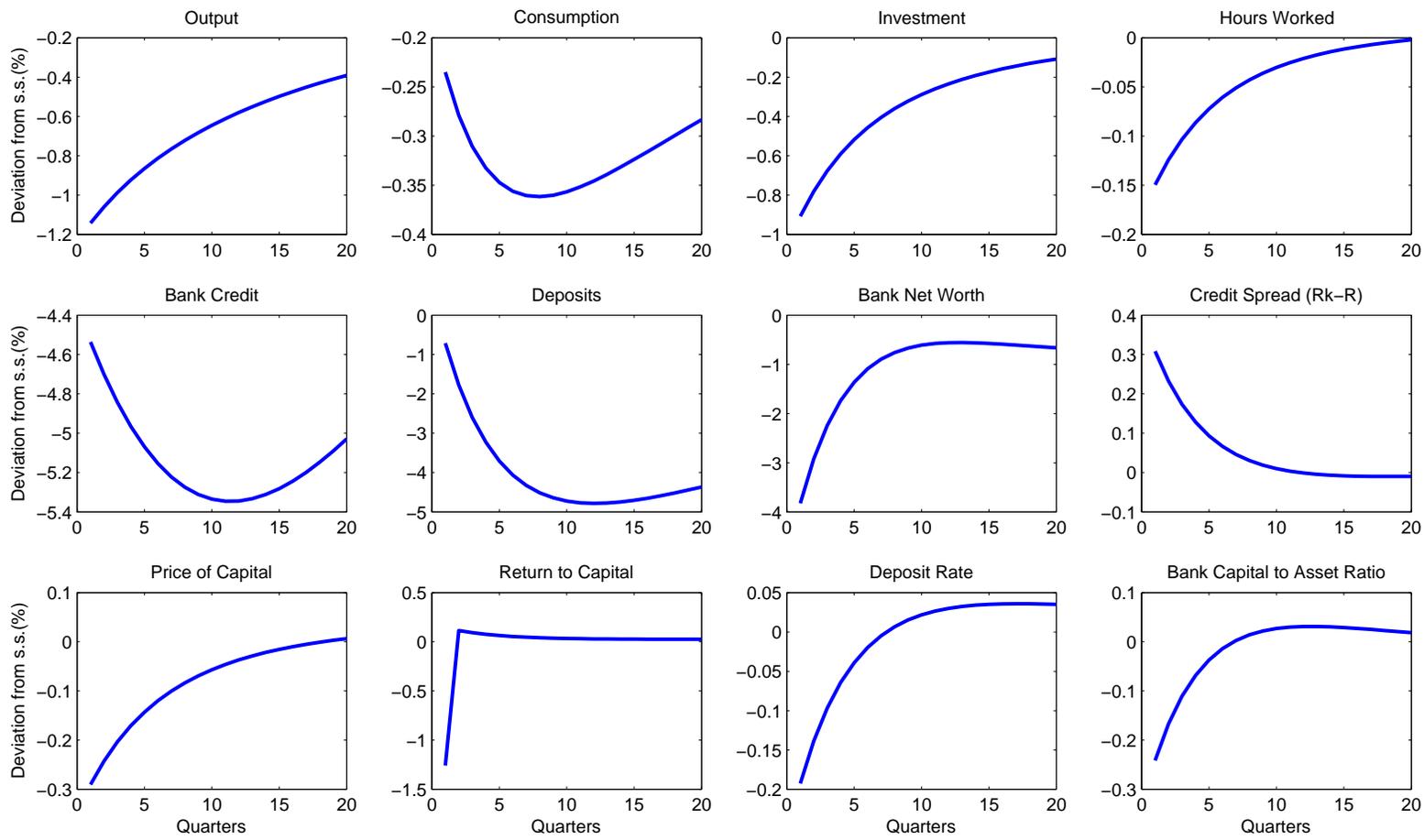
Figure 1.4: Impulse responses to a negative one-standard-deviation productivity shock
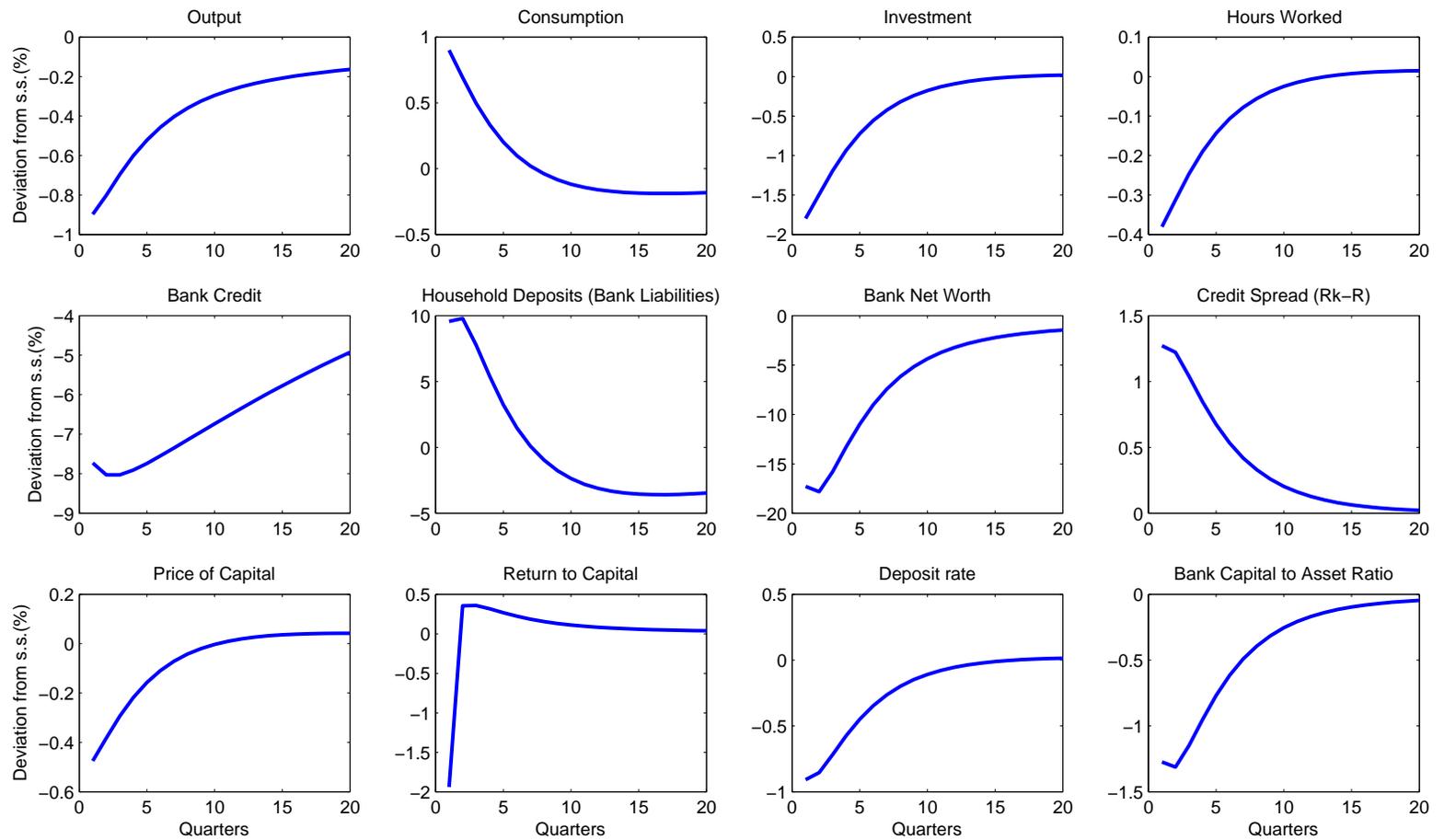
Figure 1.5: Impulse responses to a negative one-standard-deviation net worth shock

1.4.3.2 Impulse Responses to Financial Shocks

Figure 1.5 presents the impulse responses to a one-time, one-standard deviation negative shock to net worth. The negative net worth shock immediately reduces net worth of banks. Bank net worth falls roughly by 15% on impact. In order to compensate the decline in their internal financing, they need to finance a larger share of their purchases of equities from deposits. This induces a rise in their leverage ratio. Hence, the model driven by net worth shocks also generates a countercyclical leverage ratio. Although they have to finance a greater fraction of their equity investment from deposits, their ability to do so is impaired by the fall in their net worth, leading deposits to decline after five quarters. Moreover, the fall in their net worth translates into a reduction in bank credit to firms. Bank credit shrinks by roughly 8% on impact. Since firms finance their capital expenditures via bank credit, they cut back their investment severely (by about 2%). The drop in investment reduces the price of capital by 0.4%, which lowers banks' net worth further. Hours fall by 0.4% and output drops by 0.9% on impact. Finally, consumption rises on impact after the shock hits, which is what was observed at the beginning of the recent financial crisis. In the context of the model, this seemingly unappealing result can be explained as follows: On the intratemporal margin, the fall in aggregate demand caused by lower investment expenditures translates into a reduction in the demand for labor, which eventually leads to a drop in hours worked. Since wages are flexible, the reduction in labor demand also lowers wages, leading to a fall in households' wage bill. However, the rise in credit spread on impact raises banks'

profits. Since households own banks, the rise in their profits helps households sustain their consumption after the financial shock hits. On impact, the rise in bank profits dominates the reduction in wage bill, pushing consumption up.[32]

1.4.4   Business Cycle Dynamics

This section presents numerical results from stochastic simulations of the benchmark economy with productivity and net worth shocks. First, I simulate the model economy 1000 times for 1096 periods each and discard the first 1000 periods in each simulation so that each simulation has the same length as the data sample. I then compute the standard business cycle statistics using the cyclical components of the HP-filtered series. I also conduct the same quantitative exercise for the frictionless version of the benchmark economy, which is essentially the standard RBC model with capital adjustment costs, in order to compare the real fluctuations in both models. Finally, I simulate the model economy only driven by productivity shocks to see the contribution of net worth shocks to the observed dynamics of real and financial variables.

Table 1.4 presents quarterly real and financial statistics in the data and in the model economies. In particular, it displays the relative standard deviations of real and financial variables with respect to output and their cross-correlations with output. Column 3 of the table shows that the standard RBC model with capital adjustment costs driven by standard productivity shocks is able produce

---

[32]Barro and King (1984) argue that any shock that reduces the quantity of hours worked on impact has to lead a fall in consumption due to consumption-leisure optimality condition. Ajello (2010) shows that sticky wages are the key factor in generating a positive comovement between consumption and investment after a financial shock.

the key business cycle facts in the U.S. data as expected: consumption and hours less volatile than output, while investment is more volatile, all real variables are highly procyclical. However, this model can only explain 80% of the fluctuations in output and less than half of the relative volatility in hours. It also generates roughly perfect positive correlation between real variables and output, contrary to the data. Moreover, this model has no predictions about financial variables.

Column 4 of the table shows the business cycle statistics of our model economy with only productivity shocks. This model is much closer to the data in terms of real fluctuations, compared to the RBC model. It now accounts for 85% of the fluctuations in output and roughly half of the relative volatility in hours. The model is also able to replicate most of the stylized facts about financial variables: bank assets, deposits and loan spread is less volatile than output, while net worth and leverage ratio are more volatile; bank assets and net worth are procyclical, while leverage ratio and loan spread are countercyclical. However, it generates procyclical deposits, contrary to the data. Although the model does a good job in terms of key facts of financial variables, it predicts lower fluctuations. For example, it can explain less than half of the relative volatility in bank assets, roughly half of the relative volatility in deposits, less than one third of the relative volatility in net worth and leverage ratio. The model virtually matches the relative volatility of credit spread.

Table 1.4: Real and Financial Statistics

Statistic	Data	RBC	Only Productivity	Benchmark
σ_Y	1.80	1.44	1.53	1.81
σ_C	0.45	0.41	0.39	0.75
σ_I	2.73	2.45	2.98	4.64
σ_L	0.91	0.40	0.46	0.84
$\rho_{Y,I}$	0.97	1.00	0.98	0.87
$\rho_{Y,C}$	0.82	0.97	0.85	-0.03
$\rho_{Y,L}$	0.83	0.99	0.96	0.81
σ_{Assets}	0.93	–	0.40	0.58
$\sigma_{Deposits}$	0.69	–	0.39	0.87
$\sigma_{NetWorth}$	5.17	–	1.36	5.90
$\sigma_{LeverageR.}$	5.61	–	1.40	6.40
σ_{Spread}	0.08	–	0.07	0.23
$\rho_{Y,Assets}$	0.30	–	0.90	0.88
$\rho_{Y,Deposits}$	-0.39	–	0.46	-0.23
$\rho_{Y,NetWorth}$	0.52	–	0.87	0.68
$\rho_{Y,LeverageR.}$	-0.49	–	-0.71	-0.59
$\rho_{Y,Spread}$	-0.39	–	-0.86	-0.67

[a] Business cycle statistics in the table are based on HP-filtered cyclical components of quarterly simulated time series (smoothing parameter:1600).
[b] The standard deviation of output is expressed in percent; standard deviations of the remaining variables are normalized by the standard deviation of output (std(x)/std(GDP)).
[c] In all model economies, capital adjustment cost parameter is set to 3.3, which is calibrated in benchmark model to match the relative volatility of price of investment.

Column 5 of the table shows the real and financial statistics in the benchmark economy driven by both shocks. This model is even closer to the data than the previous model in terms of business cycle properties of real variables. It predicts all of the fluctuations in output, almost all of the relative volatility in hours. The cross correlations of investment and hours with output are quite inline with the data.

However, the model generates acyclical consumption due to the reasons explained in the previous section. This model has better predictions about financial variables. It is able to reproduce the key facts about aggregate financial variables. Moreover, it now explains more than half of the relative volatility in bank assets, and somewhat overpredicts the relative volatility in other financial variables. The last column of Table 1 establishes the first main result of the first chapter: the benchmark model driven by both shocks is able to deliver most of the key stylized facts about real and financial variables *simultaneously.*

1.5 Model-Based Simulations of Macro-Financial Shocks vs. U.S. Data

I also study the dynamics of the model in response to the actual sequence of shocks to see whether the model is able to generate the real and financial cycles observed in the U.S. data.[33] I feed the actual innovations to z_t and ω_t into the model and compute the responses of real and financial variables over the period 1987 to 2010.

Figure 1.6 displays the quarterly time series of output, investment and hours in the data, in the standard RBC model with capital adjustment costs, and in the benchmark economy. The RBC model is driven by standard productivity shocks, while the benchmark model is driven by both shocks. Both the quarterly times se-

---

[33]Although I feed the actual series of shocks into the model, they are not perfectly anticipated by the agents in the economy as they predict future values of z_t and ω_t using the AR(1) processes given by (1.53) and (1.54).
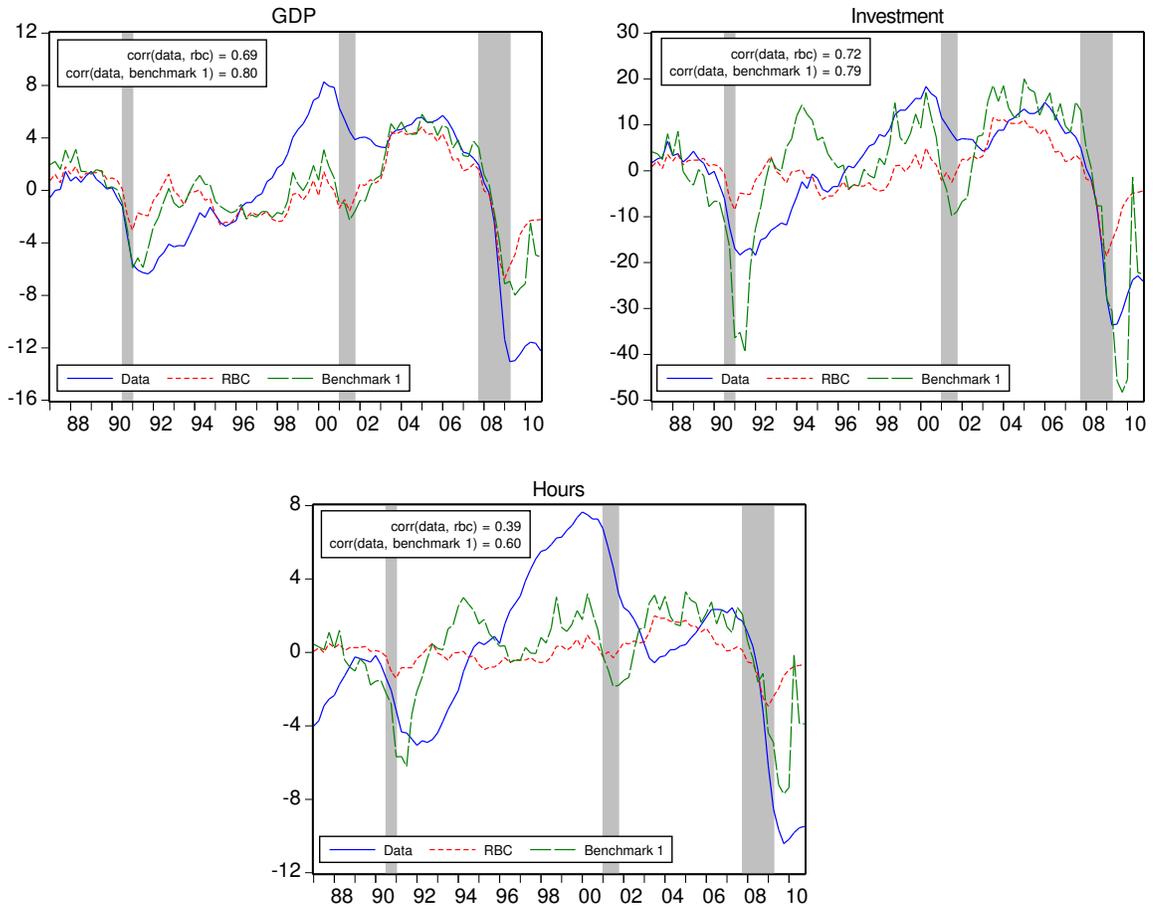
Figure 1.6: Real Fluctuations: Benchmark vs. RBC model

47

ries of the variables and their model counterparts are log-linearly detrended over the period 1987.Q1 - 2010.Q4, and plotted in percentage deviations from their trends. The correlations between the actual and the model-simulated series are also reported in the graphs. The figure suggests that both the RBC model and the benchmark economy generate series of real variables that closely follow their empirical counterparts. However, the RBC model predicts lower fluctuations in all real variables. In particular, the RBC model predicts a smaller decline in output in the 1990-91 recession. Moreover, it generates declines in investment and hours that are smaller than the actual declines in the 1990-91 and 2007-09 recessions. On the other hand, the benchmark model generates larger fluctuations in real variables, consistent with the data. Since this model has one additional shock compared to the RBC model, higher volatility can be expected. However, the benchmark model also improves upon the RBC model in the sense that for output, investment and hours, the cross-correlations between the data and the benchmark model is much higher than those between the data and the RBC model. Moreover, the model's success in generating empirically-relevant fluctuations in hours hinges on the fact that it is able to produce quantitatively reasonable fluctuations in capital. Since labor is complementary to capital stock in a standard Cobb-Douglas production function, empirically-relevant changes in capital stock lead to observed fluctuations in hours. The second dimension that the benchmark model improves upon the RBC model is that the latter has no predictions about financial variables by construction while the former generates movements in financial variables consistent with the U.S. financial data.

Figure 1.7 displays the quarterly time series of output, investment and hours
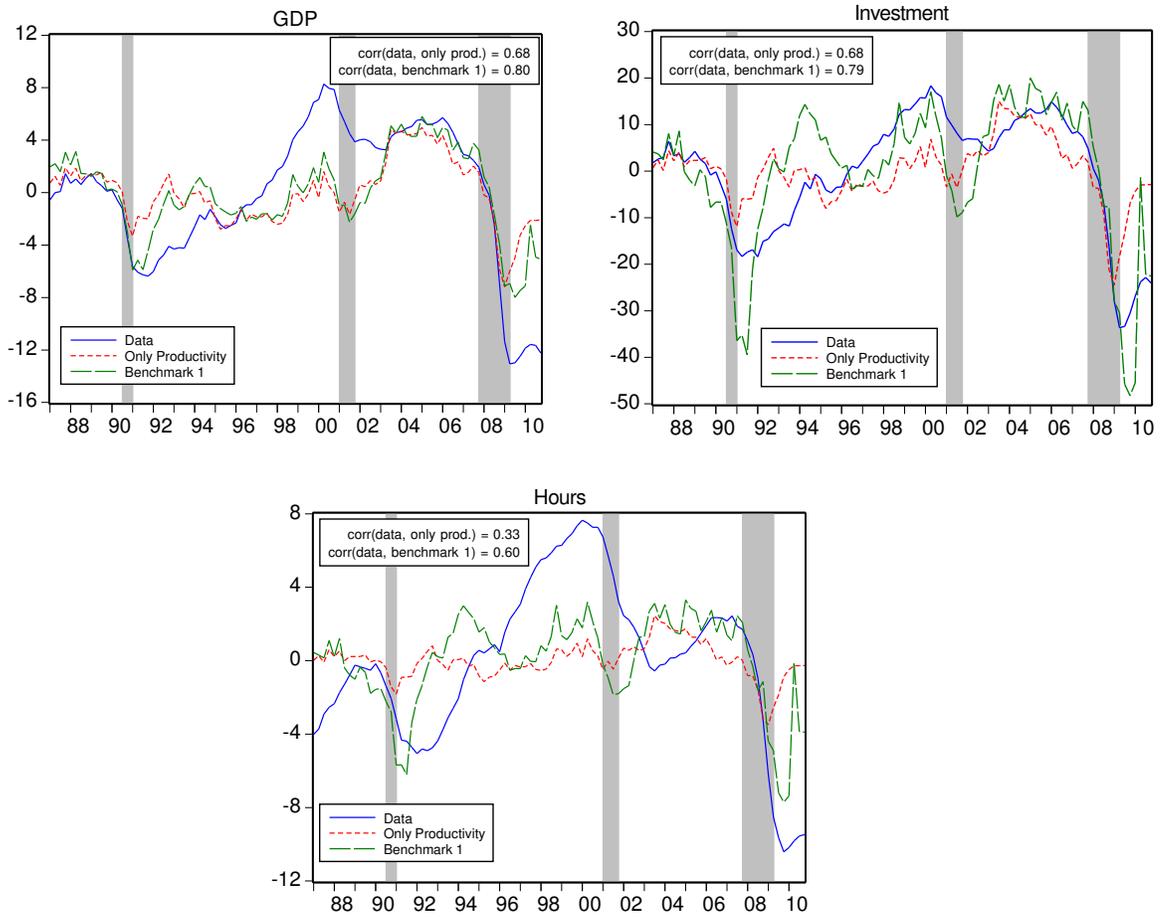
Figure 1.7: Real Fluctuations: Benchmark vs. Only Productivity
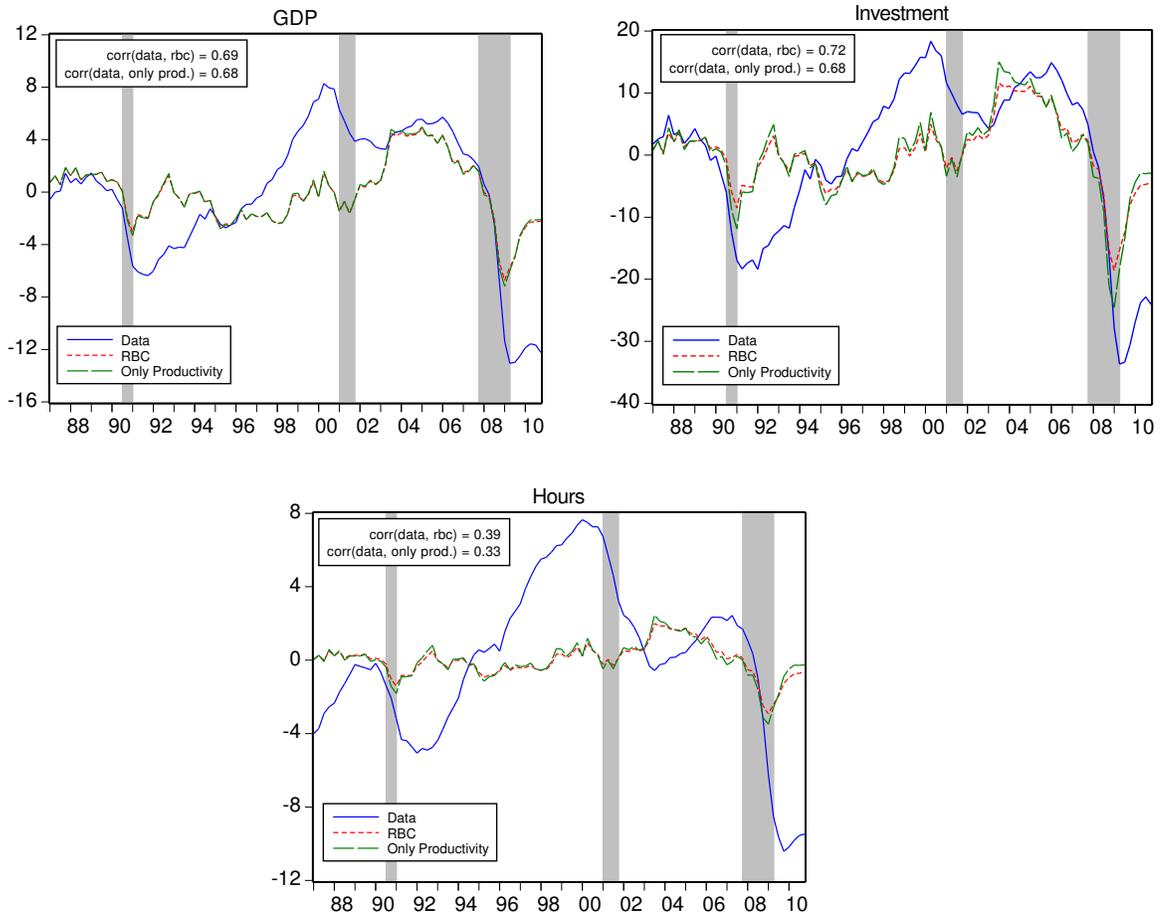
Figure 1.8: Real Fluctuations: RBC vs. Only Productivity

in the data, in the model driven only by productivity shocks, and in the benchmark economy. The figure suggests that the benchmark economy performs better than the model with only productivity shocks in terms of both volatilities of real variables and cross-correlations of those variables with the data. For all the real variables, the cross-correlations with the data in the benchmark model is higher than those with the data in the model with only productivity shocks.

