Financial intermediaries, credit Shocks and business cycles

Mimir, Yasin

University of Maryland, College Park, Department of Economics

May 2012

Financial Intermediaries, Credit Shocks and Business Cycles*

Yasin Mimir
University of Maryland

May 2012

Abstract

This paper conducts a quantitative analysis of the role of financial shocks and credit frictions affecting the banking sector in driving U.S. business cycles. I first document three key business cycle stylized facts of aggregate financial variables in the U.S. banking sector: (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. The model incorporates empirically-disciplined 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. I show that the benchmark model is able to deliver most of the above stylized facts. Financial shocks and credit frictions in banking sector are important not only for explaining the dynamics of financial variables but also for the dynamics of standard macroeconomic variables. Financial shocks play a major role in driving real fluctuations due to their impact on the tightness of bank capital constraint and the credit spread.

Keywords: Banks, Financial Fluctuations, Credit Frictions, Bank Equity, Real Fluctuations

JEL Classification: E10, E20, E32, E44

*I thank seminar participants at the Board of Governors of the Federal Reserve System, Bank of Canada, Bank of England, Uppsala University, New Economic School, Koc University, Ozyegin University, TOBB-ETU, METU-NCC, 2011 Annual Meeting of the Society for Economic Dynamics, 2011 International Conference on Computing in Economics and Finance, 2011 Eastern Economic Association Conference, University of Maryland, 2010 Midwest Macroeconomics Meetings, Bilkent University, Central Bank of the Republic of Turkey, 2010 International Conference of Middle East Economic Association, 2010 International Conference on Economic Modeling for helpful comments. I am also grateful to the Federal Reserve Board for their hospitality. I also would like to thank S. Boragan Aruoba, Sanjay K. Chugh, Pablo N. D'Erasmo, Anton Korinek, Enrique G. Mendoza, John Shea, and Enes Sunel for very constructive suggestions. All remaining errors are mine. Contact Details: Department of Economics, University of Maryland, 3105 Tydings Hall, College Park MD 20742. E-mail: mimir@econ.umd.edu.

1 Introduction

What are the cyclical properties of financial flows in the U.S. banking sector? How important are financial shocks relative standard productivity shocks in driving real and financial business cycles in the U.S.? To address these questions, this paper proposes an equilibrium 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 paper, I show that financial shocks to 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 credit spread.

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 in order to have balance sheet fluctuations of financial sector matter for real fluctuations. 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] The second departure is that the model incorporates

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

[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 D.

[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.

shocks to bank net worth (i.e."financial shocks") that alter the ability of banks to borrow and to extend loans to non-financial businesses.[4] This shock can be interpreted as 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).

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]Hancock, Laing and Wilcox (1995), Peek and Rosengren (1997, 2000) empirically show that 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 paper, 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 E. The main results of the paper do not change under these alternative measures.

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

This paper 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 paper 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

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

[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 paper. In that sense, this paper 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)

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 paper 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 undermine the flow of funds between savers and borrowers in the recent recession. My work is different from his paper 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 paper 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 & Kiyotaki (2010), and Gertler & 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 paper is structured as follows: In Section 2, I document evidence on the real and financial fluctuations in U.S. data. Section 3 describes the theoretical model. Section 4 presents the model parametrization and calibration together with the quantitative results of the model. Section 5 concludes.

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

[11] The latter also features the interbank market.

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 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.

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 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'

[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.