Figure 1.8 displays the quarterly time series of output, investment and hours in the data, in the RBC model, and in the model driven only by productivity shocks. This figure suggests that the model with only productivity shocks is not

very different from the RBC model in terms of its quantitative performance in real variables. Actually, the series of real variables generated by these two models are almost the same. Therefore, we can say that credit frictions in banking sector by themselves are not enough to improve upon the RBC model and to produce real fluctuations consistent with the data. Financial shocks are quite important in explaining the observed dynamics of real variables.

Figure 1.9 shows the quarterly time series of bank credit, deposits, net worth, leverage ratio, and credit spread both in the data, in the model driven only by productivity shocks and in the benchmark model. Both the quarterly time series of financial variables and their model counterparts are log-linearly detrended over the period 1987.Q1 - 2010.Q4, and plotted in percentage deviations from their trends. Credit spread is plotted in annualized percentages. The correlations between the actual and the model-simulated series are also reported in the graphs. For all the financial variables, the cross-correlations with the data in the benchmark model is significantly higher than those with the data in the model with only productivity shocks. Specifically, for net worth, leverage ratio and credit spread, the benchmark model produces highly positively correlated series with the data, while the model with only productivity shocks predicts negative correlations. Thus, figures 1.7 and 1.9 establish the second main result of the chapter that financial shocks contribute significantly to explaining the observed dynamics of financial variables.

Figure 1.10 plots the fluctuations in the Lagrange multiplier of bank capital constraint in the benchmark model and those in the index of credit tightness constructed by Federal Reserve Board using the Senior Loan Officer Opinion Survey
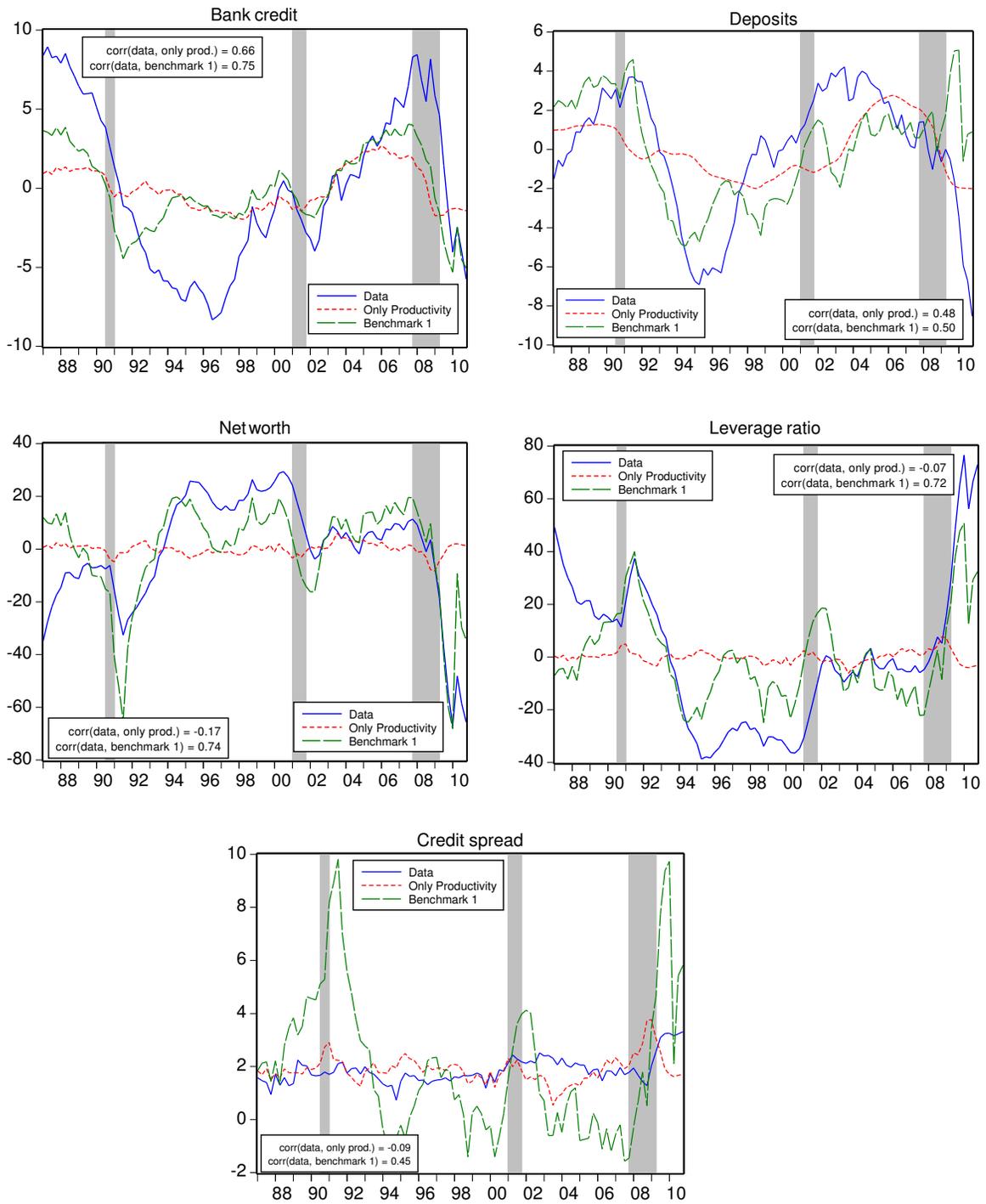
Figure 1.9: Financial Fluctuations: Benchmark vs. Only Productivity
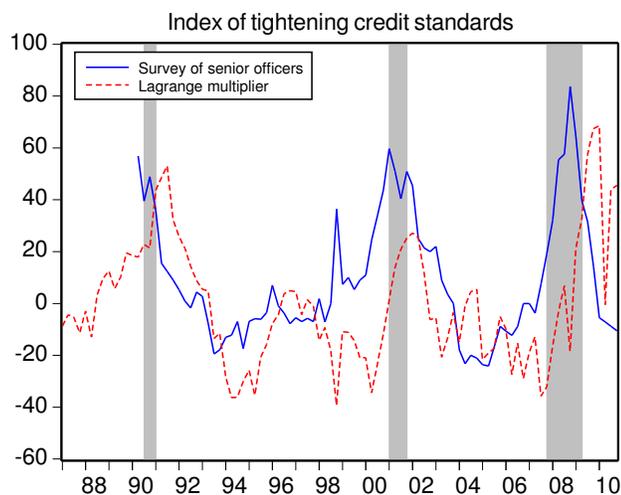
Figure 1.10: Tightness of Credit Conditions in the Benchmark Model

on Bank Lending Practices. Starting with the second quarter of 1990, this survey basically asks senior loan officers whether they have recently tighten the credit standards for commercial and industrial loans, and the collected responses are used to create an index of credit tightness as the percentage of respondents, reporting tightening standards. Increases in both the multiplier and the index show the adverse changes in bank lending to non-financial businesses. The figure shows that the multiplier tracks the index well. The multiplier also explains the severity of credit conditions experienced by the U.S. economy in the last three recessions by capturing most of the fluctuations in the index. However, there seems to be a phase shift between these two series.[34] There might be two reasons behind this. The first one is the inability of standard RBC models to match the lead-lag relationships of macro variables. The second one is using lagging financial variables from H.8 tables

---

[34]If I use loan losses data to construct the financial shock series, there is no phase shift in the tightness of credit conditions.

while constructing financial shocks rather than using leading financial variables from Consolidated Reports of Condition and Income (Call) Reports. Bearing this caveat in mind, we can say that figure 1.10 establishes the third main result of this chapter: U.S. banks experienced a significant deterioration in their lending ability in the last recessions, especially in 1990-91 and 2007-09 recessions.

1.6 Conclusion

This study quantitatively investigates the joint role of financial shocks and credit frictions affecting banking sector in driving the real and financial fluctuations in the U.S. data. To this end, I first characterize the empirical cyclical behavior of aggregate financial variables of U.S. banking sector. I then use an otherwise standard real business cycle model with a financial sector, which features an agency problem between banks and their depositors, leading to endogenous borrowing constraints for banks in obtaining funds from households. I incorporate empirically-disciplined shocks to bank net worth (i.e. "financial shocks") which affect the ability of banks to obtain funds from households and to extend credit to non-financial sector.The time series of financial shocks are constructed from the data. The resulting shock series show that credit conditions in the U.S. economy deteriorated significantly in the recent recession.

Several key findings emerge from the quantitative analysis. First, the benchmark model driven by both productivity and financial shocks is able to explain most of the empirical facts about real and financial variables simultaneously. Sec-

ond, financial shocks to banking sector contribute significantly not only to the observed dynamics of aggregate financial variables but also to the observed dynamics of standard macroeconomic variables. In particular, the benchmark model has better predictions about real and financial variables than the model driven only by productivity shocks. Third, the simulation of the benchmark model points a significant worsening in banks' lending ability in 1990-91 and 2007-09 recessions. The main transmission mechanism of financial shocks is through bank capital channel. In particular, financial shocks are transmitted to the real economy through tightening bank capital constraint, which eventually leads to rising credit spread. Non-financial firms perceive this rise in credit spread as an increase in their cost of borrowing from banks, leading to a decline in their external finance for investment expenditures. Falling aggregate demand caused by lower investment reduces the demand for labor, which brings a drop in hours worked, and hence output.

For further research, one can investigate the normative implications of the model in the light of the recent financial crisis, as U.S. government has assisted many financial firms in order to raise their franchise value, and hence to support real economic activity. In order to start thinking about how different policy tools can be implemented in an environment in which the financial sector is crucial for business cycle fluctuations and what the welfare implications of these policies are, we need a model capable of matching real and financial fluctuations simultaneously. We think that the model proposed in this study is quite successful in this dimension.

Chapter 2

Required Reserves as a Credit Policy Tool

(*joint with Enes Sunel and Temel Taşkın*)

2.1 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. For example, the Central Bank of the Republic of Turkey (CBRT, hereafter) regards the interest rate as the main policy tool for price stability, with a secondary role for financial stability, and reserve requirements as the main policy tool for financial stability, with a secondary role

---

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

for price stability.[2] The main idea behind using reserve requirements as the main instrument for financial stability and interest rate as the main instrument for price stability might be to separate tasks, which increases transparency and facilitates communication of these policies. In this regard, this study explicitly focuses on the financial stability of reserve requirements.

Central banks could 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.[3]

---

[2]Basci (2010).

[3]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

TL Required Reserve Ratios (RRR) (%)
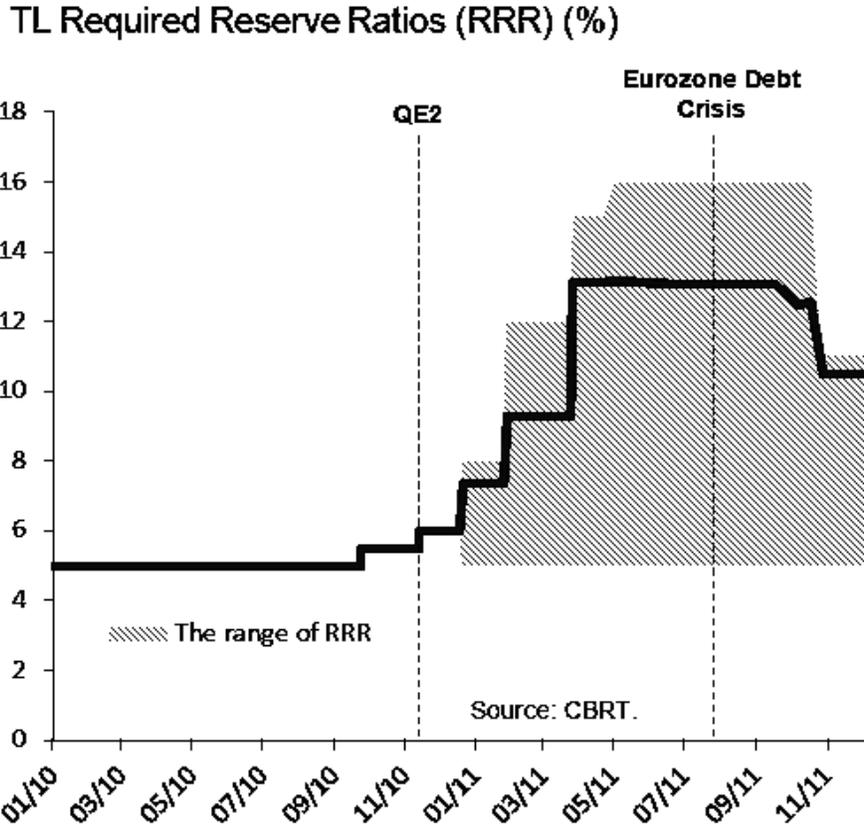
Figure 2.1: Evolution of Required Reserve Ratios in Turkey

We extend the basic financial intermediation framework to one in which "money" is explicitly modelled via a cash-in-advance constraint. Consequently, we introduce required reserves into the model in a very tractable way, since we have the concept of a monetary base.

After the mid of 2010, the CBRT has determined two policy targets in order to mitigate macro-financial imbalances in Turkish economy as Basci and Kara (2011) elaborated. The first one is to reduce short-term capital inflows to lower current account deficit, and the second one is to curb excessive credit growth in banking

any micro-foundation to this institutional framework in what follows.

58

sector. In this regard, it was decided that in addition to short-term interest rate, reserve requirements and interest rate corridor are used to foster financial stability without compromising price stability. Moreover, in order to increase the effectiveness of reserve requirements as a policy tool, the CBRT let the interest rate fluctuate in a controlled manner at overnight market to use interest rate corridor as an active policy instrument and terminated paying interest on required reserves by September 2010. It also differentiated required reserves at different maturities (having a higher required reserve ratio for short-term liabilities) and hence extended the maturity of banking sector's liabilities in order to strengthen financial stability.

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 2.1). In particular, the CBRT 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 countercycli-

cal with respect to expected credit growth.[4] We approximate the required reserves policy implemented by the CBRT with this countercyclical rule since the CBRT officials and economists stated that it used the reserve requirements to curb excessive credit growth in the banking sector after the second phase of quantitative easing conducted by many advanced economies' central banks and to ease credit conditions in the banking sector after the Eurozone debt crisis.[5] Moreover, we model the rule as the one which reacts to expected credit growth in order to reflect the CBRT's incentive to use this policy tool proactively and in a macroprudential and forward-looking manner.[6] 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 this study: First, the time-varying required reserve ratio rule mitigates 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

---

[4]We also conduct the analysis of a model economy with zero required reserves policy. The dynamics of this case strongly resemble those of the fixed RRR economy.

[5]Basci and Kara (2011) and Kara (2012).

[6]The results seem quite similar if the rule responds to current credit growth. The main idea behind this rule is to reduce the procyclicality of the banking sector in the face of adverse macro shocks and hence to stabilize the real economy.

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 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

63

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 work to the current study is that of Christensen et al. (2011) which explores the role of countercyclical bank capital regulations as a macro-prudential 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 study.

The rest of the paper is organized as follows. Section 2.2 describes the model economy and characterizes equilibrium. Section 2.3 undertakes the quantitative analysis regarding the dynamics introduced by macroeconomic and financial shocks and section 2.4 concludes.

2.2 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.

2.2.1 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.[7]

A representative household maximizes the discounted lifetime utility flow earned

---

[7]This assumption is useful in making the agency problem that we introduce in section 2.2.2 more realistic.

from consumption, c_t and leisure, l_t,

$$E_0 \sum_{t=0}^{\infty} \beta^t u\left(c_t, l_t\right) \qquad (2.1)$$

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

$$c_t + b_{t+1} + \frac{M_{t+1}}{P_t} = w_t(1 - l_t) + R_t b_t + \frac{M_t}{P_t} + \Pi_t + \frac{T_t}{P_t} \qquad (2.2)$$

where b_t is the beginning of period t balance of deposits held at commercial banks, P_t is the general nominal price level, w_t is the real wage earned per labor hour, R_t is the 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):

$$c_t \leq \frac{M_t}{P_t} + \frac{T_t}{P_t} + R_t b_t - b_{t+1} \qquad (2.3)$$

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

67

$$u_c(t) = \beta R_{t+1} E_t u_c(t+1) \tag{2.4}$$

$$\frac{u_l(t)}{P_t w_t} = \beta E_t \left\{ \frac{u_c(t+1)}{P_{t+1}} \right\} \tag{2.5}$$

Condition (2.4) is a standard consumption-savings optimality condition, which equates marginal benefit of current consumption to the expected discounted benefit of saving in deposits. Equation (2.5) 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 today 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.

2.2.2 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,

$$q_t s_{jt} = (1 - rr_t) b_{jt+1} + n_{jt} \tag{2.6}$$

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 (2.6) imply an evolution equation for net worth as follows:

$$n_{jt+1} = \left[R_{kt+1} - \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) \right] q_t s_{jt} + \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) n_{jt} \qquad (2.7)$$

It is evident in equation (2.7) 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. 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,

69

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

$$(2.8)$$

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,

$$V_{jt} \geq \lambda q_t s_{jt} \tag{2.9}$$

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

$$V_{jt}^* = \nu_t q_t s_{jt}^* + \eta_t n_{jt}^*$$ (2.10)

where the recursive objects,[8]

$$\nu_t = E_t \left\{ (1 - \theta)\beta\Lambda_{t,t+1} \left[R_{kt+1} - \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) \right] + \theta\beta\Lambda_{t,t+1}\chi_t\nu_{t+1} \right\}$$ (2.11)

and

$$\eta_t = E_t \left\{ (1 - \theta)\beta\Lambda_{t,t+1} \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) + \theta\beta\Lambda_{t,t+1}\varrho_t\eta_{t+1} \right\}$$ (2.12)

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 (2.9) and (2.10):

$$\nu_t q_t s_{jt} + \eta_t n_{jt} \geq \lambda q_t s_{jt}$$ (2.13)

The above constraint binds only if $0 < \nu_t < \lambda$. This happens because $\eta_t n_{jt}$ is greater than zero. If $\nu_t \geq \lambda$, then left hand side would be strictly greater than right

---

[8]Proofs of equations (2.10), (2.11), and (2.12) are available in technical appendix upon request.

hand side in equation (2.13). Under plausible values of parameters, this constraint always binds in equilibrium, which in turn produces the endogenous borrowing constraint for the bank as follows:

$$q_t s_{jt} = \frac{\eta_t}{\lambda - \nu_t} n_{jt} = \kappa_t n_{jt}. \tag{2.14}$$

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

Due to the fact that κ_t does not depend on j, one can aggregate equation (2.14) and obtain the following aggregate relationship:

$$q_t s_t = \kappa_t n_t \tag{2.15}$$

where s_t and n_t represent aggregate levels of banks' assets and net worth, respectively.

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}):

$$n_{t+1} = n_{et+1} + n_{nt+1}. \tag{2.16}$$

The net worth of new entrants is defined as an ϵ fraction of banks' aggregate net worth, that is:[9]

$$n_{nt+1} = \epsilon n_t \tag{2.17}$$

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

$$n_{et+1} = \theta \left\{ \left[R_{kt+1} - \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) \right] \kappa_t + \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) \right\} n_t \tag{2.18}$$

One can sum up equations (2.17) and (2.18) to obtain the evolution of net worth for the entire set of banks:

$$n_{t+1} = \left\{ \theta \left(\left[R_{kt+1} - \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) \right] \kappa_t + \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) \right) + \epsilon \right\} n_t \tag{2.19}$$

Equation (2.19) shows that the evolution of net worth depends on effective spread and leverage ratio of banks.

---

[9]This assumption is slightly different from that in Gertler&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 study significantly.

2.2.3 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

$$y_t = exp(z_t)F(k_t, h_t) \tag{2.20}$$

where

$$z_{t+1} = \rho_z z_t + \epsilon_{zt+1} \tag{2.21}$$

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

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

$$q_t s_t = q_t k_{t+1} \tag{2.22}$$

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

$$R_{kt} = \frac{z_t F_k(k_t, h_t) + q_t(1-\delta)}{q_{t-1}} \tag{2.23}$$

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

$$w_t = exp(z_t)F_h(k_t, h_t) \tag{2.24}$$

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

2.2.4 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,

$$\max_{i_t} q_t k_{t+1} - q_t(1 - \delta)k_t - i_t \tag{2.25}$$

subject to the capital accumulation technology,

$$k_{t+1} = (1 - \delta)k_t + \Phi\left(\frac{i_t}{k_t}\right)k_t \tag{2.26}$$

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,

$$q_t = \left[\Phi'\left(\frac{i_t}{k_t}\right) \right]^{-1} \tag{2.27}$$

2.2.5 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,

$$M_{0t+1} = exp(\mu_t)M_{0t} \tag{2.28}$$

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

$$\mu_{t+1} = (1 - \rho_\mu)\bar{\mu} + \rho_\mu\mu_t + \epsilon_{\mu t+1} \tag{2.29}$$

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.[10]

$$rr_t = \bar{rr} + \phi E_t \left[\log(q_{t+1}s_{t+1}) - \log(q_t s_t) \right] \tag{2.30}$$

---

[10]We also consider a rule which reacts to current credit growth rather than expected future credit growth. The main results of the study remain unchanged as can be seen from Appendix B.2.

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. The government budget constraint is given by

$$T_t = M_{t+1} - M_t + P_t rr_t b_{t+1} - P_t rr_{t-1} b_t \qquad (2.31)$$

The government uses the seignorage revenue plus the increases in its reserves to finance the lump-sum transfer payments to households, which include both workers and bankers.[11] Within this framework, the money market equilibrium turns out as the following condition:

$$M_{0t+1} = M_{t+1} + P_t rr_t b_{t+1} \qquad (2.32)$$

where P_t is the general price level of the consumption good. The money supply equals to the currency demand by workers plus the reserve demand by bankers. 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. That being said, we also want to emphasize the fact that flexible-price models are not good models in explaining the dynamics of inflation. The only reason to talk about inflation dynamics here is to show that using reserve requirements leads to a possibly interesting trade-off between price stability and financial stability faced

---

[11]The lump-sum transfer payments to the households equals to the change in money demand by workers plus the change in reserves demand by bankers.

by many emerging market central banks recently. To be precise, this trade-off is to reduce the intertemporal distortions created by the credit spread at the expense of generating higher inflation volatility.

2.2.6   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 $\{c_t, k_{t+1}, i_t, l_t, h_t, s_t, n_t, n_e t, n_n t, b_{t+1}, \Lambda_{t,t+1}, \nu_t, \eta_t, \kappa_t, \rho_{t,t+1}, \chi_{t,t+1}, \hat{m}_{t+1}, \pi_t\}_{t=0}^{\infty}$, 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:

$$\Lambda_{t,t+1} = \frac{u_c(t+1)}{u_c(t)} \tag{2.33}$$

$$1 = \beta E_t R_{t+1} \Lambda_{t,t+1} \tag{2.34}$$

$$c_t = \frac{exp(\mu_t) - 1 + \hat{m}_t \widehat{P}_t}{\widehat{P}_t exp(\mu_t)} + R_t b_t - b_{t+1} \tag{2.35}$$

$$\frac{u_l(t)}{w_t \hat{P}_t} = \beta E_t \left\{ \frac{u_c(t+1)}{\hat{P}_{t+1} exp(\mu_{t+1})} \right\} \tag{2.36}$$

$$\kappa_t = \frac{\eta_t}{\lambda - \nu_t} \tag{2.37}$$

$$q_t s_t = \kappa_t n_t \tag{2.38}$$

$$q_t s_t = (1 - rr_t)b_{t+1} + n_t \tag{2.39}$$

$$\varrho_{t,t+1} = \left(R_{kt+1} - \frac{R_{t+1} - rr_t}{1 - rr_t} \right)\kappa_t + \frac{R_{t+1} - rr_t}{1 - rr_t} \tag{2.40}$$

$$\chi_{t,t+1} = \varrho_{t,t+1}\frac{\kappa_{t+1}}{\kappa_t} \tag{2.41}$$

$$n_{et} = \theta\varrho_{t-1,t}n_{t-1} \tag{2.42}$$

$$n_{nt} = \epsilon n_{t-1} \tag{2.43}$$

$$n_t = n_{et} + n_{nt} \tag{2.44}$$

$$\nu_t = E_t \left\{ (1-\theta)\beta\Lambda_{t,t+1} \left(R_{kt+1} - \frac{R_{t+1} - rr_t}{1 - rr_t} \right) + \beta\Lambda_{t,t+1}\theta\chi_{t,t+1}\nu_{t+1} \right\} \qquad (2.45)$$

$$\eta_t = E_t \left\{ (1-\theta)\beta\Lambda_{t,t+1} \left(\frac{R_{t+1} - rr_t}{1 - rr_t} \right) + \beta\Lambda_{t,t+1}\theta\varrho_{t,t+1}\eta_{t+1} \right\} \qquad (2.46)$$

$$w_t = exp(z_t)F_h(k_t, h_t) \qquad (2.47)$$

$$R_{kt} = \frac{exp(z_t)F_k(k_t, h_t) + q_t(1-\delta)}{q_{t-1}} \qquad (2.48)$$

$$k_{t+1} = (1-\delta)k_t + \Phi\left(\frac{i_t}{k_t}\right)k_t \qquad (2.49)$$

$$q_t = \left[\Phi'\left(\frac{i_t}{k_t}\right)\right]^{-1} \qquad (2.50)$$

$$exp(z_t)F(k_t, h_t) = c_t + i_t \qquad (2.51)$$

$$s_t = k_{t+1} \qquad (2.52)$$

$$1 = l_t + h_t \qquad (2.53)$$

$$exp(\pi_t) = exp(\mu_t)\frac{\widehat{P_t}}{\widehat{P_{t-1}}} \tag{2.54}$$

$$z_{t+1} = \rho_z z_t + \epsilon_{zt+1} \tag{2.55}$$

$$\mu_{t+1} = (1 - \rho_\mu)\bar{\mu} + \rho_\mu \mu_t + \epsilon_{\mu t+1} \tag{2.56}$$

$$rr_t = \bar{rr} + \phi E_t \left[\log(q_{t+1}s_{t+1}) - \log(q_t s_t)\right] \tag{2.57}$$

$$\frac{1}{\widehat{P_t}} = \hat{m}_{t+1} + rr_t b_{t+1} \tag{2.58}$$

2.3 Quantitative Analysis

2.3.1 Functional Forms

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

$$u(c_t, l_t) = \frac{c_t^{1-\gamma}}{1-\gamma} - \psi\frac{h_t^{1+\nu}}{1+\nu} \tag{2.59}$$

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

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

production function:

$$exp(z_t)F(k_t, h_t) = exp(z_t)k_t^\alpha h_t^{1-\alpha} \tag{2.60}$$

with $0 < \alpha < 1$.

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

$$\Phi\left(\frac{i_t}{k_t}\right) = \frac{\varphi}{2}\left[\frac{i_t}{k_t} - \delta\right]^2 \tag{2.61}$$

The parameter values used in the quantitative analysis are reported in Table 2.1. 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, $\overline{L}$, 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 aggregate net

Table 2.1: Paremeter Values in the Benchmark Model

Description	Value	Target
Preferences		
Quarterly discount factor (β)	0.9885	Annualized real deposit rate (4.73%)
Relative utility weight of consumption (γ)	2	
CRRA parameter in the utility (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 $\log \Delta M1_t = \rho_\mu \log \Delta M1_{t-1} + \epsilon_{\mu t}$
Std. deviation of money growth shocks (σ_μ)	0.0275	

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.[12]

---

[12]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

The resulting values for λ and θ are 0.5 and 0.962, respectively. The benchmark model involves the macroprudential policy rule illustrated in equation (2.30) which does not alter the steady state of the model but affects the dynamics around it. We calibrate the response parameter of the RRR rule ϕ to 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.

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 using M1 series, following Cooley and Hansen (1989).[13] 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.

ratio in practice.

[13]The choice of estimation period reflects the structural disinflation that the Turkish economy has experienced, see Sunel (2011). Moreover, we also estimated an AR(1) for the money growth process using M0 series. The parameters of the process are quite similar.

2.3.2   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 2.2. 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.[14]

2.3.2.1   Amplifying Effect of Financial Frictions

The dashed plots in figures 2.2 and 2.3 represent the monetary economy that exhibits financial accelerator mechanism and the straight plots represent the cash-in-advance model with no financial frictions. Required reserves ratio in the former economy is set to zero to isolate the impact of financial frictions.

Figure 2.2 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

---

[14]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.
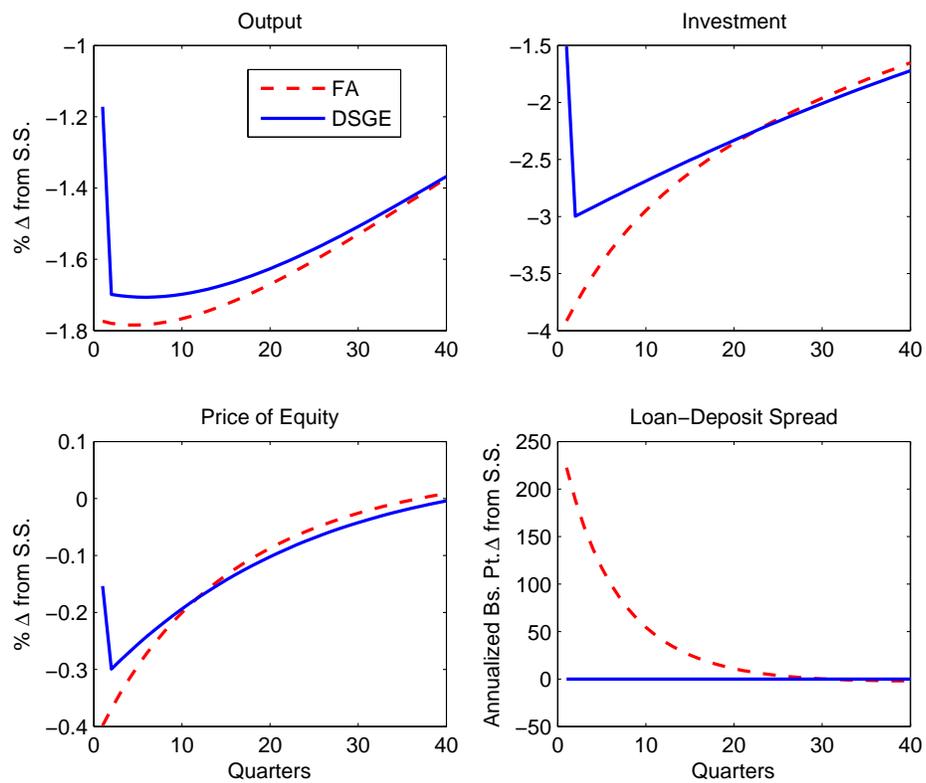
Figure 2.2: Negative Productivity Shocks
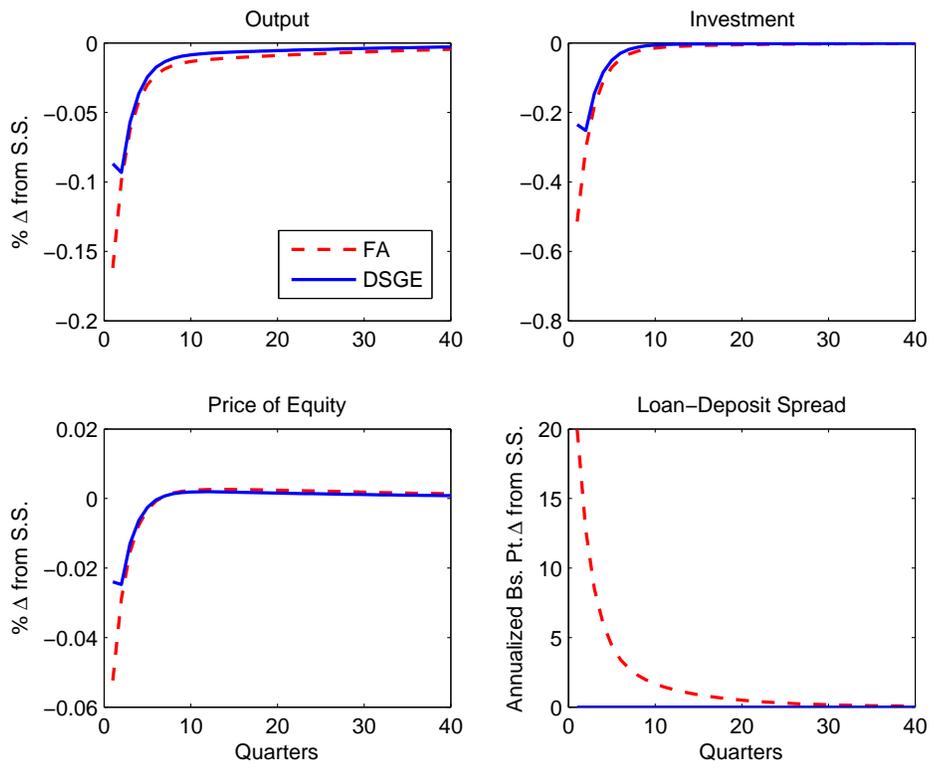
Figure 2.3: Positive Money Growth Shocks

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.

Figure 2.3 illustrates the dynamics in response to a positive money growth shock. An important feature of this cash-in-advance economy is that as equations (2.3) (with equality) and (2.5) illustrate, investment and leisure are cash and credit goods, 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.

We now analyze the implications of the RRR policy on the dynamics of real, financial, and monetary variables. In figures 2.4 and 2.5, we compare the dynamics of these variables in response to one standard deviation negative TFP and positive money growth shocks. In figure 2.6 we explore the implications of RRR policy on the dynamics model variables in a financial crisis scenario. The specific financial disruption is a balance sheet shock that bankers face as in mostly recent literature.[15]

_____

[15]Hancock, Laing and Wilcox (1995), Meh and Moran (2010), Brunnermeier and Pedersen

In figures 2.4 to 2.6, 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.[16] 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.[17]

(2009), Curdia and Woodford (2010), Mendoza and Quadrini (2010), Iacoviello (2010), and Mimir (2011).

[16]The dynamics of the economy with no reserves can be found in Appendix B.3.

[17]Charts regarding policy intensity experiments can be found in Appendix B.4.
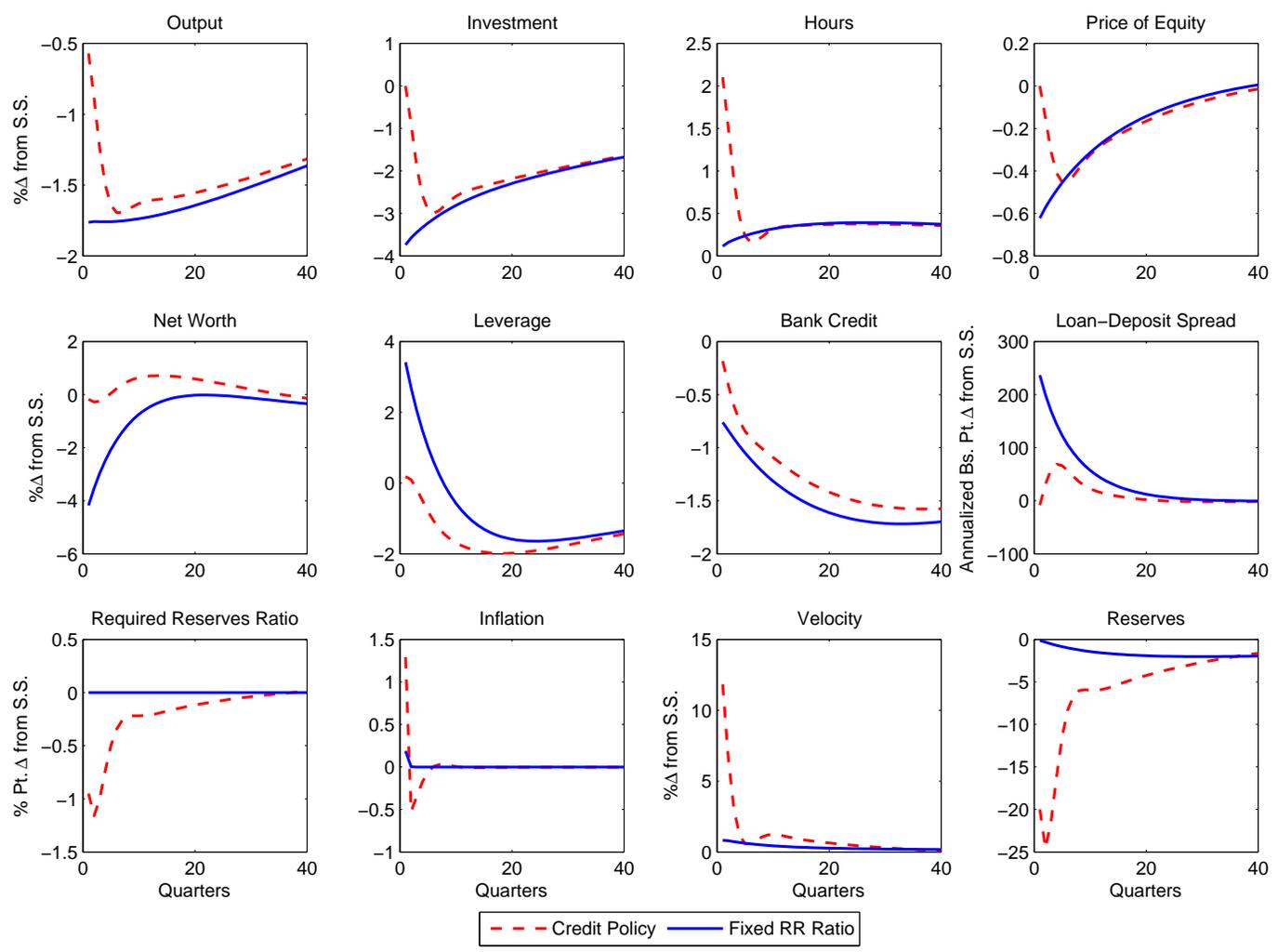
Figure 2.4: Impulse Responses Led by a 1-σ Adverse TFP Shock

2.3.2.2 Impulse Responses to TFP Shocks

The general observation that emerges from figure 2.4 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 2.4 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 (2.15). The decline in net worth in accordance with the decline in deposits downsizes the total financing for non-financial firms (see figure 2.4). 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 2.4). 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 2.4) 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 2.4). 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 2.4). 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 compared to 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 2.4. Consistent with these findings, real balances demand 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, we obtain the interesting result that 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.
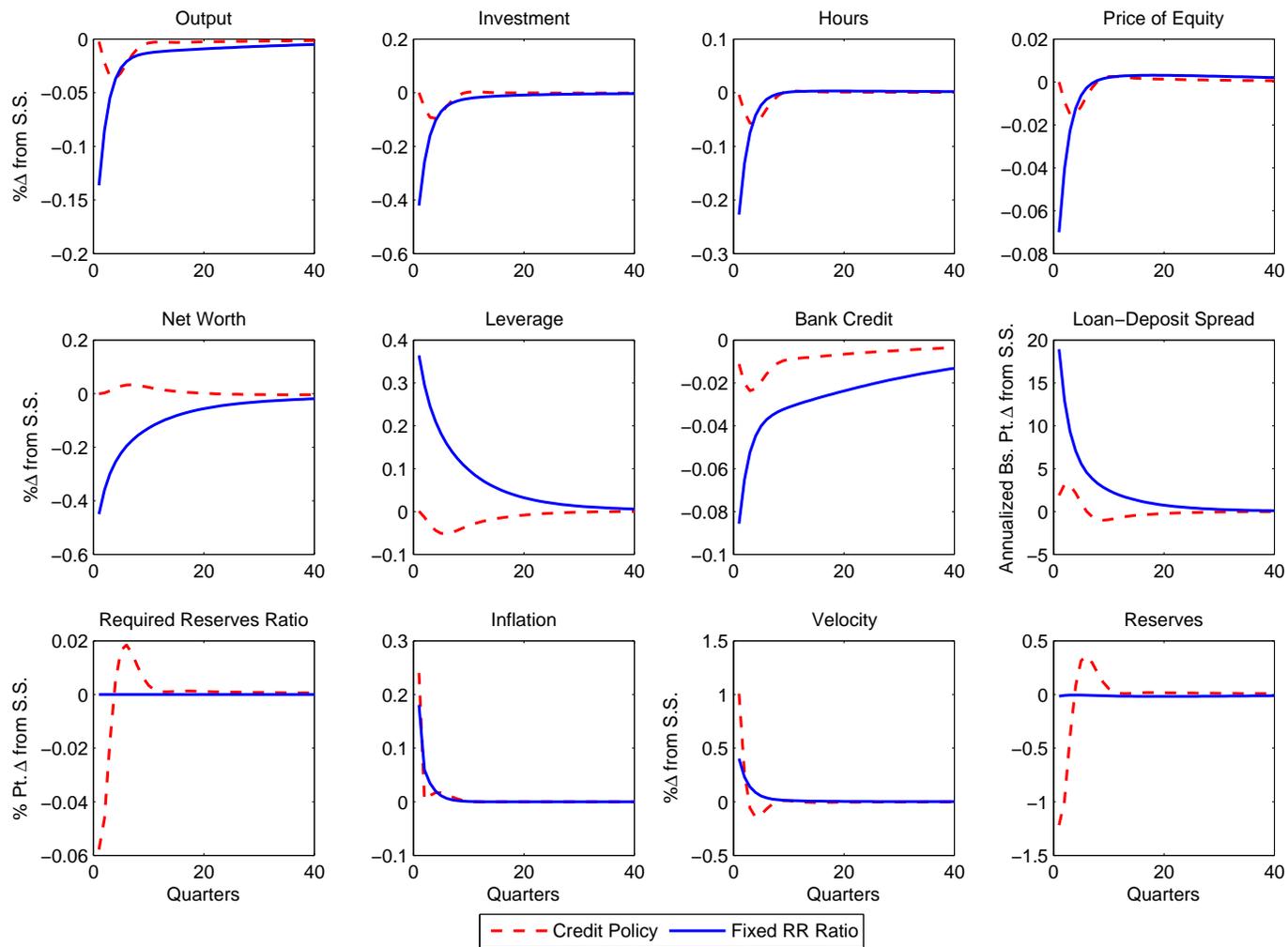
Figure 2.5: Impulse Responses Led by a 1-σ Adverse Money Growth Shock

2.3.2.3 Impulse Responses to Money Growth Shocks

In this section, we analyze the dynamics of model economies in response to a one-standard deviation positive money growth shock. Figure 2.5 displays the impulse responses of key real, financial and monetary variables. 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), which is modified to cover bank deposits in the cash-in-advance constraint. 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 (2.3) and (2.5). 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 2.5). 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.
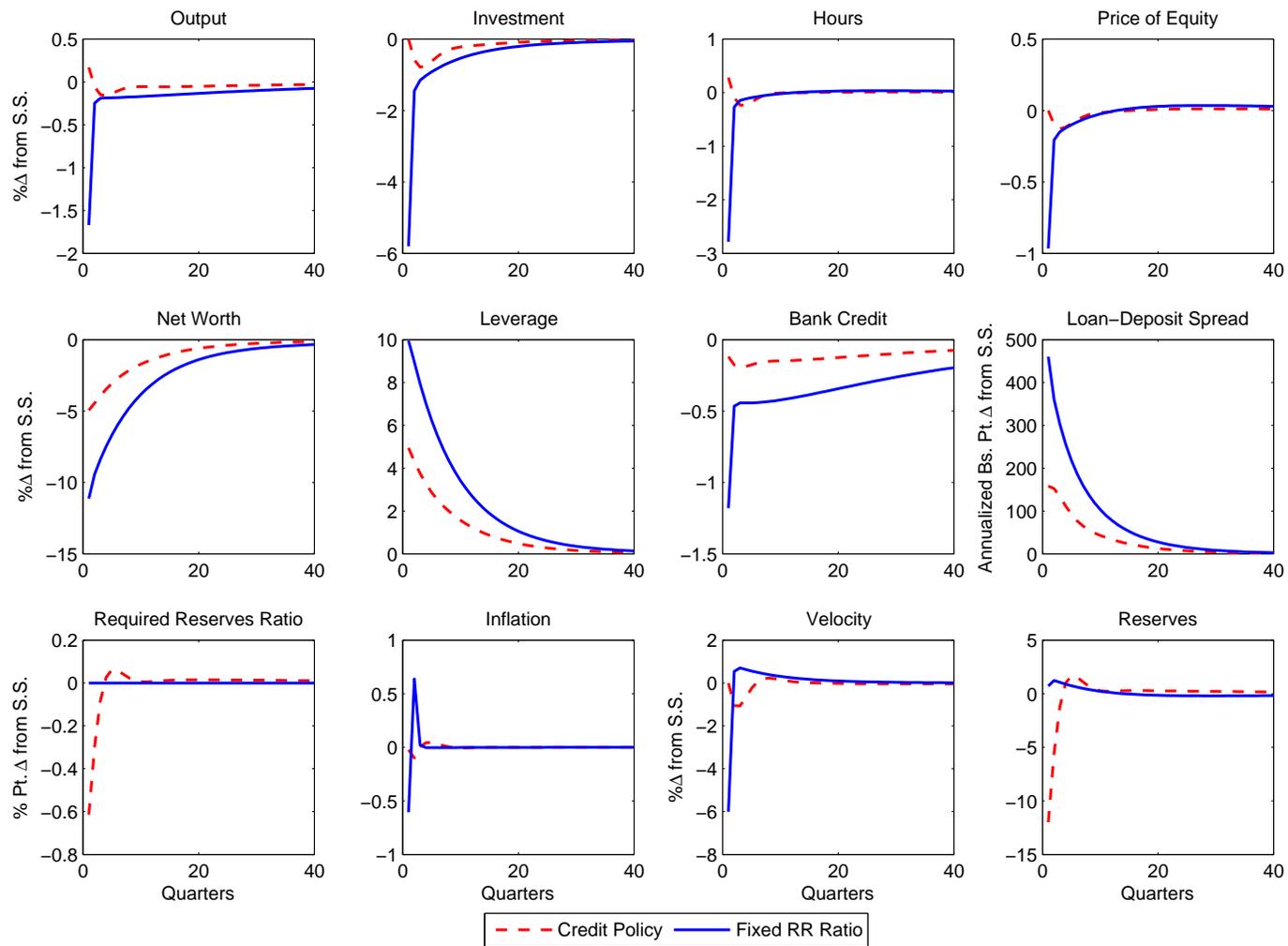
Figure 2.6: Impulse Responses Led by a 1-σ Adverse Financial Shock

2.3.2.4   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 Introduction, it might be though 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 2.6 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 2.6). 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 2.6). 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 2.6).

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 how

much it declines 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.

2.3.2.5 Effects of Time-Varying RRR Policy on Volatilities

Table 2.2 below 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 aggressive, inflation volatility gets higher.

Table 2.2: 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

2.3.2.6 Credit Policy and Welfare

Consider the time-varying reserve requirement policy, denoted by trp, and the fixed reserve requirement policy, denoted by frp. 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

$$V_0^{trp} = E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^{trp}, l_t^{trp}) \tag{2.62}$$

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

$$V_0^{frp} = E_0 \sum_{t=0}^{\infty} \beta^t U(c_t^{frp}, l_t^{frp}), \tag{2.63}$$

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

$$V_0^{trp} = E_0 \sum_{t=0}^{\infty} \beta^t U\left((1+\lambda^c)c_t^{frp}, l_t^{frp}\right) \tag{2.64}$$

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:

$$V_{0,t} = U(c_t, l_t) + \beta E_t V_{0,t+1}. \tag{2.65}$$

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

$$V_{0,t} = \overline{V_0} + \frac{1}{2}\Delta(V_0) \tag{2.66}$$

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 (2.66) 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 0.05% 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.

2.4 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.

Appendix A

A.1   Data Appendix

Quarterly seasonally-adjusted data on standard macroeconomic variables except *Hours* are taken from the Federal Reserve Economic Data (FRED) of St. Louis FED. *Hours* data are taken from Current Employment Statistics survey published by the Bureau of Labor Statistics. GDP deflator from NIPA accounts is used to deflate the time series of the nominal macro aggregates. *Consumption* is the sum of "Personal consumption expenditures on nondurables" (PCND) and "Personal consumption expenditures on services". *Investment* is the sum of "Personal consumption expenditures on durables" (PCDG) and "Gross private domestic investment" (GPDI). *GDP* is the sum of *Consumption* and *Investment*. *Hours* is computed as the multiplication of "average weekly hours in private sector" with "average number of workers in private sector". Quarterly time series of capital stock to obtain z_t series are constructed using the approach described in the online appendix of Jermann and Quadrini (2010).

Quarterly financial time series of *Bank assets* and *Bank liabilities* are constructed using the monthly data on *Assets and Liabilities of Commercial Banks in the U.S.* from Data Download Program of Statistical & Historical Database of the Federal Reserve Board. Financial data at the FED board are seasonally-adjusted but nominal. GDP deflator from NIPA accounts is used to deflate the financial time

series. *Bank assets* are bank credit at the asset side of the balance sheet of the U.S. commercial banks. *Bank liabilities* are deposits held at the U.S. commercial banks. Quarterly time series of *Loan spread* are taken from Survey of Terms of Business Lending from Statistical & Historical Database of the FED Board. *Loan spread* is commercial and industrial loan spread over intended federal funds rate. Quarterly deposit rates are constructed using monthly data on 3-month certificate of deposit secondary market rate from FRED. The inflation rate computed from GDP deflator is used to make nominal deposit rate data real.

Table A.1: Business Cycle Properties of Real and Financial Variables, Quarterly U.S. Data, 1987.Q1-2007.Q1

	Standard Deviation	x_{t-4}	x_{t-3}	x_{t-2}	x_{t-1}	x_t	x_{t+1}	x_{t+2}	x_{t+3}	x_{t+4}
Real Variables										
Output	1.48	0.15	0.39	0.66	0.88	1.00	0.87	0.66	0.39	0.15
Consumption	0.44	-0.20	0.07	0.37	0.66	**0.82**	0.80	0.67	0.46	0.25
Investment	2.68	0.27	0.49	0.71	0.87	**0.97**	0.82	0.59	0.33	0.09
Hours	0.96	-0.01	0.19	0.43	0.65	0.83	**0.89**	0.83	0.68	0.44
Financial Variables										
Bank credit	0.82	0.07	0.21	0.34	0.45	0.54	0.56	**0.57**	0.50	0.39
Deposits	0.83	0.09	0.00	-0.09	-0.19	-0.29	**-0.37**	-0.36	-0.31	-0.24
Net Worth	5.29	0.03	0.20	0.38	0.55	0.70	**0.76**	0.74	0.63	0.47
Leverage Ratio	5.99	0.00	-0.16	-0.34	-0.51	-0.65	**-0.70**	-0.68	-0.56	-0.39
Loan Spread	0.09	-0.18	-0.23	-0.32	-0.34	**-0.35**	-0.22	-0.17	-0.09	-0.03

[a] Business cycle statistics in the table are based on HP-filtered cyclical components of quarterly empirical time series (smoothing parameter:1600).
[b] The standard deviation of output is expressed in percent; standard deviations of the remaining variables are normalized by the standard deviation of output (std(x)/std(GDP)).
[c] The correlation coefficients in bold font are the maximum ones in their respective rows.