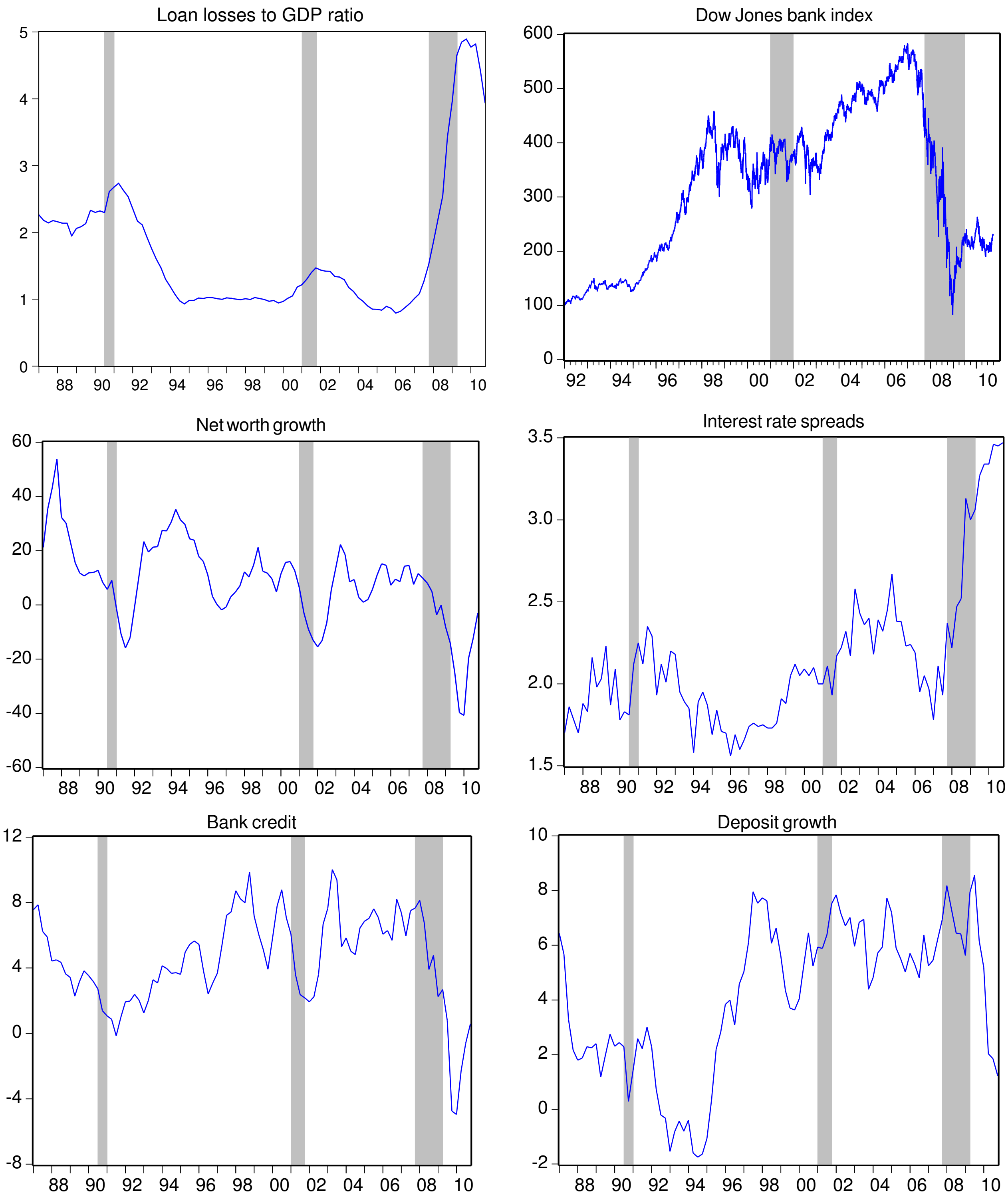


Figure 1: Financial Flows in the U.S. Economy

Table 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.

assets (bank credit), liabilities (deposits), net worth, leverage ratio and loan spread. 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 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 more volatile. Bank 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.[13]

[13]I also reproduce Table 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 reproduced table is available upon request. The results show that the key stylized facts about real and financial variables described above are robust to the sample period taken.

Table 2: The Sequence of Events in a Given Time Period

1. Productivity z_t is realized.
2. Firms hire labor H_t and use capital K_t they purchased in period $t-1$, which are used for production, $Y_t = z_t\text{F}(K_t,\, H_t)$.
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 probability (1-θ).
5. Recovery rate ω_t is realized.
6. Households make their consumption and saving decisions and deposit their resources at banks.
7. Firms sell their depreciated capital to capital producers. These agents make investment and produce new capital K_{t+1}.
8. Firms issue shares $[s_t = K_{t+1}]$ and sell these shares to banks to finance their capital expenditures.
9. Banks purchase firms' shares and their incentive constraints bind.
10. Firms purchase capital K_{t+1} from capital producers at the price of q_t with borrowed funds.