A.2 Proofs

A.2.1 Proof of Proposition 1

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

$$V_{jt} = \nu_t q_t s_{jt} + \eta_t n_t \tag{A.1}$$

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

$$\nu_t q_t s_{jt} = E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} [(r_{kt+1+i} - r_{t+1+i}) q_{t+i} s_{jt+i}] \tag{A.2}$$

$$\eta_t n_{jt} = E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} (1 + r_{t+1+i}) n_{jt+i} \tag{A.3}$$

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

$$\nu_t = \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} \left[(r_{kt+1+i} - r_{t+1+i}) x_{t,t+i} \right] \tag{A.4}$$

where $x_{t,t+i} = \frac{q_{t+i} s_{jt+i}}{q_t s_{jt}}$.

$$\nu_t = (1-\theta)\beta \Lambda_{t,t+1}(r_{kt+1} - r_{t+1}) + \sum_{i=1}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} \left[(r_{kt+1+i} - r_{t+1+i}) x_{t,t+i} \right]$$

$$\tag{A.5}$$

$$\nu_t = (1-\theta)\beta\Lambda_{t,t+1}(r_{kt+1}-r_{t+1}) + \beta\Lambda_{t,t+1}\theta x_{t,t+1}\sum_{i=0}^{\infty}(1-\theta)\theta^{i+1}\beta^{i+1}\Lambda_{t+1,t+2+i}\left[(r_{kt+2+i} - r_{t+2+i})x_{t+1,t+1+i}\right]$$

$$(A.6)$$

The infinite sum at the right-hand side of equation (A.6) is one period updated version of equation (A.4), given by

$$\nu_{t+1} = \sum_{i=0}^{\infty}(1-\theta)\theta^{i+1}\beta^{i+1}\Lambda_{t+1,t+2+i}\left[(r_{kt+2+i} - r_{t+2+i})x_{t+1,t+1+i}\right] \qquad (A.7)$$

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 (A.6) with the expectations as follows:

$$\nu_t = E_t[(1-\theta)\beta\Lambda_{t,t+1}(r_{kt+1} - r_{t+1}) + \beta\Lambda_{t,t+1}\theta x_{t,t+1}\nu_{t+1}] \qquad (A.8)$$

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

$$\eta_t = \sum_{i=0}^{\infty}(1-\theta)\theta^i\beta^{i+1}\Lambda_{t,t+1+i}(1+r_{t+1+i})z_{t,t+i} \qquad (A.9)$$

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

$$\eta_t = (1-\theta)\beta\Lambda_{t,t+1}(1+r_{t+1}) + \sum_{i=1}^{\infty}(1-\theta)\theta^i\beta^{i+1}\Lambda_{t,t+1+i}(1+r_{t+1+i})z_{t,t+i} \qquad (A.10)$$

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

$$(A.11)$$

The infinite sum at the right-hand size of equation (A.11) is one period updated

version of equation (A.9), given by

$$\eta_{t+1} = \sum_{i=1}^{\infty}(1-\theta)\theta^{i+1}\beta^{i+1}\Lambda_{t+1,t+2+i}(1+r_{t+2+i})z_{t+1,t+1+i} \qquad (A.12)$$

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

Hence, we can re-write equation (A.11) with the expectations as follows:

$$\eta_t = E_t[(1-\theta)\beta\Lambda_{t,t+1}(1+r_{t+1}) + \beta\Lambda_{t,t+1}\theta z_{t,t+1}\eta_{t+1}] \qquad (A.13)$$

A.2.2   Proof of Proposition 2

The profit maximization problem by a representative bank is given by

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

$$(A.14)$$

$$s.t. \ \ V_{jt} \geq \lambda q_t s_{jt} \qquad (\mu_t) \qquad (A.15)$$

where μ_t is the Lagrange multiplier associated with the incentive compatibility con-

straint. Using the solution for V_{jt} in Proposition 2, I can re-write the intermediary's maximization problem using the Lagrangian,

$$Ł = \nu_t q_t s_{jt} + \eta_t n_{jt} + \mu_t [\nu_t q_t s_{jt} + \eta_t n_{jt} - \lambda q_t s_{jt}] \tag{A.16}$$

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

$$(1 + \mu_t) \nu_t q_t = \mu_t \lambda q_t \tag{A.17}$$

$$V_{jt} - \lambda q_t s_{jt} = 0 \tag{A.18}$$

Rearranging (A.17) gives us the following expression,

$$\nu_t = \frac{\mu_t \lambda}{(1 + \mu_t)} \tag{A.19}$$

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. Replacing the definition of ν_t, we obtain

$$E_t[(1 - \theta)\beta \Lambda_{t,t+1}(r_{kt+1} - r_{t+1}) + \beta \Lambda_{t,t+1} \theta \frac{q_{t+1} s_{jt+1}}{q_t s_{jt}} \nu_{t+1}] = \frac{\mu_t \lambda}{(1 + \mu_t)} \tag{A.20}$$

Imposing the steady-state, we get the following expression,

$$\frac{(1-\theta)\beta(r_k - r)}{(1-\beta\theta)} = \frac{\mu\lambda}{(1+\mu)} \tag{A.21}$$

Rearranging gives us

$$(r_k - r) = \frac{(1-\beta\theta)\mu\lambda}{(1-\theta)\beta(1+\mu)} \tag{A.22}$$

As long as μ is positive, i.e. the incentive compatibility constraint binds, risk premium is positive. Since I solve the model using linear approximation around the steady-state and the shocks are sufficiently small, the premium is always positive in numerical simulations.

A.3   Business Cycle Statistics of Aggregate Financial Variables of the whole U.S. Financial Sector

For interested readers, this section documents empirical cyclical properties of aggregate measures of the leverage ratio, debt and equity of U.S. financial firms and of the credit spread using quarterly data for the period 1952-2009. In particular, I compute standard business cycle statistics of the aggregate financial variables, such as their standard deviations, cross-correlations with output.

I use quarterly balance sheet data from the Flow of Funds Accounts of the Federal Reserve Board.[1] The theoretical model described below treats the entire financial intermediary sector as a group of identical institutions although there is a considerable amount of heterogeneity among financial institutions in terms of both their functions and balance sheet structures. For example, some financial intermediaries such as private pension funds, mutual funds, retirement funds, are financed only by equity while some others such as banks, security-brokers and dealers use leverage extensively. In order to be consistent with the model, I only select financial institutions that always carry some leverage.

I focus on both depository and non-depository financial institutions. The depository institutions are U.S. chartered commercial banks, savings institutions, and credit unions. The non-depository institutions are issuers of asset-backed securities, bank holding companies, security brokers and dealers, finance companies, insurance

---

[1]Total financial assets and total liabilities in the Flow of Funds Accounts are partly measured at book values and may be different from market values. The differences between book values and market values are more likely to disappear when the balance sheet of a particular financial institution is marked to market and/or when total financial assets or liabilities are short-term.

companies, funding corporations, and real estate investment trusts. These institutions perform the majority of activity in the U.S. financial sector as measured by their total assets.[2] *Liabilities* are defined as the sum of "Total liabilities" of each of the aforementioned depository and non-depository financial institutions in the U.S. financial system, while *Net Worth* is defined as the sum of "Total financial assets" minus the sum of "Total liabilities" of the same institutions. *Leverage ratio* is the ratio of *Liabilities* to *Net Worth*. *Credit spread* measure I use is the difference between quarterly real return to capital and quarterly real deposit rate. Quarterly real return to capital data are taken from Gomme et.al. (2011). Quarterly deposit rate data is taken from Federal Reserve Economic Data (FRED) of St. Louis FED. I use quarterly inflation rate computed using GDP deflator to make nominal deposit rates real.

Quarterly financial data are taken from the Flow of Funds Accounts (FFA) of the Federal Reserve Board. Quarterly real data except *Hours* and deposit rate data are taken from Federal Reserve Economic Data (FRED) of St. Louis FED. *Hours* data are taken from Current Employment Statistics survey published by the Bureau of Labor Statistics. The return to capital data are taken from Gomme et al. (2011). This paper constructs an empirical measure of the return to capital for the U.S., which directly corresponds to the definition of the return to capital in this paper. The balance sheet data in the level tables of FFA are nominal and

---

[2]The total assets of these institutions is 90% of the total assets of the U.S. financial sector. Moreover, our definition of U.S. financial sector includes important marked based financial institutions such as security broker&dealers, finance companies, asset backed security (ABS) issuers, and commercial banks as Adrian and Shin (2009) suggest. They argue that the balance sheet fluctuations of these institutions are important determinants of real fluctuations.

are not seasonally adjusted. All financial data are seasonally adjusted using Census X12 and are deflated using GDP deflator. I use FFA coded level tables released on March 10, 2011 when I refer to the balance sheet items of financial sector. Financial and real data sources for figures 1 and 2, and tables 1 and 2 are given below.

Liabilities are the sum of "Total liabilities" of each of the following financial institutions: U.S. chartered commercial banks (Table L.110, Line 23), savings institutions (Table L.114, Line 23), credit unions (Table L.115, Line 16), issuers of asset-backed securities (Table L.126, Line 11), bank holding companies (Table L.112, Line 11), security brokers and dealers (Table L.129, Line 13), finance companies (Table L.127, Line 10), property-casualty insurance companies (Table L.116, Line 16), life insurance companies (Table L.117, Line 16), funding corporations (Table L.130, Line 12), and real estate investment trusts (Table L.128, Line 11).

Net Worth is the sum of "Total financial assets" minus the sum of "Total liabilities" of each of the following financial institutions: U.S. chartered commercial banks (Table L.110, Line 1 minus Line 23), savings institutions (Table L.114, Line 1 minus Line 23), credit unions (Table L.115, Line 1 minus Line 16), issuers of asset-backed securities (Table L.126, Line 1 minus Line 11), bank holding companies (Table L.112, Line 1 minus Line 11), security brokers and dealers (Table L.129, Line 1 minus Line 13), finance companies (Table L.127, Line 1 minus Line 10), property-casualty insurance companies (Table L.116, Line 1 minus Line 16), life insurance companies (Table L.117, Line 1 minus Line 16), funding corporations (Table L.130, Line 1 minus Line 12), and real estate investment trusts (Table L.128, Line 1 minus Line 11).

Leverage Ratio is is the ratio of *Liabilities* to *Net Worth*. Finally, *Credit Spread* is computed as the difference between the quarterly return to capital and the quarterly deposit rate.

Consumption is the sum of "Personal consumption expenditures on nondurables" (PCND) and "Personal consumption expenditures on services". *Investment* is the sum of "Personal consumption expenditures on durables" (PCDG) and "Gross private domestic investment" (GPDI). *GDP* is the sum of *Consumption* and *Investment*. *Hours* is computed as the multiplication of "average weekly hours in private sector" with "average number of workers in private sector".

Table A.2: Business Cycle Statistics, Quarterly U.S. Data, 1952-2009

		GDP	C	I	Leverage R.	Liabilities	Net Worth	Credit Spread
Standard deviation (%)		1.97	0.89	5.56	5.33	2.16	5.76	0.22
Quarterly autocorrelation		0.83	0.86	0.82	0.74	0.92	0.79	0.75
	GDP	1	0.54	0.96	-0.08	0.57	0.28	-0.56
	C	–	1	0.29	0.10	0.07	-0.08	-0.05
Correlation matrix	I	–	–	1	-0.10	0.63	0.33	-0.62
	Leverage R.	–	–	–	1	-0.03	-0.92	0.14
	Liabilities	–	–	–	–	1	0.40	-0.51
	Net Worth	–	–	–	–	–	1	-0.32
	Credit Spread	–	–	–	–	–	–	1

[a] Business cycle statistics for GDP, consumption and investment are computed using quarterly data from FRED database. Consumption is the sum of personal consumption expenditures on nondurables and services (PCND + PCESV). Investment is the sum of personal consumption expenditures on durable goods and gross private domestic investment (PCDG + GPDI). GDP is the sum of consumption and investment.
[b] Business cycle statistics in the table are based on HP-filtered cyclical components over the period 1952-2009.
[c] The correlation coefficients greater than 0.13 are statistically significant at 5% significance level.

Table A.1 presents business cycle statistics for the aggregate leverage ratio, aggregate liabilities, and aggregate equity of U.S. financial sector together with those for the credit spread. The volatility of the leverage ratio is nearly 3 times larger than that of output and is roughly equal to that of investment. Table 1 shows that the financial leverage ratio is acyclical. The contemporaneous correlation between the financial leverage ratio and output is -0.08. The volatility of aggregate

equity is 3 times larger than that of output, while the volatility of aggregate debt is roughly equal to that of output.[3] The contemporaneous correlation between aggregate liabilities and output is 0.57 while that between aggregate equity and output is 0.28, indicating that both series are procyclical.[4] Moreover, the contemporaneous correlation with between credit spread and GDP is -0.56, showing that it is countercyclical.

Table A.3: Cross Correlations of Financial Variables with Lags and Leads of GDP

Variable	Y_{t-5}	Y_{t-4}	Y_{t-3}	Y_{t-2}	Y_{t-1}	Y_t	Y_{t+1}	Y_{t+2}	Y_{t+3}	Y_{t+4}	Y_{t+5}
Liabilities	0.01	0.13	0.27	0.41	0.52	**0.57**	0.57	0.50	0.39	0.26	0.12
NetWorth	0.00	0.04	0.09	0.14	0.21	0.28	0.34	**0.35**	0.31	0.20	0.05
LeverageR.	0.00	0.00	0.00	0.00	-0.03	-0.08	-0.14	-0.18	**-0.18**	-0.10	0.00
Spread	0.28	0.17	0.03	-0.15	-0.34	-0.56	**-0.67**	-0.60	-0.46	-0.29	-0.11

[a] See the footnote (b) in Table 2 for the construction of aggregate financial variables.
[b] Business cycle statistics in the table are based on HP-filtered cyclical components over the period 1952-2009.
[c] The correlation coefficients greater than 0.13 are statistically significant at 5% significance level.

Table A.2 displays the cross-correlations of financial variables with different lags and leads of GDP. It shows that aggregate financial variables lead business cycles in the U.S. In particular, the financial leverage ratio, equity and credit spread lead output by three, two and one quarters, respectively. However, liabilities contemporaneously move with output.

The following facts emerge from the empirical analysis above: (1) Financial

---

[3]Using the Flow of Funds database, Jermann and Quadrini (2009) shows that relative volatilities of non-financial sector debt and equity to nonfinancial business sector GDP are 1.29 and 1.05, respectively.

[4]Jermann and Quadrini (2009) find that debt is countercyclical and equity is procyclical for non-financial firms for the same time period. In addition, using Compustat database, Covas and Den Haan (2006) shows that debt and equity issuance is procyclical for the majority of publicly listed firms.

leverage ratio and equity are three times more volatile than output, liabilities are a little more volatile than output, (2) liabilities and equity are procyclical, financial leverage ratio is acyclical, and credit spread is countercyclical, and (3) Financial leverage ratio, equity and credit spread lead output by three, two and one quarters, respectively, while liabilities contemporaneously move with output.

A.4   Alternative Measures of Financial Shocks

This section presents alternative measures of financial shocks and the simulation results of the benchmark models under these alternative measures. I label the benchmark model presented in the text as *Benchmark* 1.

The first alternative measure for ω_t series is constructed using the charge-off and delinquency rates of all loans, the level of outstanding loans, and net worth of U.S. commercial banks from the Federal Reserve Board:

$$\omega_t = \frac{(1 - Loanlossrates) * Outstandingloans}{Networth} \tag{A.23}$$

Then I construct the log-deviation of ω_t series by linearly detrending the log of these series over the period 1987.Q1-2010.Q4. The ω_t series can be interpreted as the level of recovery rates of loans as a percentage of net worth. These recovery rates determine the level of credit conditions in the economy since banks' ability to extend loans to non-financial businesses depends on their level of net worth, which can be seen from equation (1.20). Therefore, the innovations to ω_t are shocks to the recovery rates, hence to the level of financial conditions in the economy. First, I estimate a VAR(1) for both TFP series and this alternative measure of ω. However, the cross-terms in the VAR coefficient matrix are not statistically significant at 5% significance level. Then I estimate two independent AR(1) processes for both series. The resulting persistence of the ω series is $\rho_\omega = 0.9690$ and the standard deviation of the shock is $\sigma_\omega = 0.003111$. The levels of z_t and ω_t series and the innovations to those series are plotted in Figure A.1. I label the model driven by both standard

productivity shock and this alternative measure of financial shock as *Benchmark* 2.

The second alternative measure for ω_t series is constructed by calibrating the persistence, ρ_ω, and the standard deviation of the shock, σ_ω, to match the persistence and the volatility of net worth in the data. The resulting persistence is $\rho_\omega = 0.55$, and the resulting standard deviation of the shock is $\sigma_\omega = 0.04$. I label the model driven by both standard productivity shock and this alternative measure of financial shock as *Benchmark* 3.

Finally, the third alternative measure for ω_t series is constructed as in the main text. However, this time I estimate a VAR(1) for both TFP and ω series instead of estimating two independent AR(1) processes as follows:

$$
\begin{bmatrix} \widehat{z}_{t+1} \\ \widehat{\omega}_{t+1} \end{bmatrix} = \begin{bmatrix} \rho_z & \rho_{z,\omega} \\ \rho_{\omega,z} & \rho_\omega \end{bmatrix} \begin{bmatrix} \widehat{z}_t \\ \widehat{\omega}_t \end{bmatrix} + \begin{bmatrix} \epsilon_{z,t+1} \\ \epsilon_{\omega,t+1} \end{bmatrix}
$$

.

The resulting parameters are $\rho_z = 0.9467$, $\rho_{z,\omega} = -0.0142$, $\rho_{\omega,z} = 0.9129$, $\rho_\omega = 0.2824$, $\sigma_z = 0.006378$, and $\sigma_\omega = 0.0489$. I assume that the shocks are i.i.d. as the correlation coefficient between the innovations is not statistically significant at 5% significant level. I label the model driven by both standard productivity shock and this alternative measure of financial shock as *Benchmark* 4.

Table A.3 presents the business cycle properties of real and financial variables of four different benchmark models under alternative financial shock measures. The table suggests that main results of the paper don't change across under alternative financial shock series: all of the benchmark models are able to reproduce the key

business cycle facts about real variables: consumption and hours are less volatile than output, while investment is more volatile. Investment and hours are highly procyclical. However, Benchmark 1, 3 and 4 generates a counterfactual negative or zero correlation between consumption and output. Moreover, Benchmark 4 predicts higher volatilities in real variables compared to other three models. In terms of financial variables, all of the benchmark models can explain most of the key empirical regularities about aggregate financial variables: bank assets, deposits, and spread are less volatile than output, while net worth and leverage ratio are more volatile. Assets and net worth are procyclical, while leverage ratio and spread are countercyclical. Benchmark 1 and 3 predict countercyclical deposits, consistent with the data, while Benchmark 2 and 4 generate procyclical deposits, contrary to the data. Overall, regardless of which financial shock measure is taken, we can say that financial shocks help the theoretical model explain financial fluctuations better, while preserving most of its predictions about real variables.

For interested readers, I also include the figures A.2 to A.9 that display the quarterly time series of real variables in the data, in the standard RBC model with capital adjustment costs, and in the benchmark model economies (2 and 4) and that display the quarterly time series of financial variables in the data, in the model driven only by productivity shocks, and in the benchmark model economies (2 and 4).
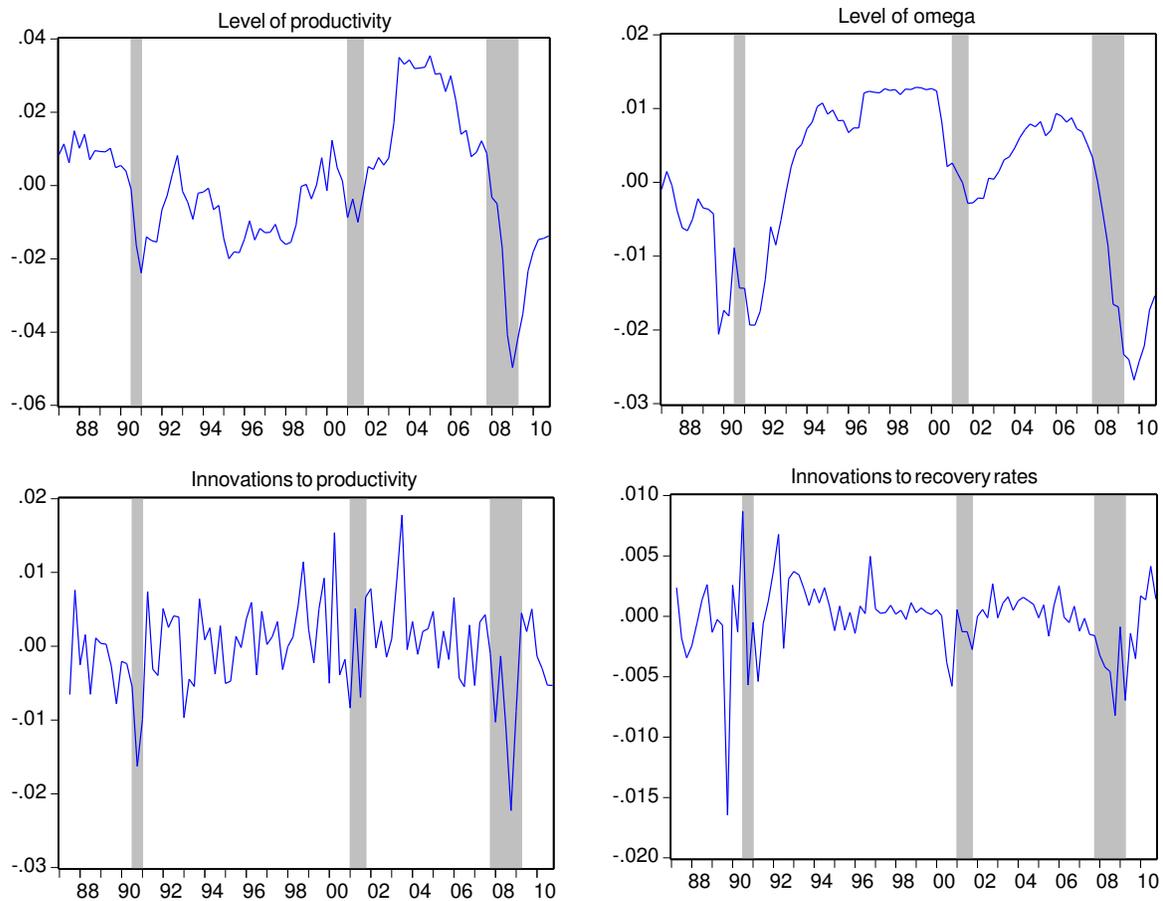
Figure A.1: Time Series of Shocks to Productivity and Credit Conditions
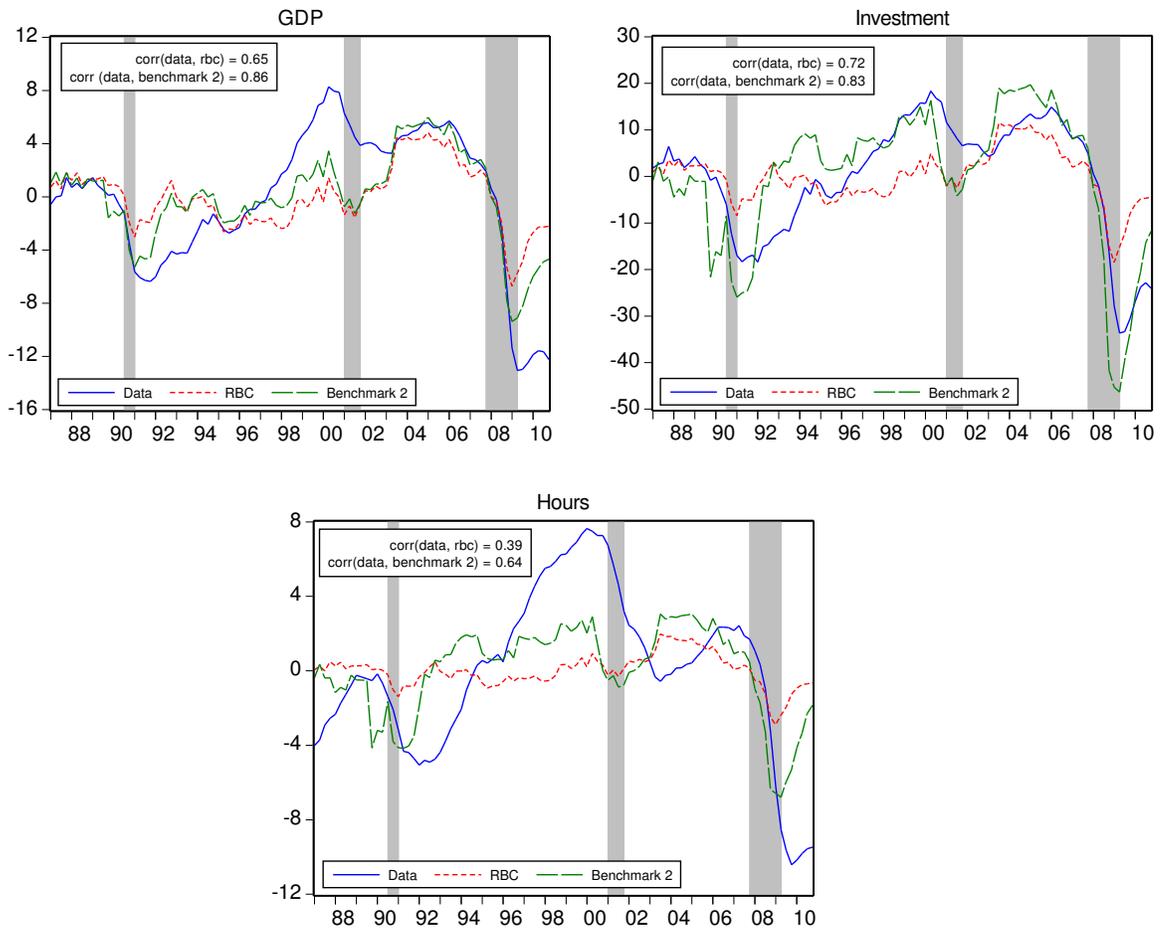
Figure A.2: Real Fluctuations: Benchmark 2 vs. RBC model
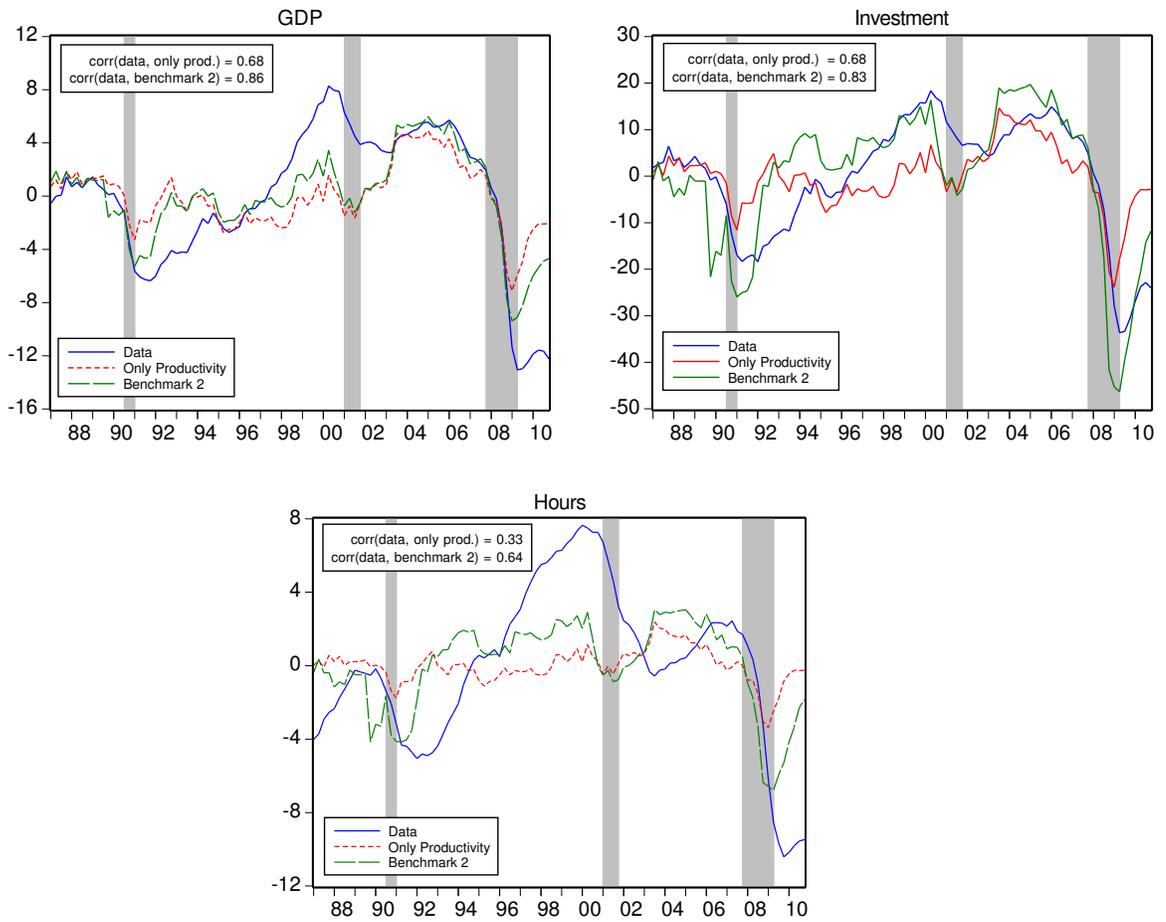
Figure A.3: Real Fluctuations: Benchmark 2 vs. Only Productivity
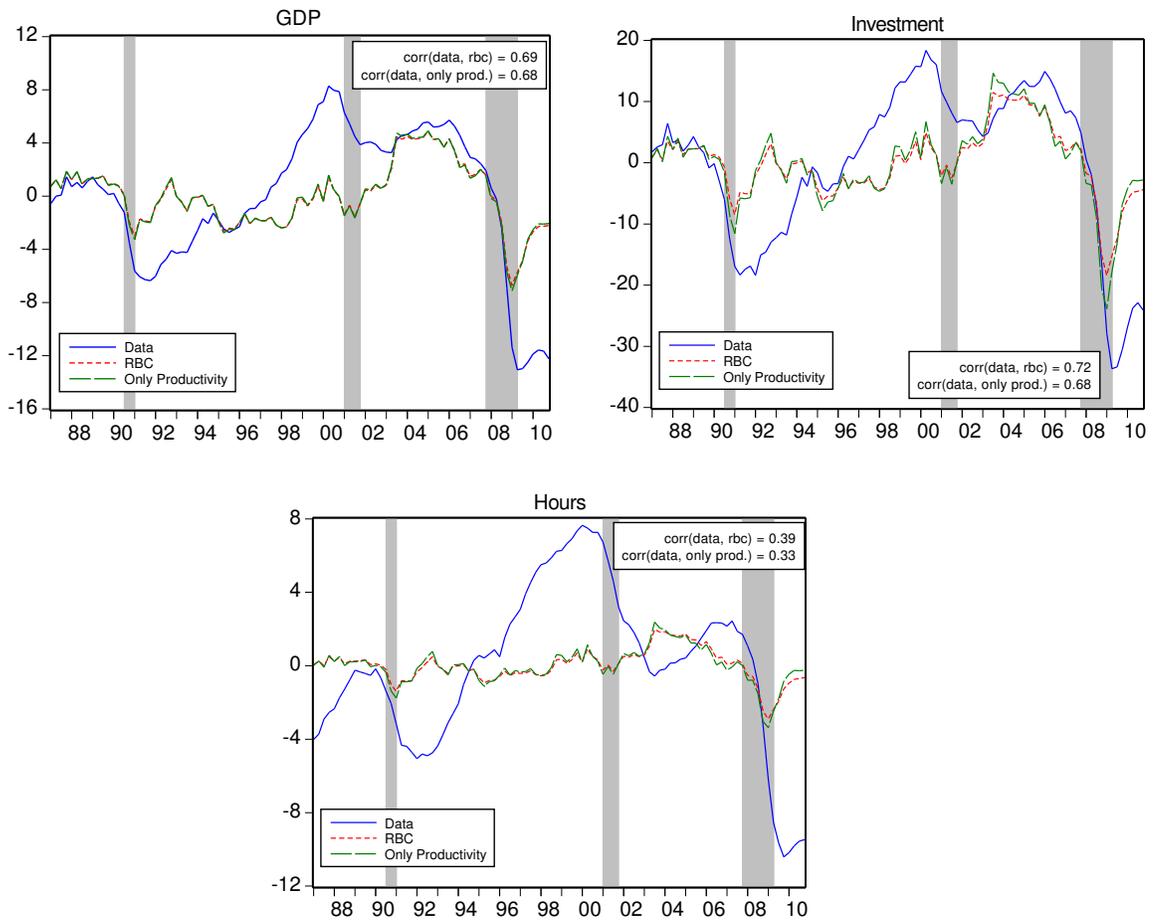
Figure A.4: Real Fluctuations: RBC vs. Only Productivity with Benchmark 2 calibration
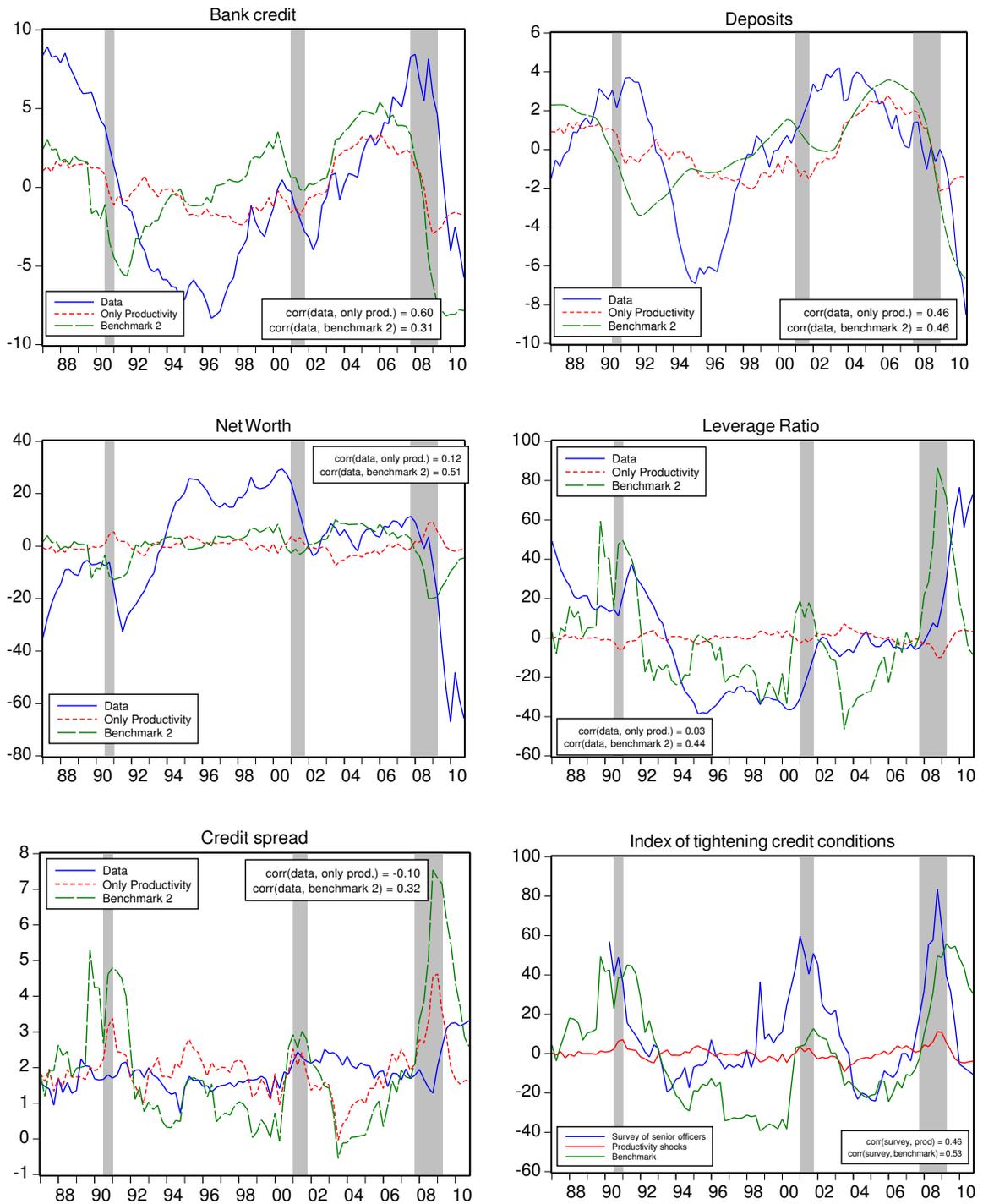
Figure A.5: Financial Fluctuations: Benchmark 2 vs. Only Productivity
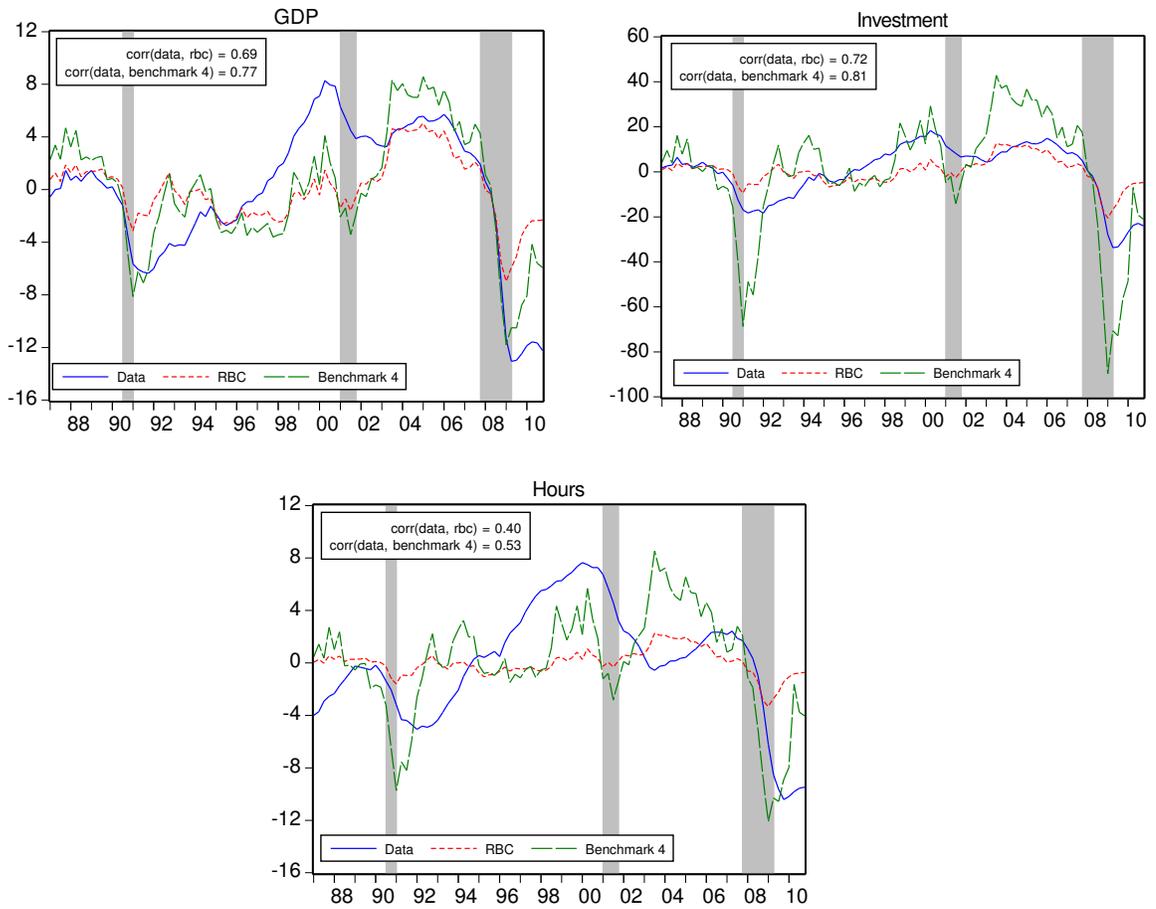
Figure A.6: Real Fluctuations: Benchmark 4 vs. RBC model
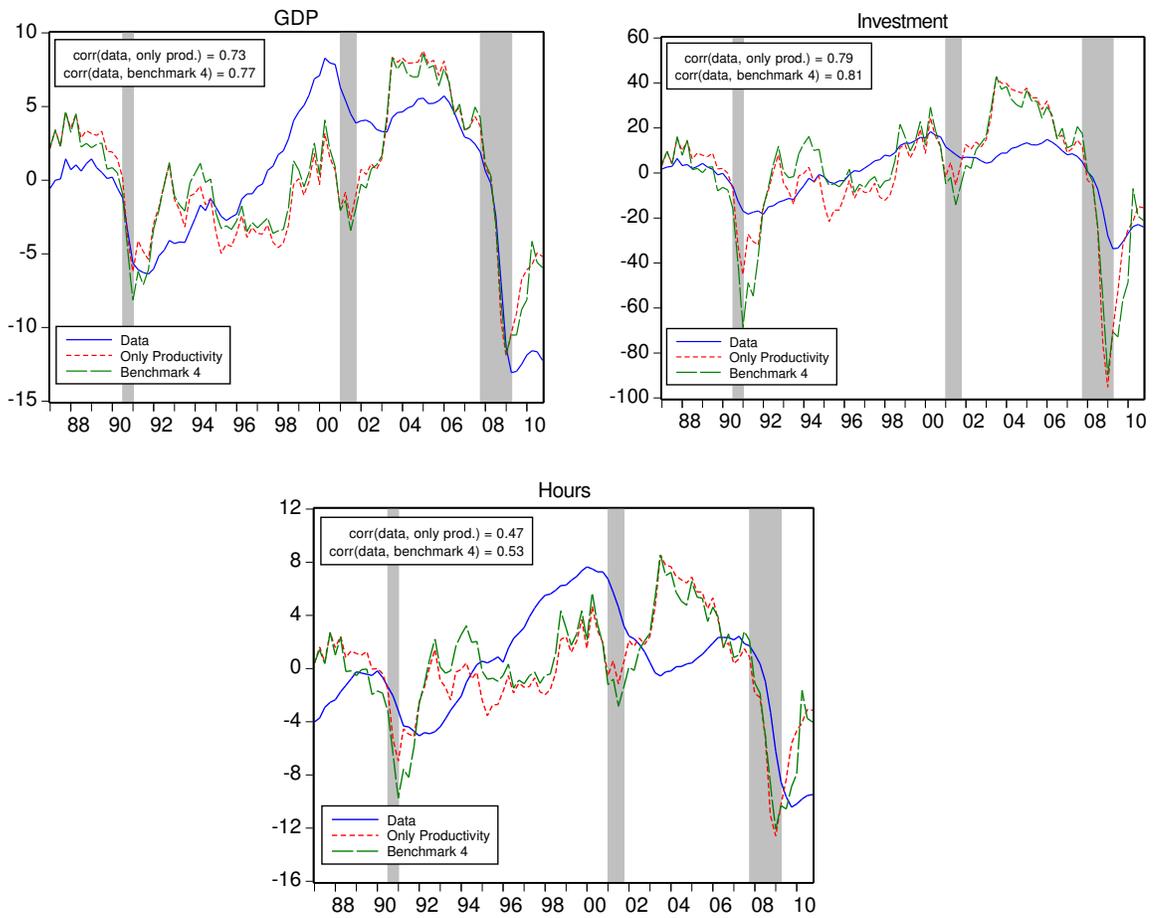
Figure A.7: Real Fluctuations: Benchmark 4 vs. Only Productivity
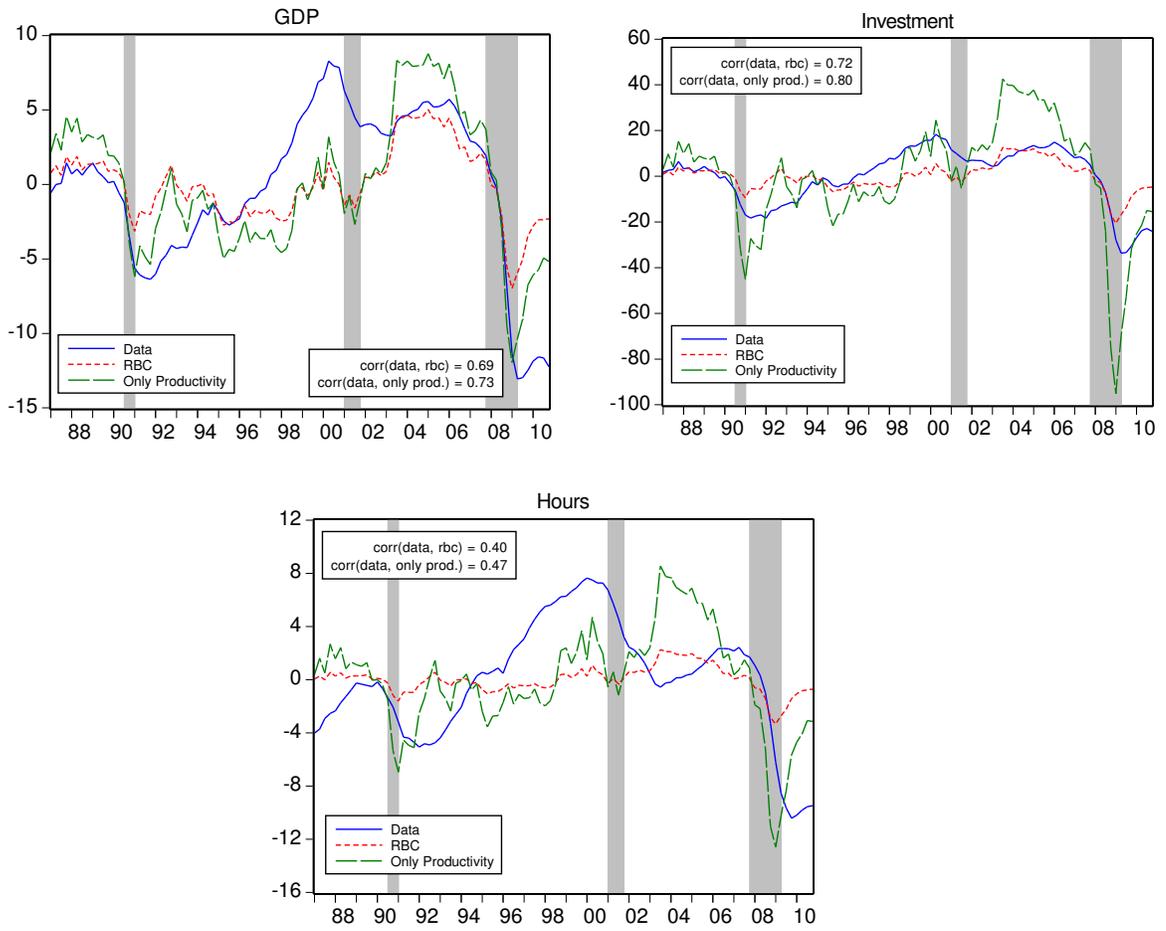
Figure A.8: Real Fluctuations: RBC vs. Only Productivity with Benchmark 4 calibration
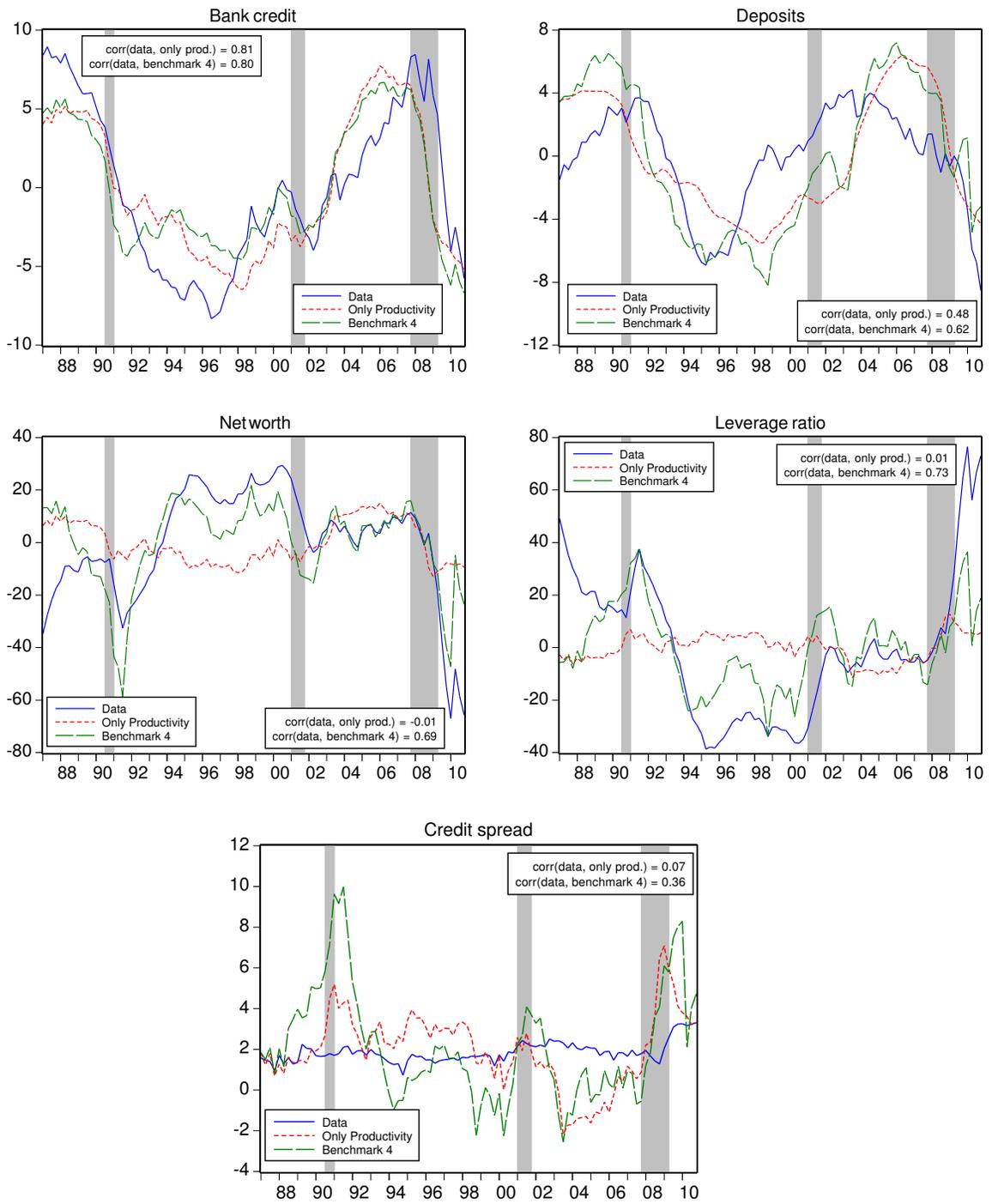
Figure A.9: Financial Fluctuations: Benchmark 4 vs. Only Productivity