3 A Business Cycle Model with Financial Sector

The model is an otherwise standard real business cycle model with a financial sector. 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 are incorporated into the model in order to introduce capital adjustment costs in a tractable way. Table 2 shows the sequence of events in a given time period in the theoretical model described below. The section below will clarify this timeline.

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

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

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.[14] Moreover, there is perfect consumption insurance within each household.

At any point in time the fraction $1-\zeta$ of the household members are workers 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. 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.[15]

The household budget constraint is given by

$$c_t + b_{t+1} = w_t L_t + (1+r_t)b_t + \Pi_t \tag{2}$$

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 gives to 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 (minus) the amount of wealth redistributed from banks (households) to households (banks).

The household chooses c_t, L_t, and b_{t+1} to maximize (1) subject to the sequence of flow budget constraints in (2). The resulting first order conditions for labor supply and deposit holdings are given by

$$\frac{U_l(t)}{U_c(t)} = w_t \tag{3}$$

$$U_c(t) = \beta(1+r_{t+1})E_t U_c(t+1) \tag{4}$$

[14]This assumption ensures independent decision-making. Depositors are not the owners of the bank, so the banker don't maximize the depositors' utility, but their own expected terminal net worth.

[15]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).

The first condition states that the marginal rate of substitution between consumption and leisure is equal to the wage rate. The second condition 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.

3.2 Financial Intermediaries

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, $\omega_t \widetilde{n}_{jt}$ is the effective net worth of the financial intermediary. For notational convenience, I denote $\omega_t \widetilde{n}_{jt}$ 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

$$q_t s_{jt} = b_{jt+1} + n_{jt} \tag{5}$$

where q_t is the price of 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.[16] 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 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

[16] 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.

households (liabilities of financial intermediary). Thus the law of motion for bank net worth is given by

$$\widetilde{n}_{jt+1} = (1 + r_{kt+1})q_t s_{jt} - (1 + r_{t+1})b_{jt+1} \tag{6}$$

Using the balance sheet of the financial firm given by (5), we can re-write (6) as follows:

$$\widetilde{n}_{jt+1} = (r_{kt+1} - r_{t+1})q_t s_{jt} + (1 + r_{t+1})n_{jt} \tag{7}$$

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, $q_t s_{jt}$.

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

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

Since the 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, the 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.[17]

[17] 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.

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:

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

The left-hand side of (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 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.

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.

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 B.1

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

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

where

$$\nu_t = E_t[(1-\theta)\beta\Lambda_{t,t+1}(r_{kt+1} - r_{t+1}) + \beta\Lambda_{t,t+1}\theta\frac{q_{t+1}s_{jt+1}}{q_t s_{jt}}\nu_{t+1}] \tag{11}$$

$$\eta_t = E_t[(1-\theta)\beta\Lambda_{t,t+1}(1 + r_{t+1}) + \beta\Lambda_{t,t+1}\theta\frac{n_{jt+1}}{n_{jt}}\eta_{t+1}] \tag{12}$$

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:

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

Proposition 2 *The incentive compatibility constraint binds as long as* $0 < \nu_t < \lambda$.

Proof: I prove this by contradiction. Assume that $\nu_t \geq \lambda$. Then the left-hand side of (13) is always greater than the right-hand side of (13) since $\eta_t n_{jt} > 0$ as can be seen from (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:

$$E_{t+i} \beta \Lambda_{t,t+1+i} (r_{kt+1+i} - r_{t+1+i}) \geq 0 \quad \forall i \geq 0 \tag{14}$$

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

Proof: See Appendix B.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:

$$q_t s_{jt} = \frac{\eta_t}{\lambda - \nu_t} n_{jt} \tag{15}$$

The constraint (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, de-leveraging 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:

$$\frac{b_{jt+1}}{n_{jt}} = \frac{\eta_t}{\lambda - \nu_t} - 1 \tag{16}$$

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.[18]

Using (15), I can re-write the law of motion for the banker's net worth as follows:

$$\widetilde{n}_{jt+1} = [(r_{kt+1} - r_{t+1})\frac{\eta_t}{\lambda - \nu_t} + (1 + r_{t+1})]n_{jt} \tag{17}$$