133

A.5 Model-Based Simulations of Macro-Financial Shocks using Utilization-Adjusted TFP series
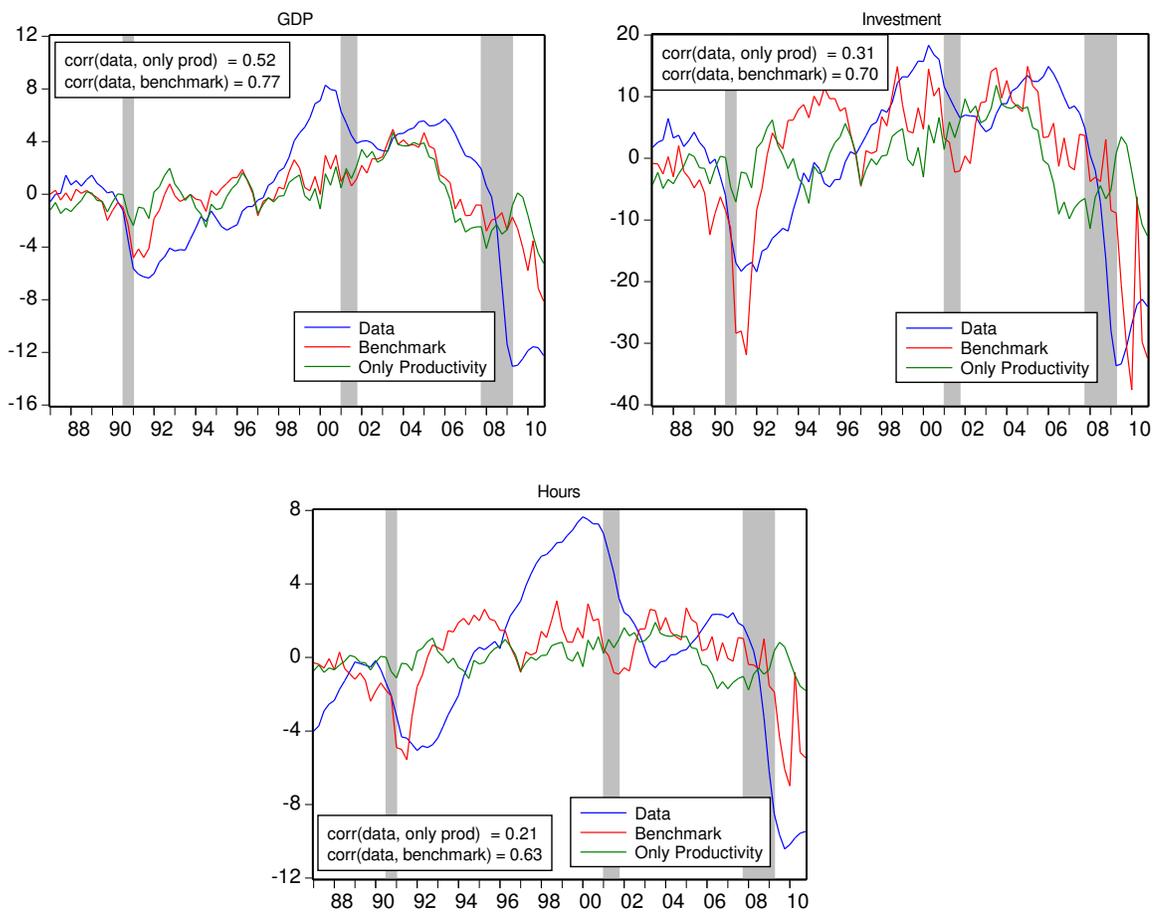
Figure A.10: Real Fluctuations: Benchmark 1 vs. Only Productivity model
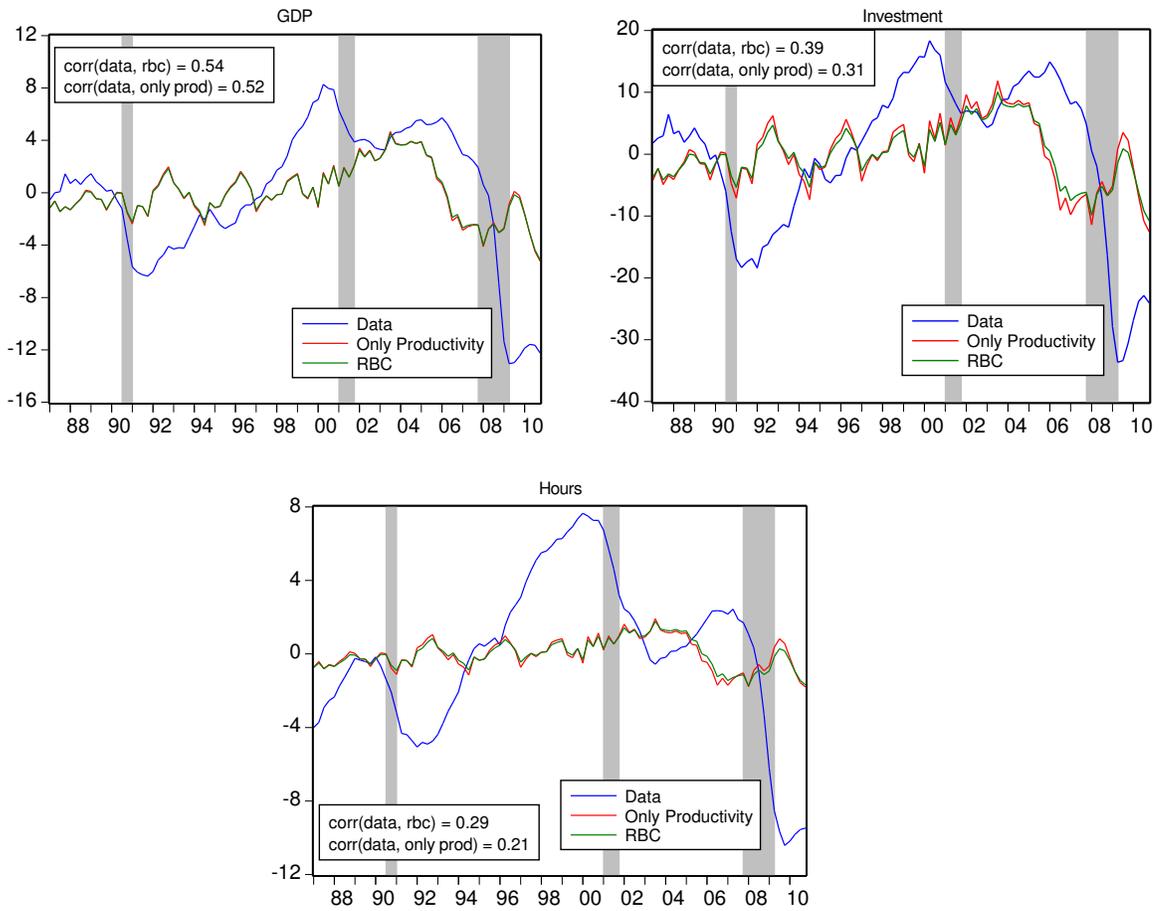
Figure A.11: Real Fluctuations: RBC vs. Only Productivity
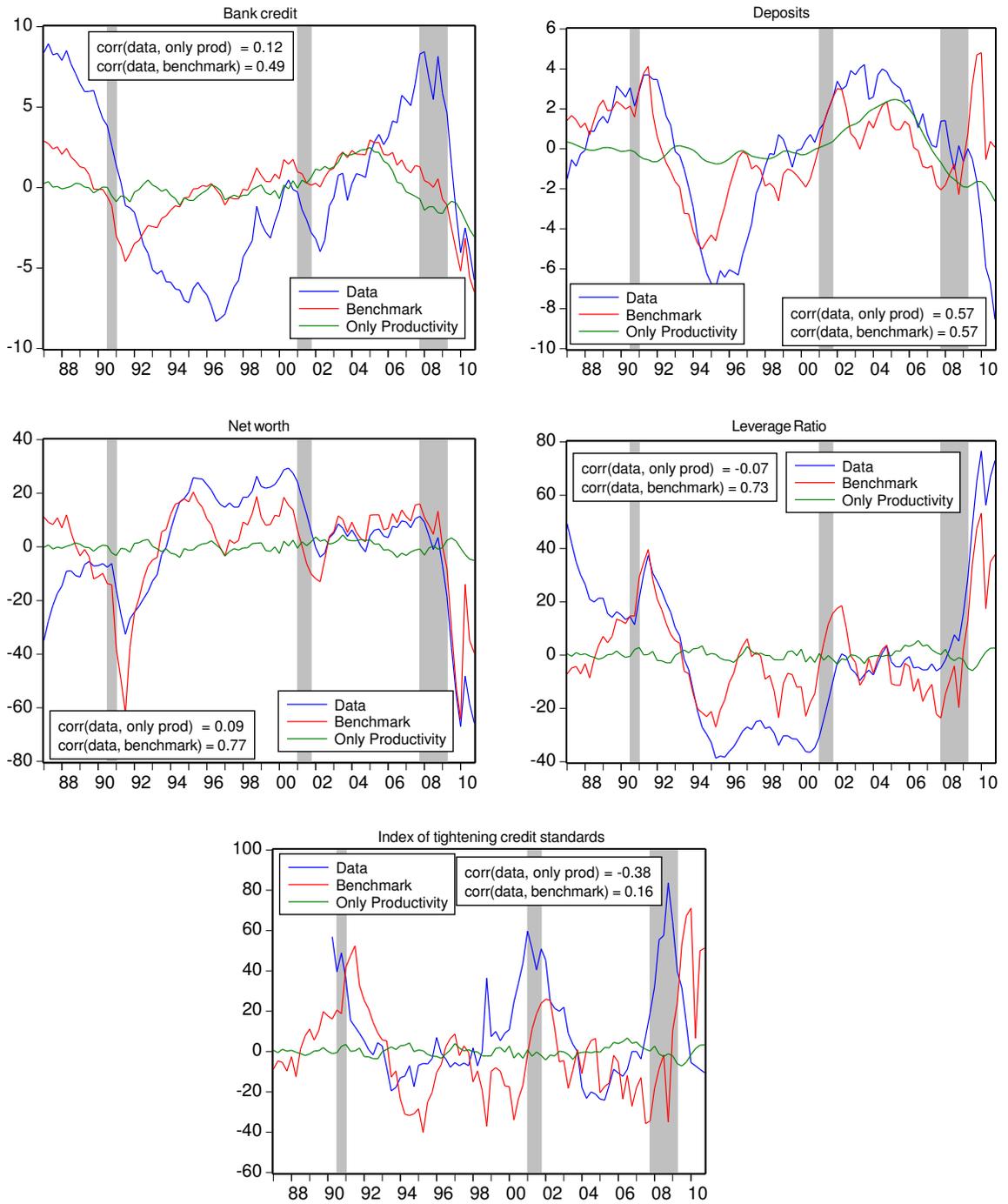
Figure A.12: Financial Fluctuations: Benchmark 1 vs. Only Productivity

Table A.4: Real and Financial Statistics

Statistic	Data	Benchmark 1	Benchmark 2	Benchmark 3	Benchmark 4
σ_Y	1.80	1.81	1.65	1.83	2.75
σ_C	0.45	0.75	0.52	0.77	0.57
σ_I	2.73	4.64	3.77	4.68	5.13
σ_L	0.91	0.84	0.64	0.88	0.94
$\rho_{Y,I}$	0.97	0.87	0.92	0.88	0.97
$\rho_{Y,C}$	0.82	-0.03	0.34	-0.09	-0.70
$\rho_{Y,L}$	0.83	0.81	0.86	0.81	0.96
σ_{Assets}	0.93	0.58	0.53	0.57	0.69
$\sigma_{Deposits}$	0.69	0.87	0.44	0.74	0.74
$\sigma_{NetWorth}$	5.17	5.90	2.10	5.17*	4.21
$\sigma_{LeverageR.}$	5.61	6.40	2.18	5.92	3.68
σ_{Spread}	0.08	0.23	0.11	0.22	0.17
$\rho_{Y,Assets}$	0.30	0.88	0.91	0.87	0.86
$\rho_{Y,Deposits}$	-0.39	-0.23	0.48	-0.21	0.19
$\rho_{Y,NetWorth}$	0.52	0.68	0.82	0.67	0.70
$\rho_{Y,LeverageR.}$	-0.49	-0.71	-0.57	-0.66	-0.60
$\rho_{Y,Spread}$	-0.39	-0.67	-0.78	-0.70	-0.83

[a] Business cycle statistics in the table are based on HP-filtered cyclical components of quarterly simulated time series (smoothing parameter:1600).
[b] The standard deviation of output is expressed in percent; standard deviations of the remaining variables are normalized by the standard deviation of output (std(x)/std(GDP)).
[c] * denotes calibration target.

Appendix B

B.1 Banks' Profit Maximization Problem

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

$$V_{jt} = \nu_t q_t s_{jt} + \eta_t n_t \tag{B.1}$$

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

$$\nu_t q_t s_{jt} = E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} \left[R_{kt+1+i} - \left(\frac{R_{t+1+i} - rr_{t+i}}{1 - rr_{t+i}} \right) \right] q_{t+i} s_{jt+i} \tag{B.2}$$

$$\eta_t n_{jt} = E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} \left[\frac{R_{t+1+i} - rr_{t+i}}{1 - rr_{t+i}} \right] n_{jt+i} \tag{B.3}$$

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,

$$\nu_t q_t s_{jt} = E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} ESP_{t+i} q_{t+i} s_{jt+i} \tag{B.4}$$

$$\eta_t n_{jt} = E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} RR_{t+i} n_{jt+i} \tag{B.5}$$

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.

$$\nu_t = \sum_{i=0}^{\infty}(1-\theta)\theta^i\beta^{i+1}\Lambda_{t,t+1+i}ESP_{t+i}x_{t,t+i} \tag{B.6}$$

where $x_{t,t+i} = \frac{q_{t+i}s_{jt+i}}{q_t s_{jt}}$. Let's separate (B.6) into two parts.

$$\nu_t = (1-\theta)\beta\Lambda_{t,t+1}ESP_t + \sum_{i=1}^{\infty}(1-\theta)\theta^i\beta^{i+1}\Lambda_{t,t+1+i}ESP_{t+i}x_{t,t+i} \tag{B.7}$$

Rearrange the second term at the right-hand size of the expression (B.7),

$$\nu_t = (1-\theta)\beta\Lambda_{t,t+1}ESP_t + \beta\Lambda_{t,t+1}\theta x_{t,t+1}\sum_{i=0}^{\infty}(1-\theta)\theta^{i+1}\beta^{i+1}\Lambda_{t+1,t+2+i}ESP_{t+1+i}x_{t+1,t+1+i} \tag{B.8}$$

The infinite sum at the right-hand side of equation (B.8) is one period updated version of equation (B.6), given by

$$\nu_{t+1} = \sum_{i=0}^{\infty}(1-\theta)\theta^{i+1}\beta^{i+1}\Lambda_{t+1,t+2+i}ESP_{t+1+i}x_{t+1,t+1+i} \tag{B.9}$$

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 (B.8) with the expectations as follows:

$$\nu_t = E_t[(1-\theta)\beta\Lambda_{t,t+1}ESP_t + \beta\Lambda_{t,t+1}\theta x_{t,t+1}\nu_{t+1}] \tag{B.10}$$

140

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

$$\eta_t = \sum_{i=0}^{\infty}(1-\theta)\theta^i\beta^{i+1}\Lambda_{t,t+1+i}RR_{t+i}z_{t,t+i} \tag{B.11}$$

where $z_{t,t+i} = \frac{n_{jt+i}}{n_{jt}}$. Let's separate (B.11) into two parts.

$$\eta_t = (1-\theta)\beta\Lambda_{t,t+1}RR_t + \sum_{i=1}^{\infty}(1-\theta)\theta^i\beta^{i+1}\Lambda_{t,t+1+i}RR_{t+i}z_{t,t+i} \tag{B.12}$$

Rearrange the second term at the right-hand size of the expression (B.12),

$$\eta_t = (1-\theta)\beta\Lambda_{t,t+1}RR_t + \beta\Lambda_{t,t+1}\theta z_{t,t+1}\sum_{i=0}^{\infty}(1-\theta)\theta^{i+1}\beta^{i+1}\Lambda_{t+1,t+2+i}RR_{t+1+i}z_{t+1,t+1+i} \tag{B.13}$$

The infinite sum at the right-hand size of equation (B.12) is one period updated version of equation (B.10), given by

$$\eta_{t+1} = \sum_{i=1}^{\infty}(1-\theta)\theta^{i+1}\beta^{i+1}\Lambda_{t+1,t+2+i}RR_{t+1+i}z_{t+1,t+1+i} \tag{B.14}$$

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

Hence, we can re-write equation (B.12) with the expectations as follows:

$$\eta_t = E_t[(1-\theta)\beta\Lambda_{t,t+1}RR_t + \beta\Lambda_{t,t+1}\theta z_{t,t+1}\eta_{t+1}] \tag{B.15}$$

The profit maximization problem by a representative bank is given by

141

$$V_{jt} = \max_{s_{jt}} E_t \sum_{i=0}^{\infty}(1-\theta)\theta^i\beta^{i+1}\Lambda_{t,t+1+i}ESP_{t+i}q_{t+i}s_{jt+i} + RR_{t+i}n_{jt+i}] \qquad \text{(B.16)}$$

$$s.t. \ \ V_{jt} \geq \lambda q_t s_{jt} \qquad (\mu_t) \qquad \text{(B.17)}$$

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,

$$Ł = \nu_t q_t s_{jt} + \eta_t n_{jt} + \mu_t[\nu_t q_t s_{jt} + \eta_t n_{jt} - \lambda q_t s_{jt}] \qquad \text{(B.18)}$$

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

$$(1+\mu_t)\nu_t q_t = \mu_t \lambda q_t \qquad \text{(B.19)}$$

$$V_{jt} - \lambda q_t s_{jt} = 0 \qquad \text{(B.20)}$$

Rearranging (B.19) gives us the following expression,

$$\nu_t = \frac{\mu_t \lambda}{(1+\mu_t)} \qquad \text{(B.21)}$$

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.

B.2 Impulse Responses under an Alternative RRR Policy Rule reacting to Current Credit Growth
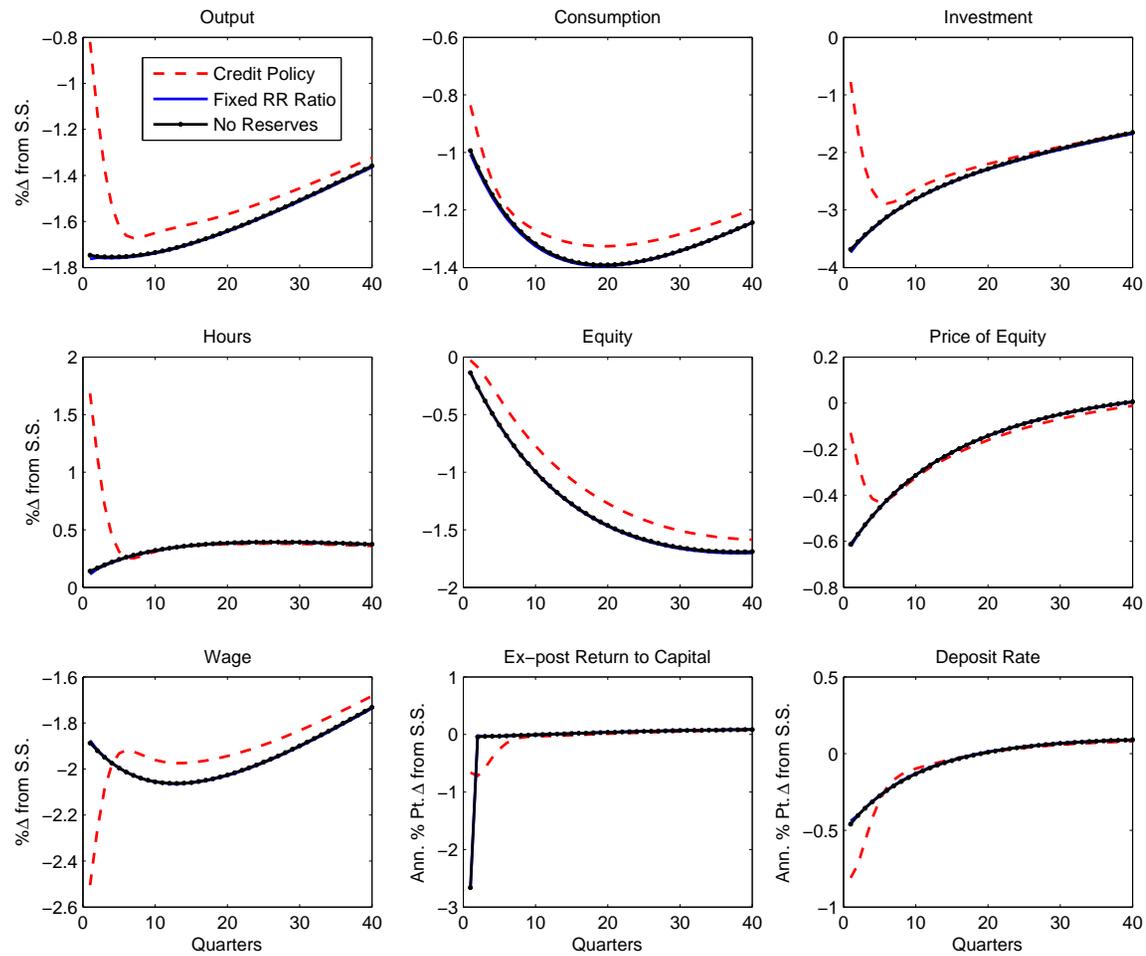
Figure B.1: The Effect of Adverse TFP Shocks on Real Variables
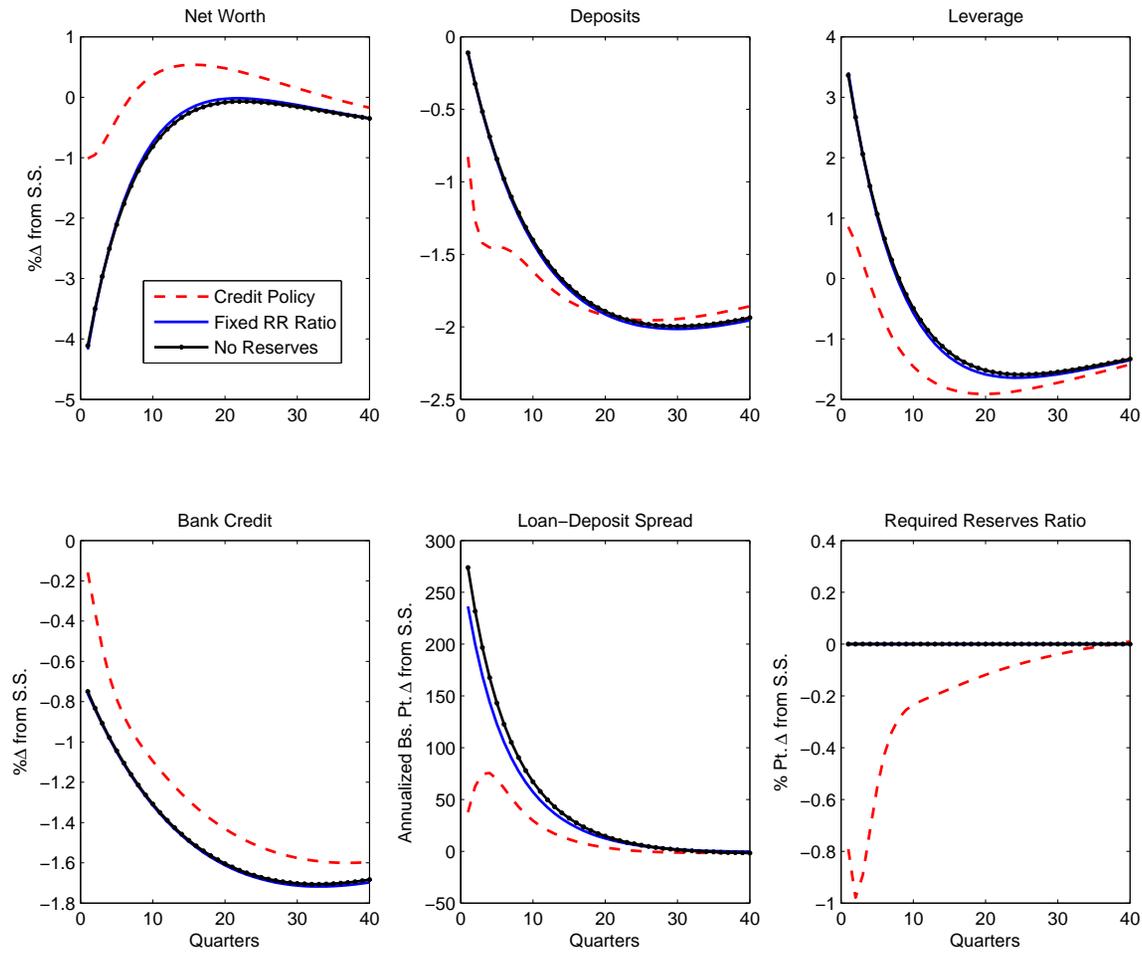
Figure B.2: The Effect of Adverse TFP Shocks on Financial Variables
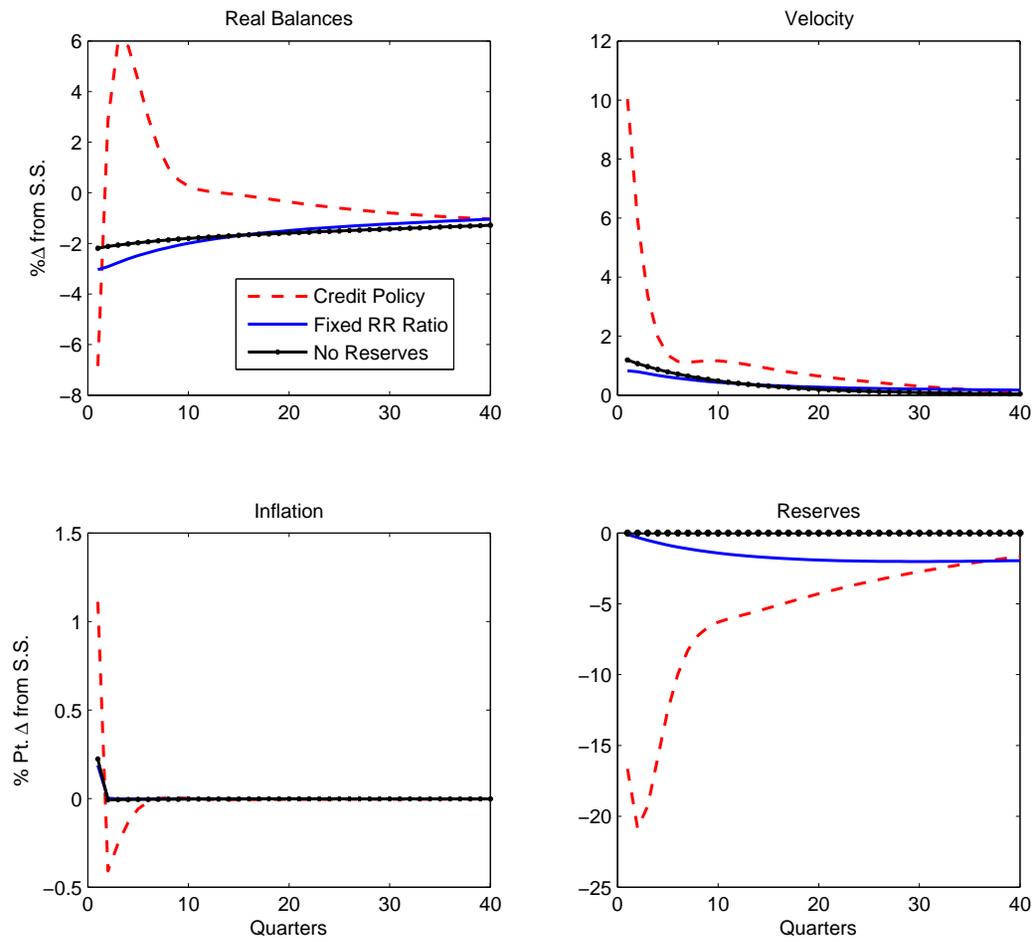
Figure B.3: The Effect of Adverse TFP Shocks on Monetary Variables
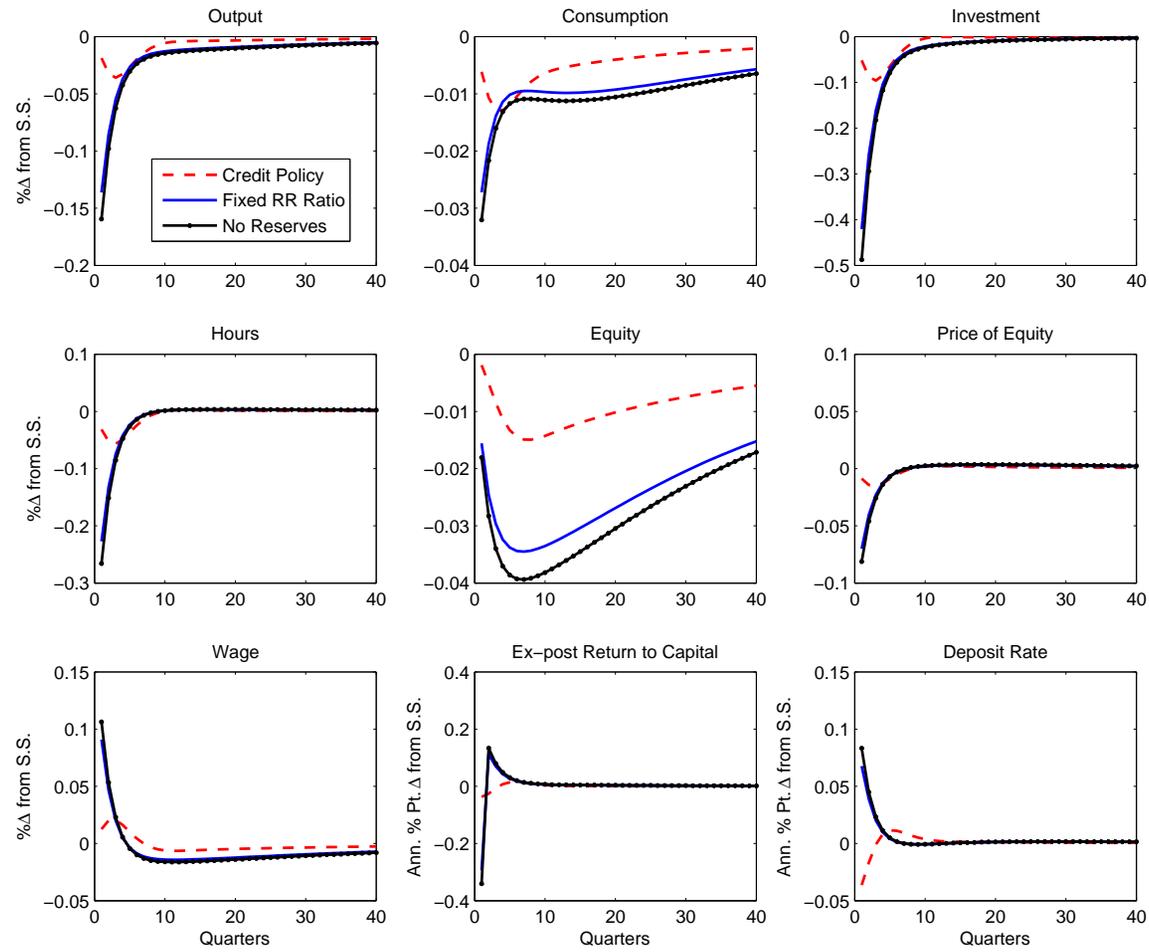
Figure B.4: The Effect of Adverse Money Growth Shocks on Real Variables
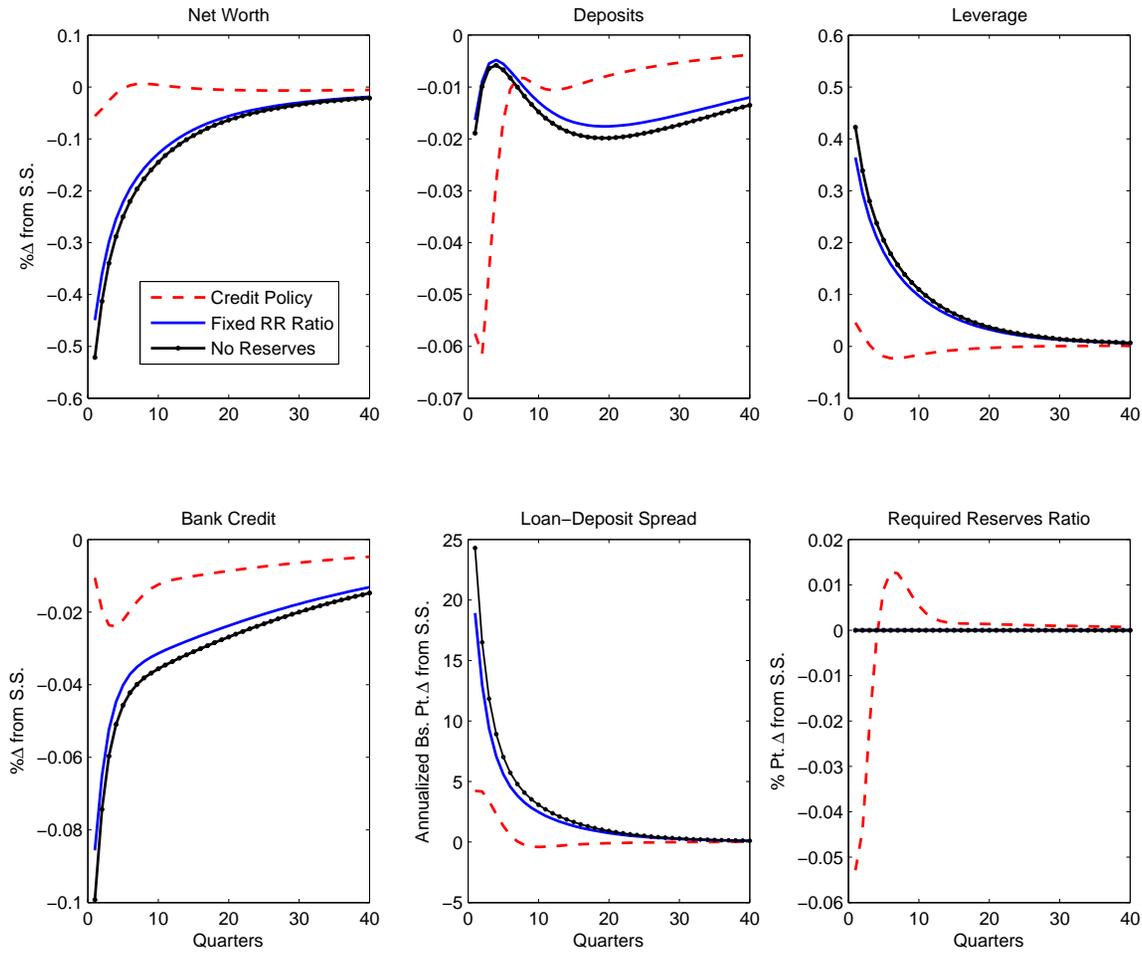
Figure B.5: The Effect of Adverse Money Growth Shocks on Financial Variables
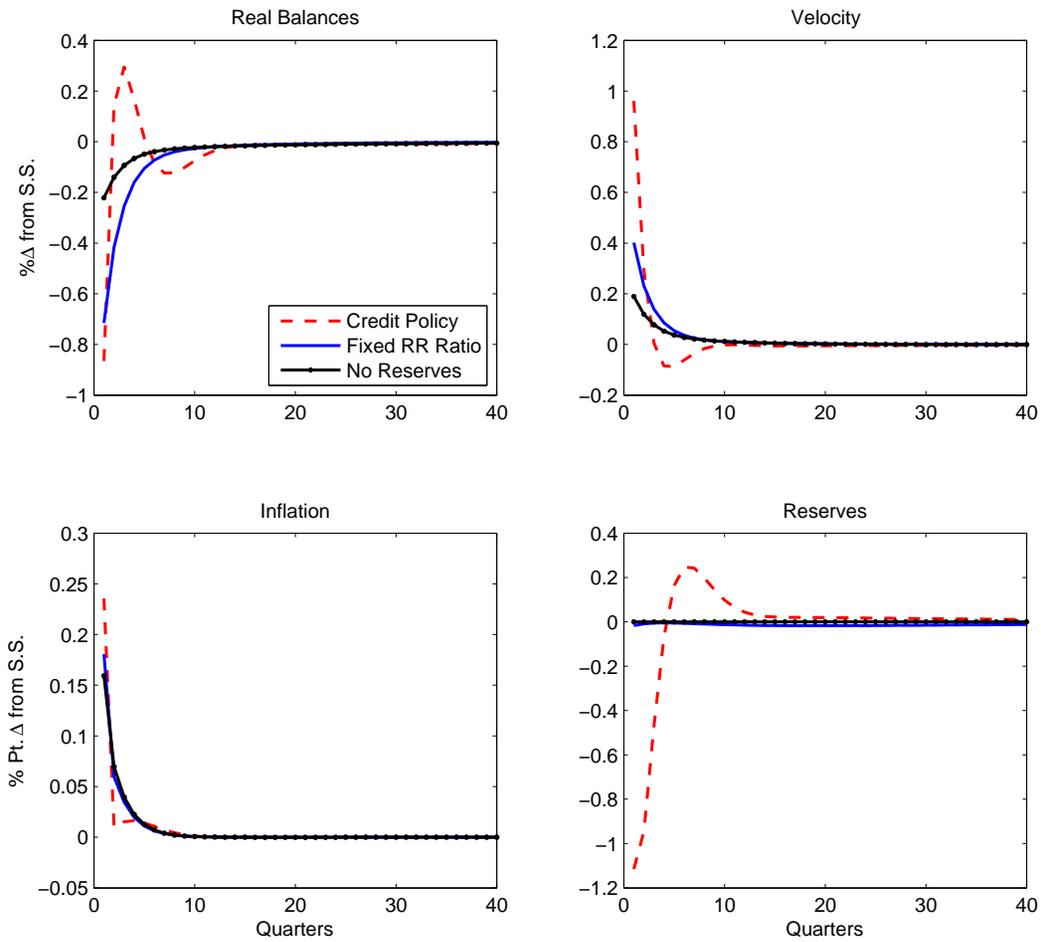
Figure B.6: The Effect of Adverse Money Growth Shocks on Monetary Variables
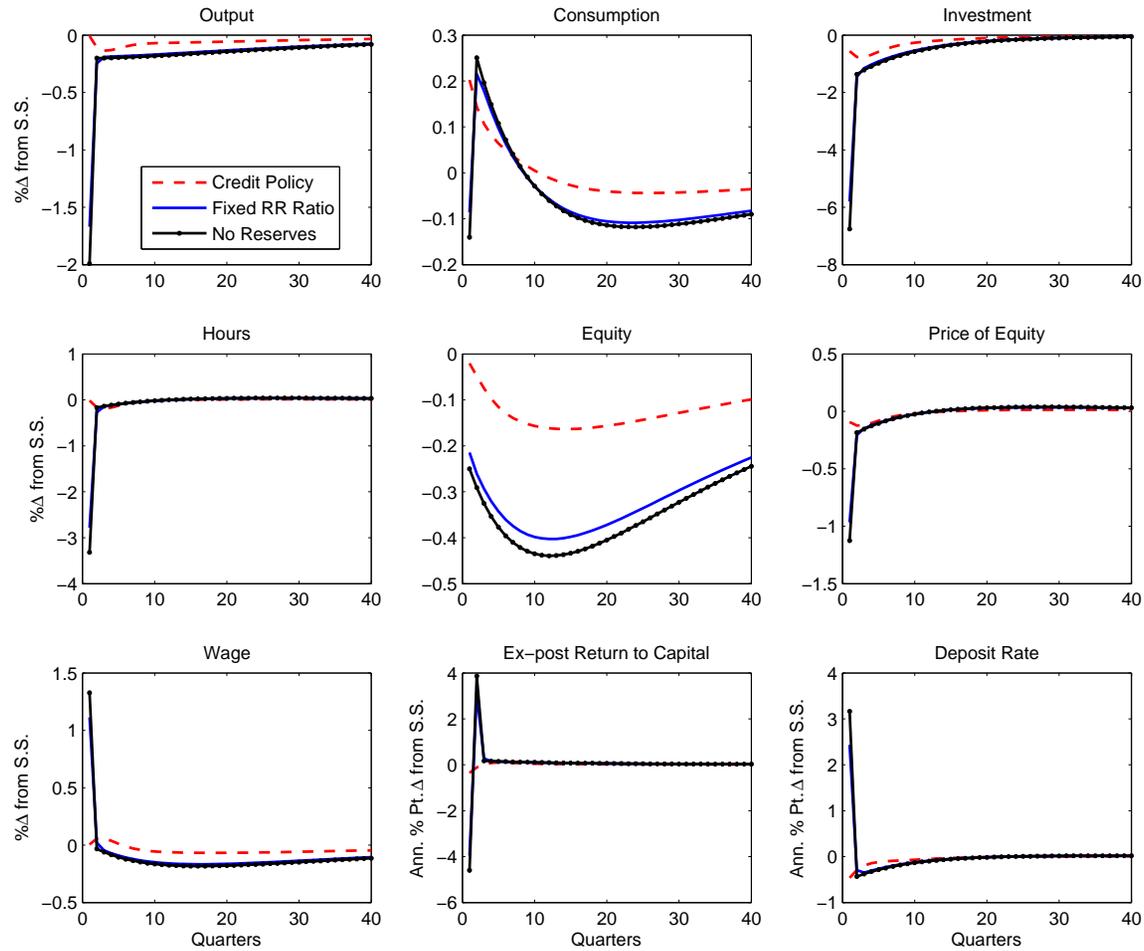
Figure B.7: The Effect of Adverse Financial Shocks on Real Variables
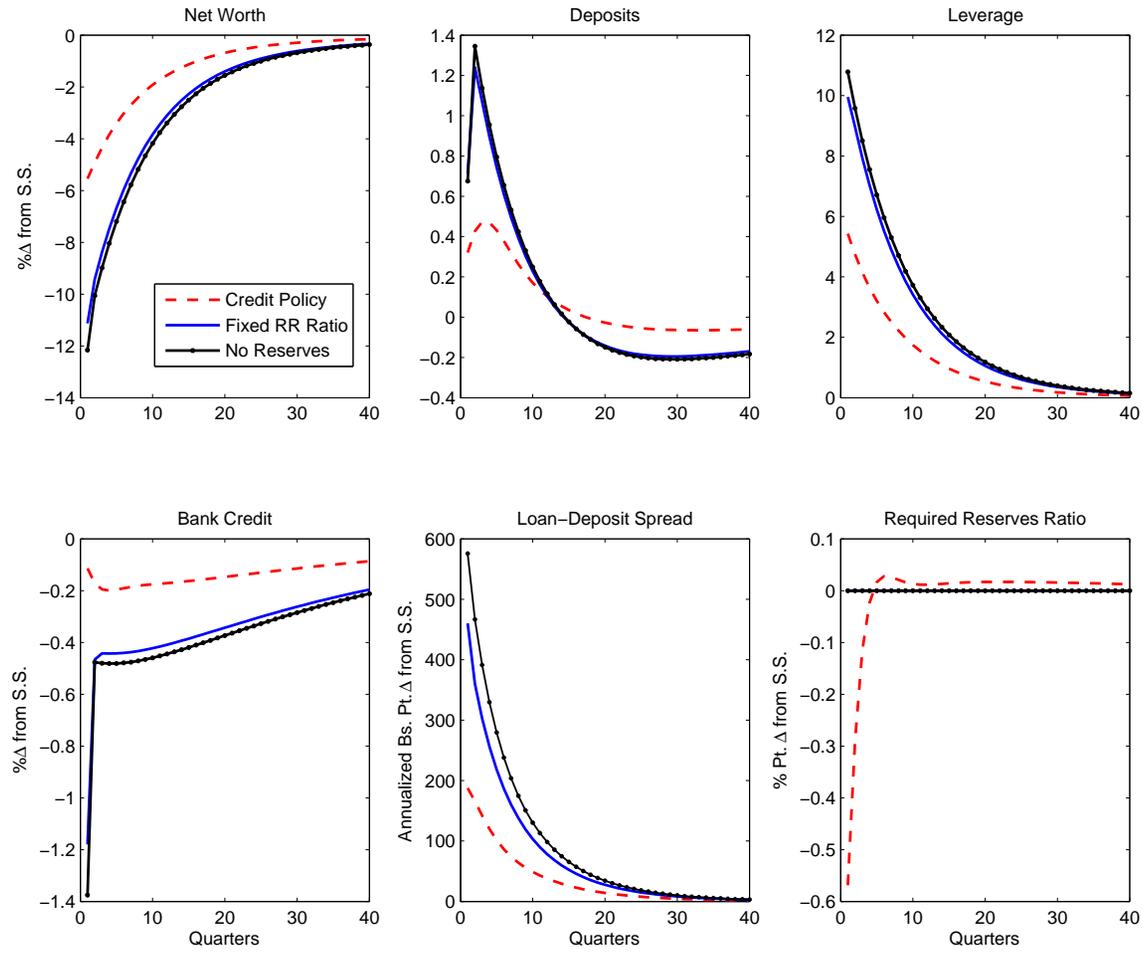
Figure B.8: The Effect of Adverse Financial Shocks on Financial Variables
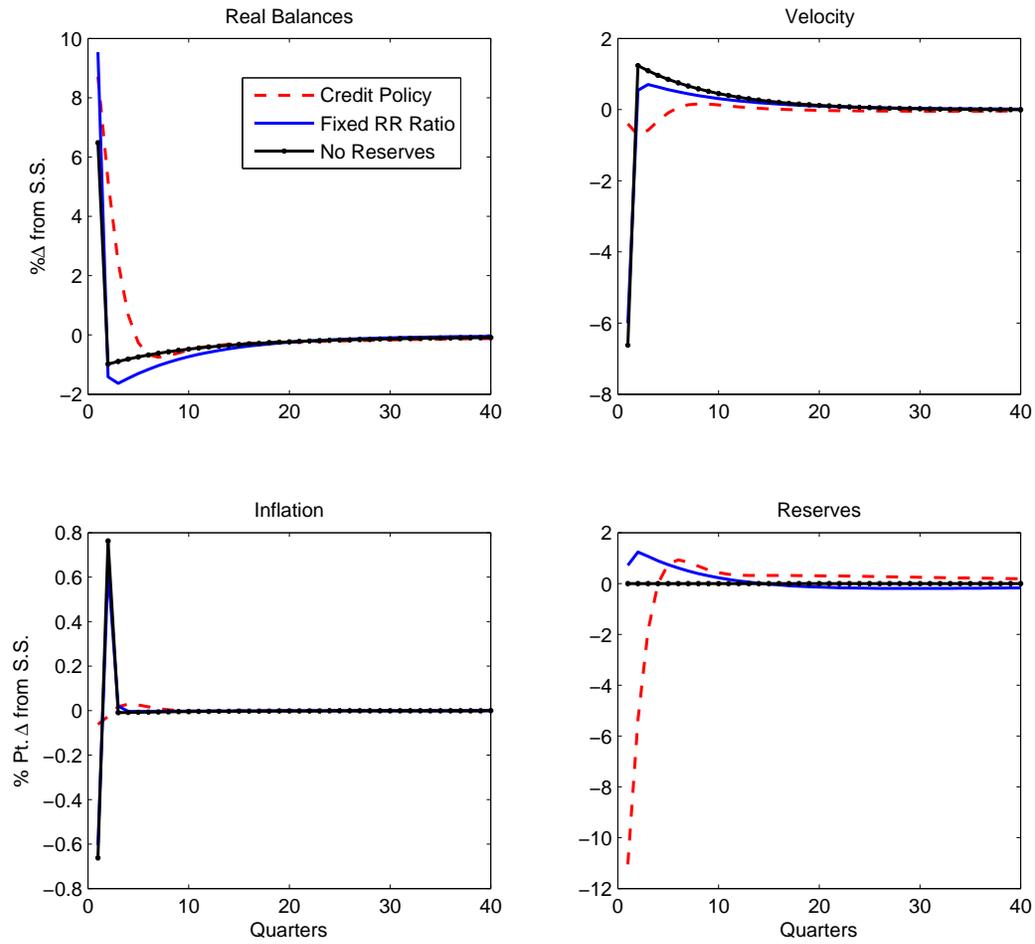
Figure B.9: The Effect of Adverse Financial Shocks on Monetary Variables