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

Proof: From (17), one can obtain the following:

$$\frac{n_{jt+1}}{n_{jt}} = [(r_{kt+1} - r_{t+1})\frac{\eta_t}{\lambda - \nu_t} + (1 + r_{t+1})] \tag{18}$$

$$\frac{q_{t+1}s_{jt+1}}{q_t s_{jt}} = \frac{\frac{\eta_{t+1}}{\lambda - \nu_{t+1}}}{\frac{\eta_t}{\lambda - \nu_t}} \frac{n_{jt+1}}{n_{jt}} \tag{19}$$

The expressions above show that banks have identical expected growth rates of assets and

[18] 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.

net worth, thus have identical leverage ratios.[19]

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

$$q_t s_t = \frac{\eta_t}{\lambda - \nu_t} n_t \tag{20}$$

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), $\widetilde{n}_{t+1}$, is the sum of the net worth of surviving financial intermediaries from the previous period, $\widetilde{n}_{et+1}$, and the net worth of entering financial intermediaries, $\widetilde{n}_{nt+1}$. Thus, we have

$$\widetilde{n}_{t+1} = \widetilde{n}_{et+1} + \widetilde{n}_{nt+1} \tag{21}$$

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

$$\widetilde{n}_{et+1} = \theta[(r_{kt+1} - r_{t+1})\frac{\eta_t}{\lambda - \nu_t} + (1 + r_{t+1})]n_t \tag{22}$$

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. 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

$$\widetilde{n}_{nt+1} = \epsilon n_t \tag{23}$$

Using (21), (22), and (23), we obtain the following law of motion for $\widetilde{n}_{t+1}$:

$$\widetilde{n}_{t+1} = \theta[(r_{kt+1} - r_{t+1})\frac{\eta_t}{\lambda - \nu_t} + (1 + r_{t+1})]n_t + \epsilon n_t \tag{24}$$

[19]This immediately implies that η_t and ν_t are independent of j. In Appendix B.1, I use this result in explicit derivation of η_t and ν_t.

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 the constant returns to scale function:

$$Y_t = z_t F(K_t, H_t) = z_t K_t^{\alpha} H_t^{1-\alpha} \tag{25}$$

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

$$q_t s_t = q_t K_{t+1} \tag{26}$$

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:

$$w_t = z_t F_H(K_t, H_t) \tag{27}$$

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

$$r_{kt+1} = \frac{z_{t+1} F_K(K_{t+1}, H_{t+1}) + q_{t+1}(1-\delta)}{q_t} - 1 \tag{28}$$

Labor demand condition (27) simply states that the wage rate is equal to the marginal product of labor. Moreover, condition (28) states that the ex-post real rate of return on capital is equal to the marginal product of capital plus the capital gain from changed prices.

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 some 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.[20]

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:

$$\max_{I_t} q_t K_{t+1} - q_t(1-\delta)K_t - I_t \tag{29}$$

$$s.t.\ \ K_{t+1} = (1-\delta)K_t + \Phi\left(\frac{I_t}{K_t}\right)K_t \tag{30}$$

where I_t) is the total investment by capital producing firms and $\Phi\left(\frac{I_t}{K_t}\right)$ is the capital adjustment cost function. The resulting optimality condition gives the following "Q" relation for investment:

$$q_t = \left[\Phi'\left(\frac{I_t}{K_t}\right)\right]^{-1} \tag{31}$$

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 expenditures 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.

I leave the definition of the competitive equilibrium of the model to Appendix C.

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

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.

4.1 Functional Forms, Parametrization and Calibration

The quantitative analysis uses the following functional forms for preferences, production technology and capital adjustment costs:[21]

$$U(c, 1-L) = log(c) + \upsilon(1-L) \tag{32}$$

$$F(K, H) = K^{\alpha} H^{1-\alpha} \tag{33}$$

$$\Phi\left(\frac{I}{K}\right) = \frac{I}{K} - \frac{\varphi}{2}\left[\frac{I}{K} - \delta\right]^2 \tag{34}$$

Table 4 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. 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.[22] The quarterly depreciation rate of capital is set to 2.25% to match the average annual investment to capital ratio.

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.[23] I pick other two parameters

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

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

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

Table 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

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. Using the production function, I obtain

$$z_t = \frac{y_t}{K_t^\alpha H_t^{1-\alpha}} \tag{35}$$

Using the empirical series for output, y_t, capital, K_t, and labor, H_t, I use equation (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

$$\omega_t = \frac{1}{\theta[(r_{kt+1} - r_{t+1})\frac{\eta_t}{\lambda - \nu_t} + (1 + r_{t+1})] + \epsilon} \frac{\widetilde{n}_{t+1}}{\widetilde{n}_t} \tag{36}$$

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 (52) obtain the ω_t series.[24] Then I construct the

[24] I constructed two ω 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).

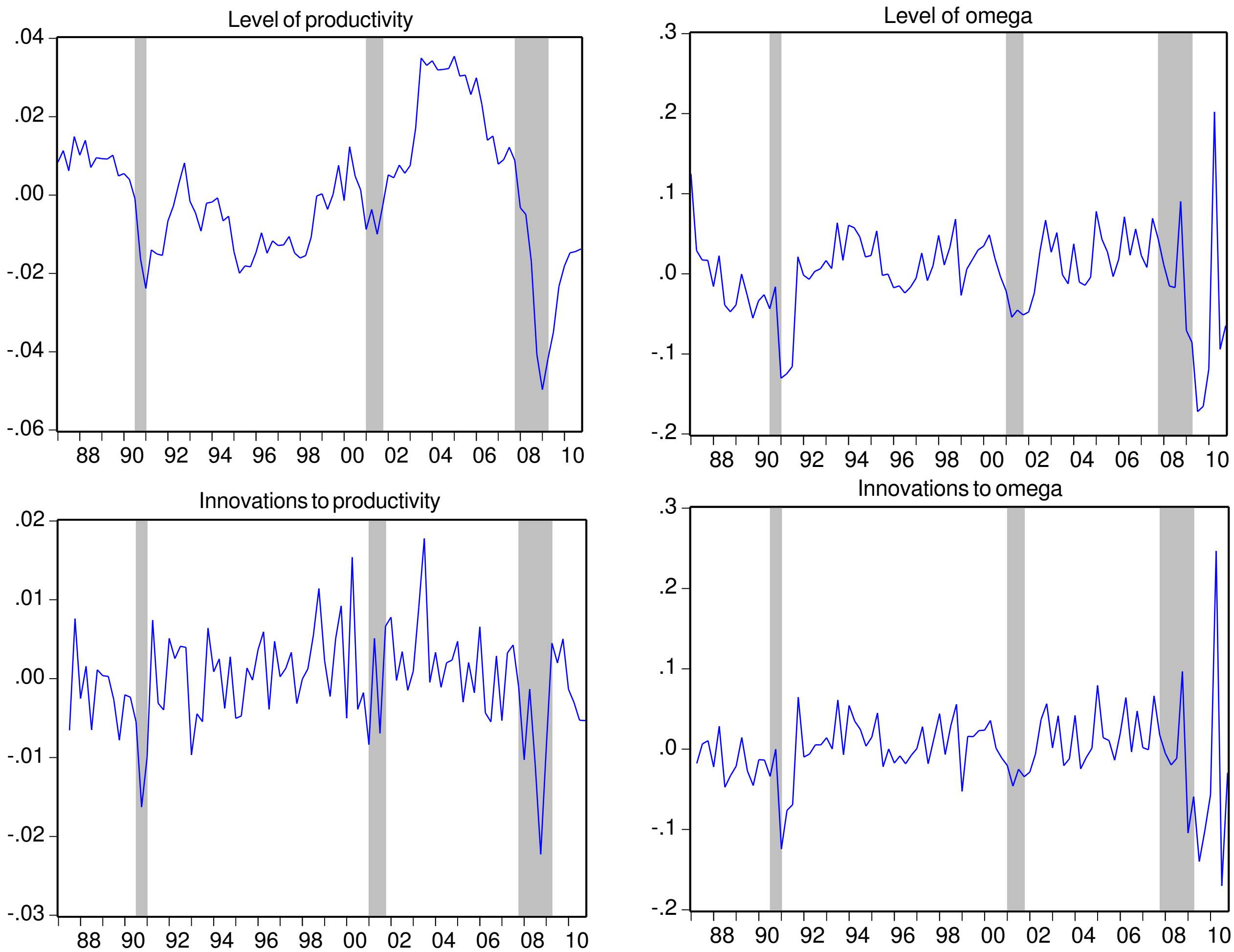


Figure 2: Time Series of Shocks to Productivity and Credit Conditions

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:

$$log(z_{t+1}) = \rho_z log(z_t) + \epsilon^z_{t+1} \tag{37}$$

$$log(\omega_{t+1}) = \rho_\omega log(\omega_t) + \epsilon^\omega_{t+1} \tag{38}$$

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 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. The bottom panels 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.