B.3 Impulse Responses under Zero RRR Policy
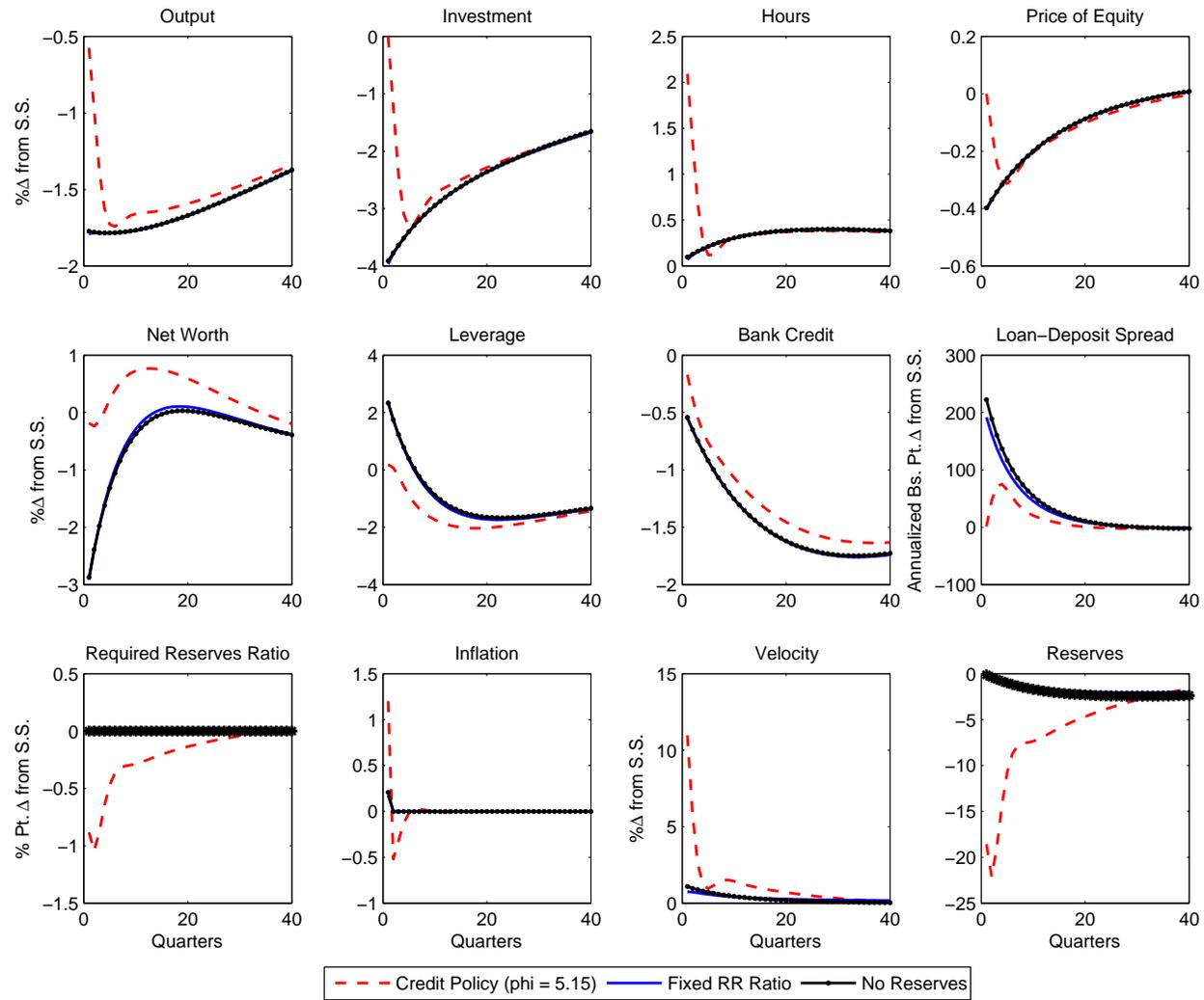
Figure B.10: Impulse Responses Led by a 1-σ Adverse TFP Shock
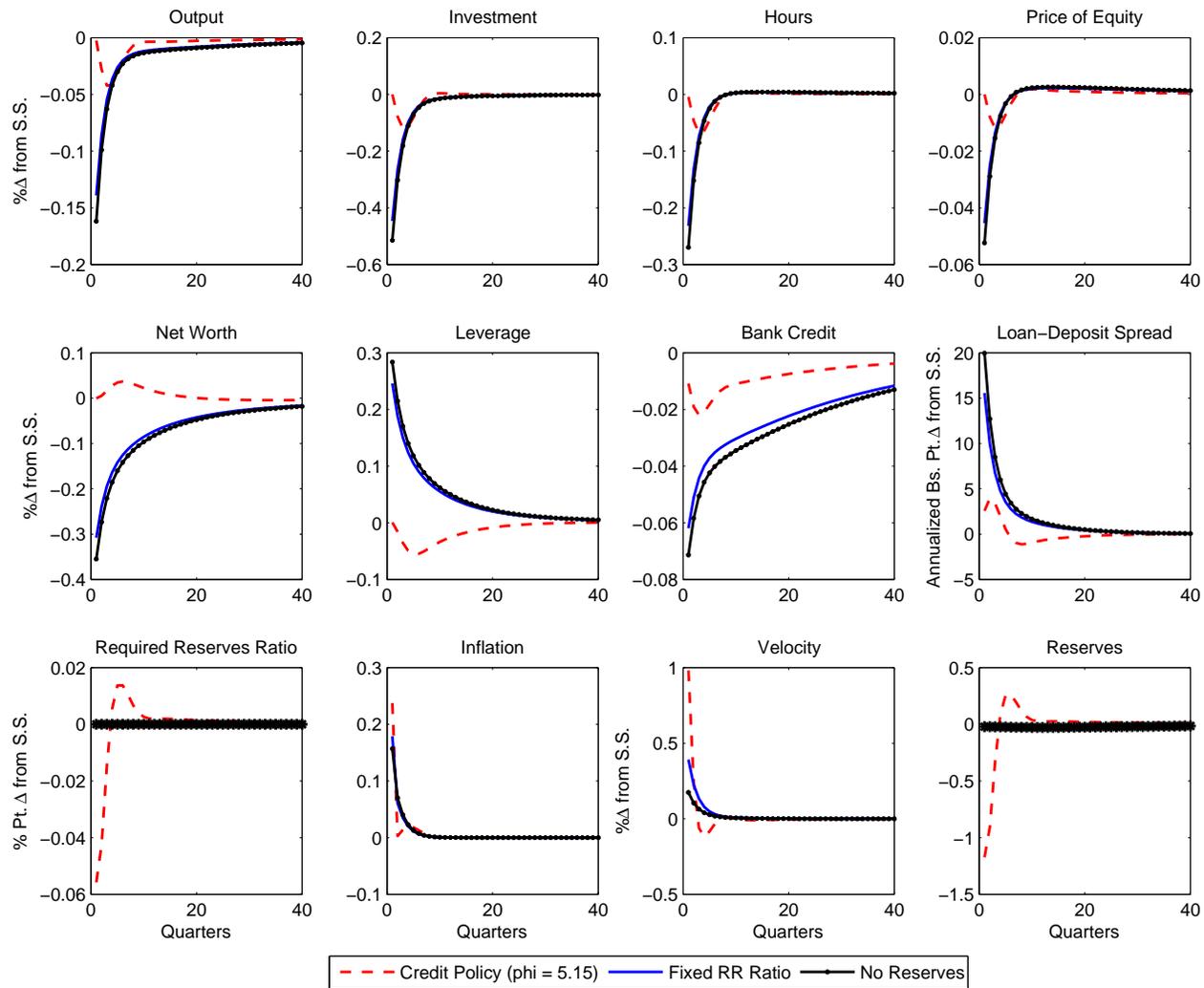
Figure B.11: Impulse Responses Led by a 1-σ Adverse Money Growth Shock
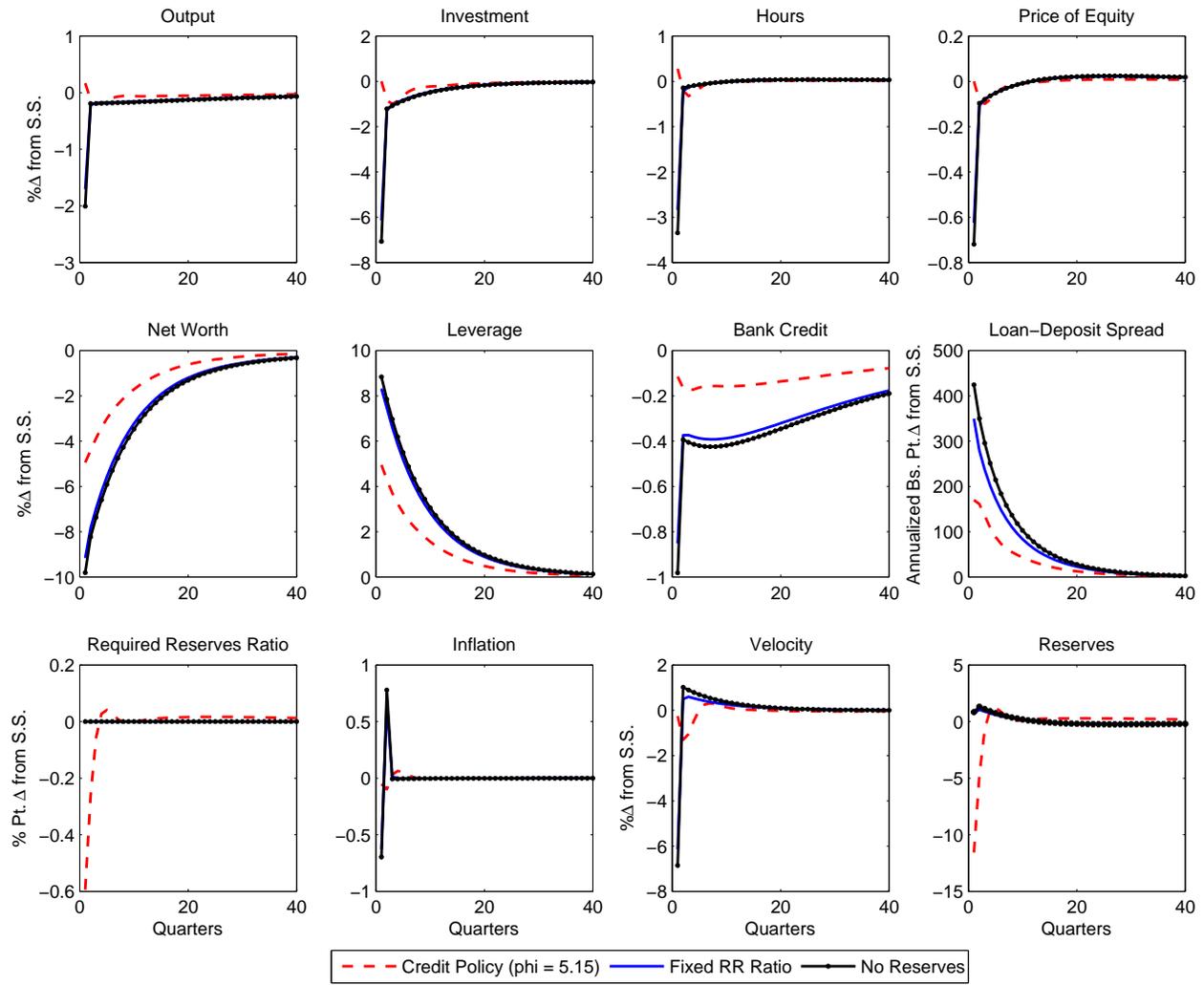
Figure B.12: Impulse Responses Led by a 1-σ Adverse Financial Shock

## B.4   Policy Intensity Experiments
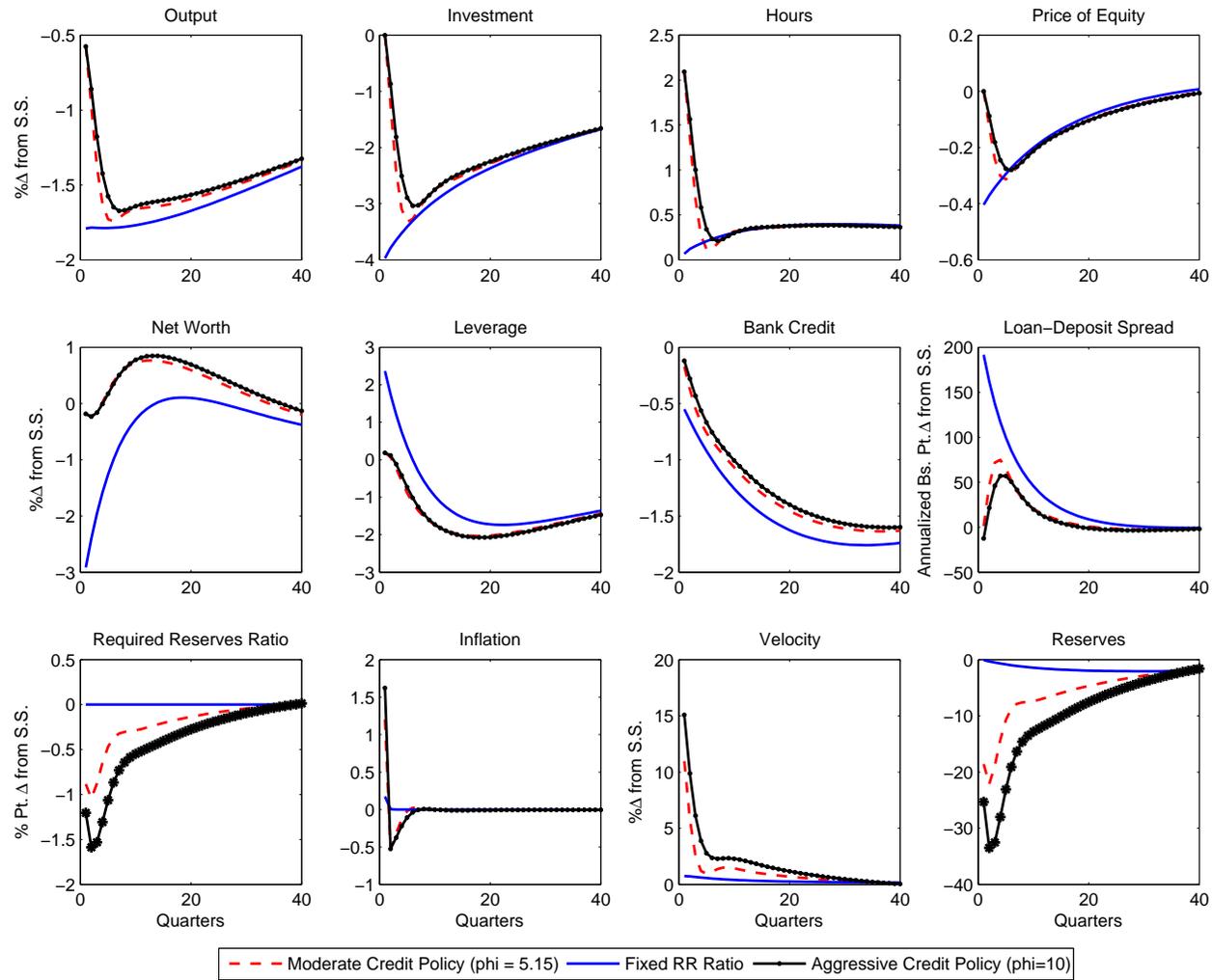
Figure B.13: Impulse Responses Led by a 1-σ Adverse TFP Shock
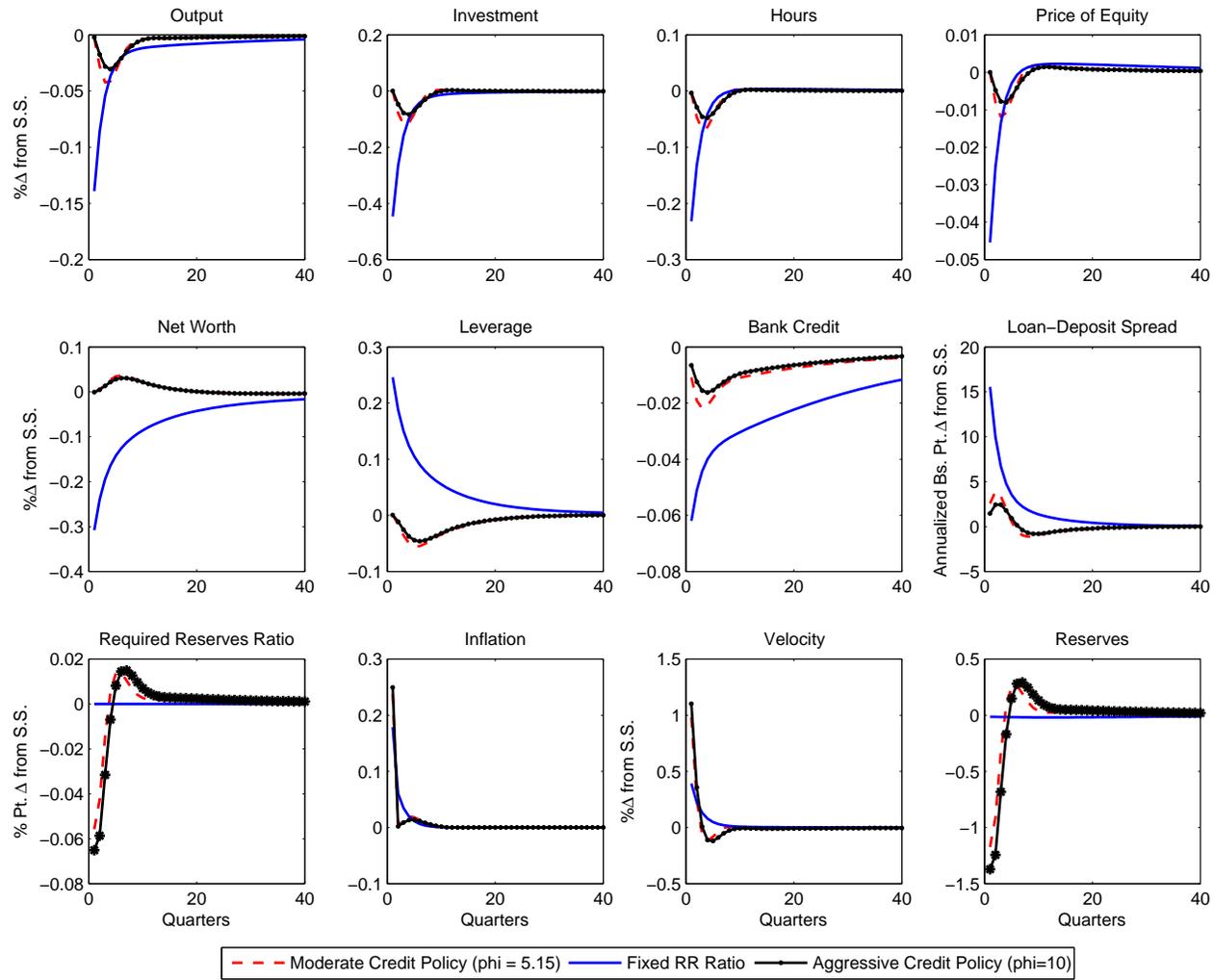
Figure B.14: Impulse Responses Led by a 1-σ Adverse Money Growth Shock
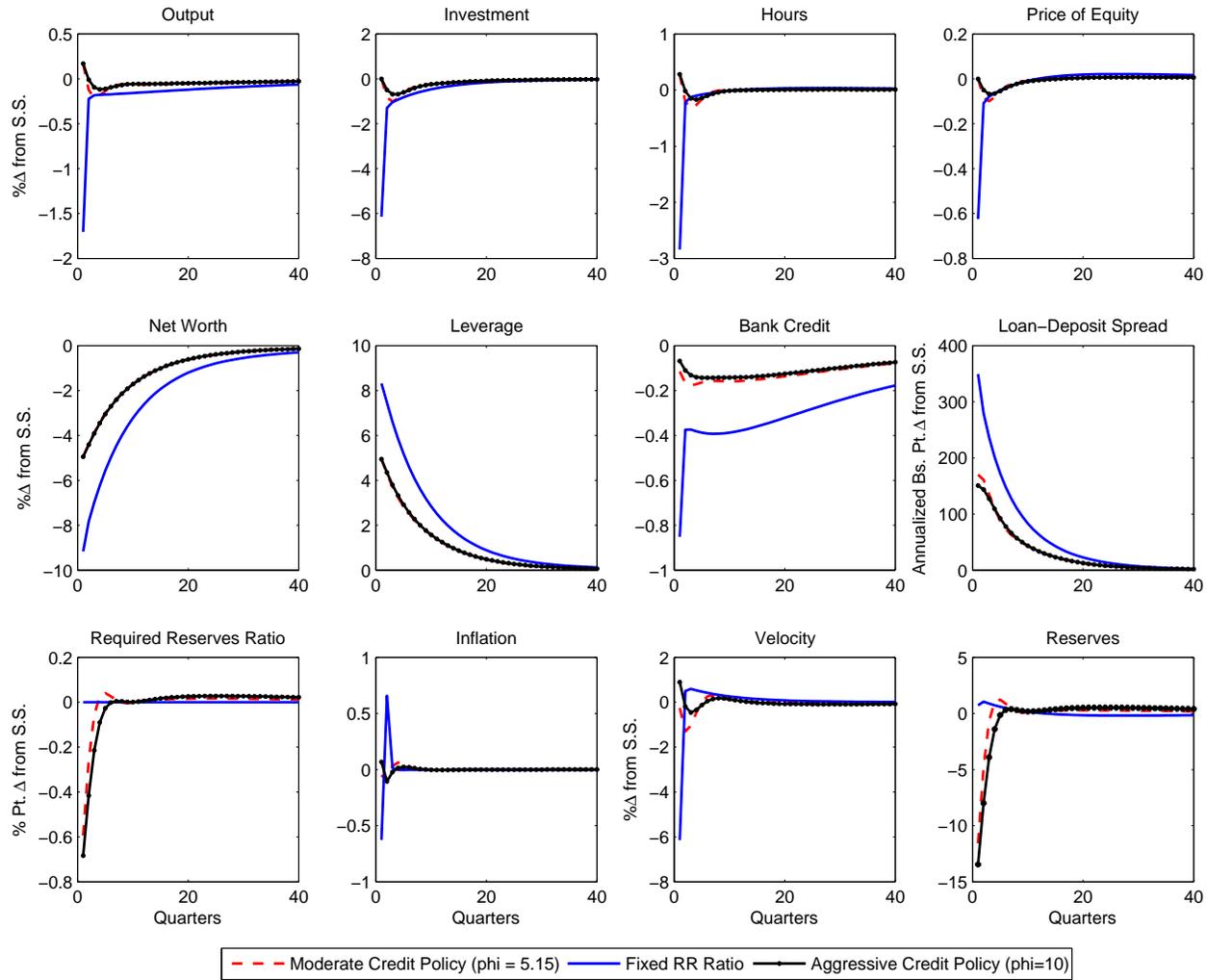
Figure B.15: Impulse Responses Led by a 1-σ Adverse Financial Shock

Bibliography

[1] Adrian, T., Shin, H.S., 2008. "Liquidity and Leverage." *Journal of Financial Intermediation*, Vol.19 (3), pp. 418-437.

[2] Adrian, T., Shin, H.S., 2009. "Financial Intermediaries and Monetary Economics." *Federal Reserve Bank of New York Staff Reports*, No. 398.

[3] Ajello, A. 2010. "Financial Intermediation, Investment Dynamics and Business Cycle Fluctuations." Unpublished manuscript, Northwestern University.

[4] Angeloni, I., Faia, E., 2010. "Capital Regulation and Monetary Policy with Fragile Banks." Unpublished manuscript, European Central Bank.

[5] Barro, R., King, R., 1984. "Time-Separable Preferences and Intertemporal-Substitution Models of Business Cycles." *The Quarterly Journal of Economics*, pp. 817-839.

[6] Basci, E., 2010. "Central Banks and Financial Stability." Presentation at the ECB High-Level PolicyWorkshop on Macroprudential Policy, Frankfurt, December 15.

[7] Basci, E., Kara, A.H., 2011. "Finansal Istikrar ve Para Politikasi." *Iktisat Isletme ve Finans*, Vol.26, p. 302.

[8] 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.

[9] Bernanke, B.S., Gertler M., Gilchrist, S., 1999. "The Financial Accelerator in a Quantitative Business Cycle Framework." In *Handbook of Macroeconomics*, edited by John B. Taylor and Michael Woodford, Vol. 1C. Elsevier.

[10] Boyd, J.H., 2007. "Financial Intermediation." *The New Palgrave Dictionary of Economics Online*.

[11] Brunnermeier, M.K. and Pedersen, L.H., 2009. "Market Liquidity and Funding Liquidity." *The Review of Financial Studies* Vol. 22 (6), pp. 2201-2238.

[12] Carlson, M.A., King, T.B., Lewis, K.F., 2008. "Distress in the Financial Sector and Economic Activity." *Finance and Economics Discussion Series*, Federal Reserve Board, Washington, D.C., 2008-43.

[13] Carlstrom, C.T., Fuerst, T.S., 1998. "Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis." *American Economic Review*, Vol.87, pp. 893-910.

[14] Carlstrom, C.T., Fuerst, T.S., 1998. "Agency Costs and Business Cycles." *Economic Theory*, Vol.12, pp. 583-597.

[15] Christensen, I., Meh C. and Moran, K., 2011. "Bank Leverage Regulation and Macroeconomic Dynamics." *Bank of Canada Working Paper*, No. 2011-32.

[16] 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.

[17] Christiano, L., 2010. "Remarks on Unconventional Monetary Policy." IJCB Conference, Bank of Japan.

[18] Chugh, S., 2010. "Firm Risk and Leverage Based Business Cycles." Unpublished manuscript, University of Maryland.

[19] Cooley, T. and Hansen, G., 1989. "The Inflation Tax in a Real Business Cycle Model." *American Economic Review* Vol. 79 (4), pp. 733-748.

[20] Covas, F., Den Haan, W.J., 2011. "The Cyclical Behavior of Debt and Equity Finance." *American Economic Review*, forthcoming.

[21] Fernald, J., 2009. "A Quarterly, Utilization-Adjusted Series on Total Factor Productivity." Unpublished manuscript, Federal Reserve Bank of San Francisco.

[22] Gertler, M., Gilchrist, S., Natalucci, F.M., 2007. "External Constraints on Monetary Policy and the Financial Accelerator." *Journal of Money, Credit, and Banking*, Vol. 39(2-3), pp. 295-330.

[23] Gertler, M. and Karadi, P., 2011. "A Model of Unconventional Monetary Policy." *Journal of Monetary Economics* Vol. 58, pp. 17-34.

[24] Gertler, M., Kiyotaki, N. 2010. "Financial Intermediation and Credit Policy in Business Cycle Analysis." Unpublished manuscript, Princeton University.

[25] Gertler, M., Kiyotaki, N., Queralto, A. 2011. "Financial Crisis, Bank Risk Exposure and Government Financial Policy." Unpublished manuscript, New York University and Princeton University.

[26] Gilchrist, S., Yankov V., Zakrajsek, E., 2010. "Credit Market Shocks and Economic Fluctuations: Evidence from Corporate Bond and Stock Markets." *Journal of Monetary Economics*, forthcoming.

[27] Gilchrist, S., Zakrajsek, E., 2011. "Monetary Policy and Credit Supply Shocks." *IMF Economic Review*, forthcoming.

[28] 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.

[29] Gray, S., 2011. "Central Bank Balances and Reserve Requirements." *IMF Working Paper*, No.11/36.

[30] Gomme, P., Ravikumar, B., Rupert, P., 2011. "The Return to Capital and the Business Cycle." *Review of Economic Dynamics*, Vol.14, pp. 262-278.

[31] 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.

[32] Hellmann, T.F., Murdock, K.C., Stiglitz, J.E., 2000. "Liberalization, Moral Hazard in Banking, and Prudential Regulation: Are Capital Requirements Enough?." *American Economic Review*, Vol.90(1), pp. 147-165.

[33] Holmstrom B. and Tirole, J., 1997. "Financial Intermediation, Loanable Funds and the Real Sector." *Quarterly Journal of Economics*, Vol.112, pp. 663-691.

[34] Iacoviello, M., 2010. "Financial Business Cycles." *Unpublished manuscript*, Federal Reserve Board.

[35] IMF, 2010. "Global Financial Stability Report (April 2010)." International Monetary Fund.

[36] Jeanne, O., Korinek, A., 2009. "Managing Credit Booms and Busts: A Pigouvian Taxation Approach." Unpublished manuscript, University of Maryland.

[37] Jermann, U., Quadrini, V., 2010. "Macroeconomic Effects of Financial Shocks." *American Economic Review*, forthcoming.

[38] 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.

[39] Kara, A.H., 2012. "Kuresel Kriz Sonrasi Para Politikasi." *CBRT Working Paper Series*, No: 12/17.

[40] Kiyotaki, N., Moore, J., 1997. "Credit Cycles." *Journal of Political Economy*, Vol.105, pp. 211-248.

[41] Kiyotaki, N. and Moore, J., 2008. "Liquidity, Business Cycles, and Monetary Policy.", mimeo.

[42] Kollmann, R., Enders, Z., Muller, G.J., 2011. "Global Banking and International Business Cycles." *European Economic Review*, Vol.55, pp. 407-426.

[43] Korajczyk, R.A., Levy, A., 2003. "Capital Structure Choice: Macroeconomic Conditions and Financial Constraints." *Journal of Financial Economics*, Vol.68, pp. 75-109.

[44] Levin, A.T., Natalucci, F.M., Zakrajsek, E., 2004. "The Magnitude and Cyclical Behavior of Financial Market Frictions." *Finance and Discussion Series*, Federal Reserve Board of Governors, No.70.

[45] 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.

[46] Mendoza, E.G., Quadrini, V., 2010. "Financial Globalization, Financial Crises and Contagion." *Journal of Monetary Economics*, Vol.57, pp. 24-39.

[47] 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.

[48] Mendoza, E.G., Quadrini, V., 2010. "Financial Globalization, Financial Crises and Contagion." *Journal of Monetary Economics*, Vol.57, pp. 24-39.

[49] Mimir, Y., 2011. "Financial Intermediaries, Credit Shocks, and Business Cycles." *Unpublished manuscript*, University of Maryland.

[50] Montoro, C., 2011. "Assessing the Role of Reserve Requirements under Financial Frictions." *Unpublished manuscript*, Bank for International Settlements.

[51] 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.

[52] 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.

[53] Schmitt-Grohe, S., Uribe, M., 2004. "Solving Dynamic General Equilibrium Models Using a Second-Order Approximation to the Policy Function." *Journal of Economic Dynamics and Control*, Vol.28, pp. 755-775.

[54] 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.

[55] Sunel, Enes, 2011. "Essays on the Distributional and Welfare Consequences of Disinflation in Emerging Economies." *Ph.D. Dissertation*, Department of Economics, University of Maryland.

[56] Woodford, M., Curdia, V., 2010. "Credit Spreads and Monetary Policy." *Journal of Money, Credit and Banking*, forthcoming.