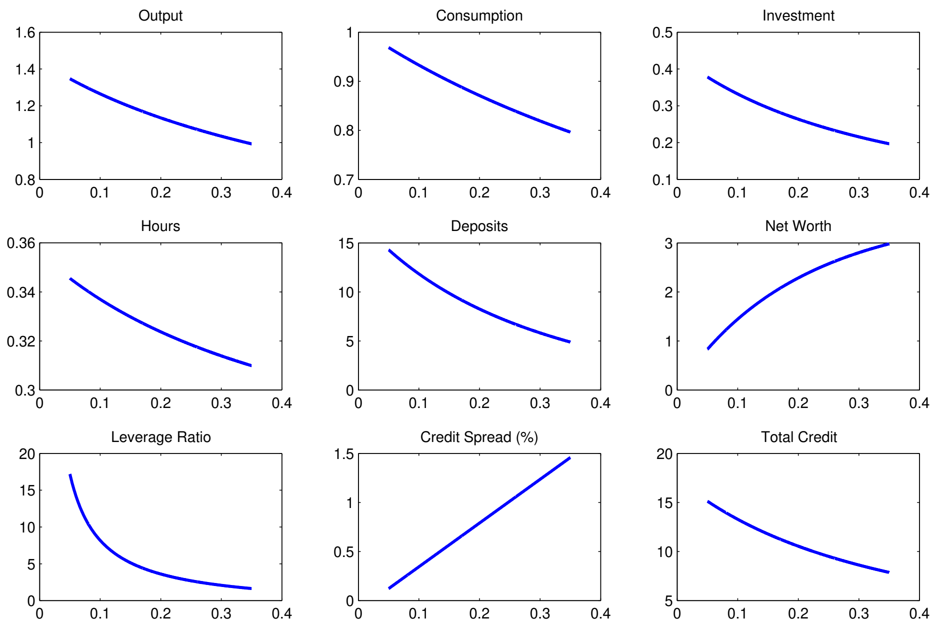


Figure 3: Long-run equilibrium as a function of fraction of diverted funds by bankers

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:

$$y = \left[\frac{\alpha}{\frac{(1-\beta\theta)\mu\lambda}{(1-\theta)\beta(1+\mu)} + \frac{(1-\beta)}{\beta} + \delta} \right]^{\frac{1}{(1-\alpha)}} \overline{L}^{2-\alpha} \tag{39}$$

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

$$\frac{\partial y}{\partial \mu} = -\frac{\alpha}{(1-\alpha)} \left[\frac{\alpha}{\frac{(1-\beta\theta)\mu\lambda}{(1-\theta)\beta(1+\mu)} + \frac{(1-\beta)}{\beta} + \delta} \right]^{\frac{\alpha}{(1-\alpha)}} \overline{L}^{2-\alpha} \left[\frac{(1-\theta)\beta(1-\beta\theta)\lambda}{[(1-\theta)\beta(1+\mu)]^2} \right]^{-2} < 0 \tag{40}$$

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.

$$(r_k - r) = \frac{(1-\beta\theta)\mu\lambda}{(1-\theta)\beta(1+\mu)} \tag{41}$$

The term at the right-hand side of equation (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.

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

$$\frac{\partial y}{\partial \lambda} = -\frac{\alpha \overline{L}^{2-\alpha}}{(1-\alpha)} \left[\frac{\alpha \left[\frac{(1-\beta\theta)[(1-\epsilon)\beta-\theta]}{(1-\theta)\beta(1-\epsilon)\beta} \right]^{\frac{(1-\alpha)}{\alpha}}}{\frac{(1-\beta\theta)[(1-\epsilon)\beta-\theta]\lambda}{(1-\theta)\beta(1-\epsilon)\beta} + \frac{(1-\beta)+\beta\delta}{\beta}} \right]^{\frac{\alpha}{(1-\alpha)}} \left[\frac{(1-\beta\theta)[(1-\epsilon)\beta-\theta]\lambda}{(1-\theta)\beta(1-\epsilon)\beta} + \frac{(1-\beta)+\beta\delta}{\beta} \right]^{-2} < 0 \tag{42}$$

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 3. Figure 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.

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.

Figure 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 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.[25]

[25]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.

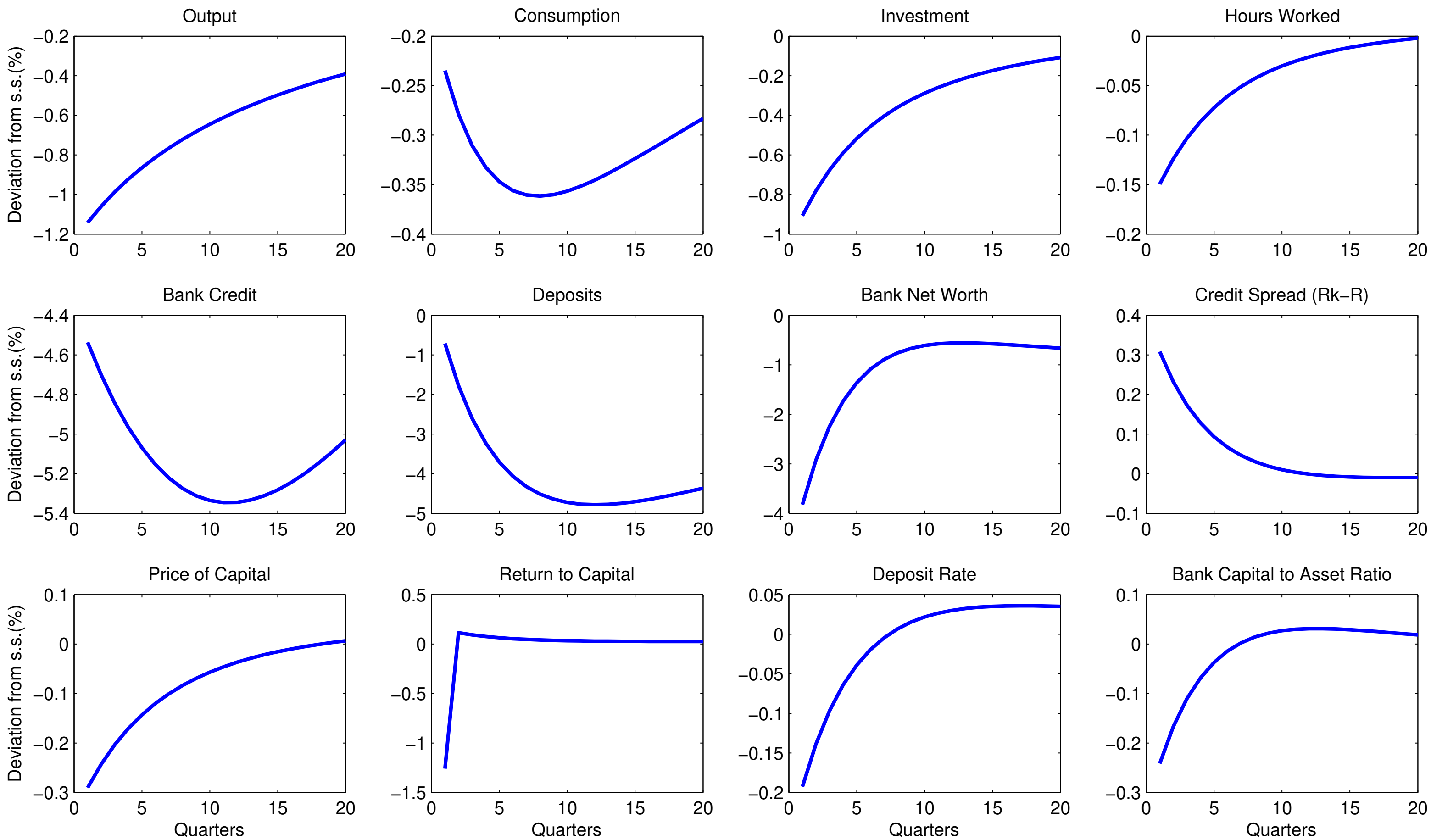


Figure 4: Impulse responses to a negative one-standard-deviation productivity shock

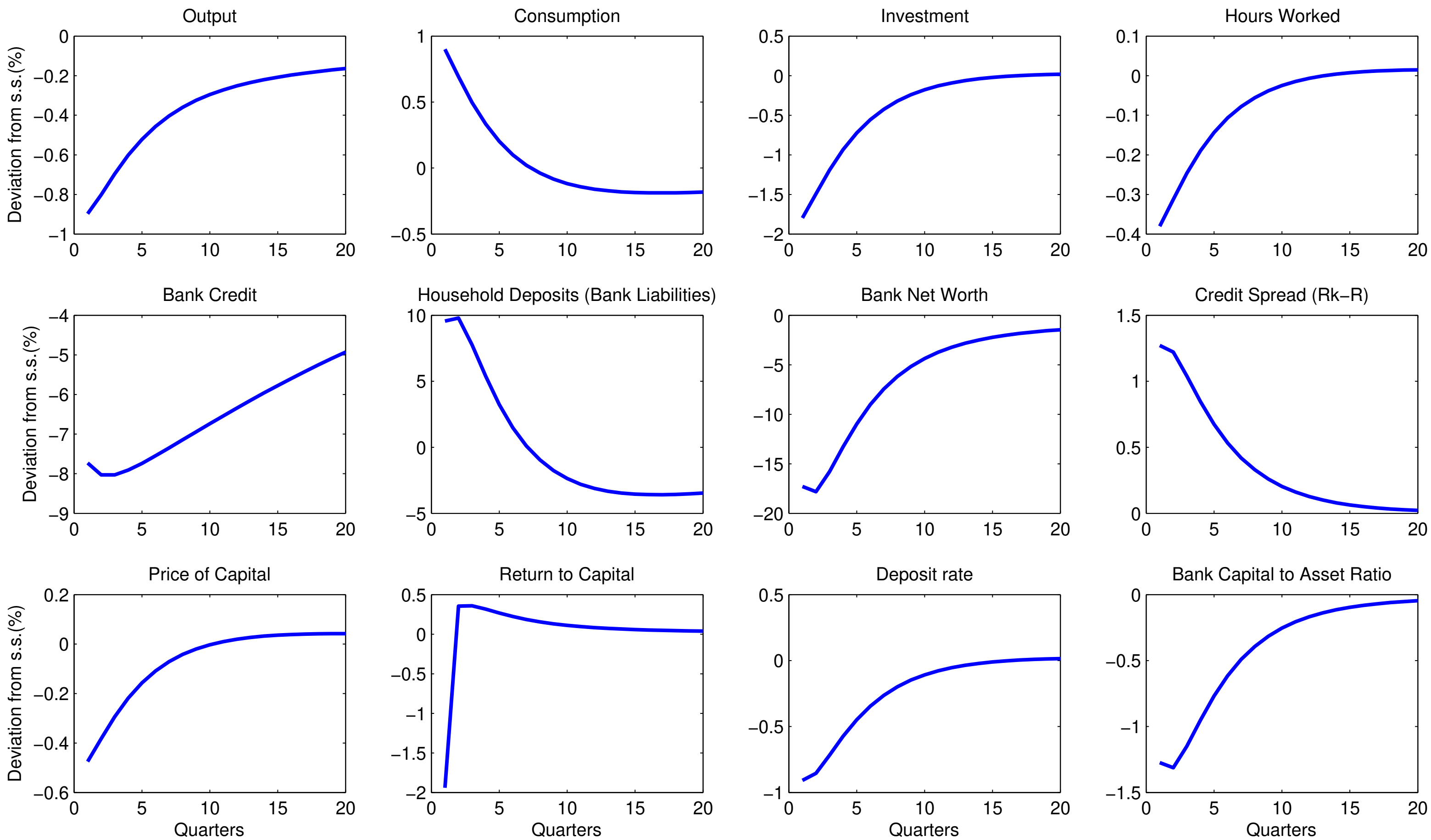


Figure 5: Impulse responses to a negative one-standard-deviation net worth shock

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 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 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. Column 5 of the table shows the real and financial statistics in the benchmark economy driven by both shocks. This model is even closer

Table 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.

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. 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 paper: the benchmark model driven by both shocks is able to deliver most of the key stylized facts about real and financial variables simultaneously.

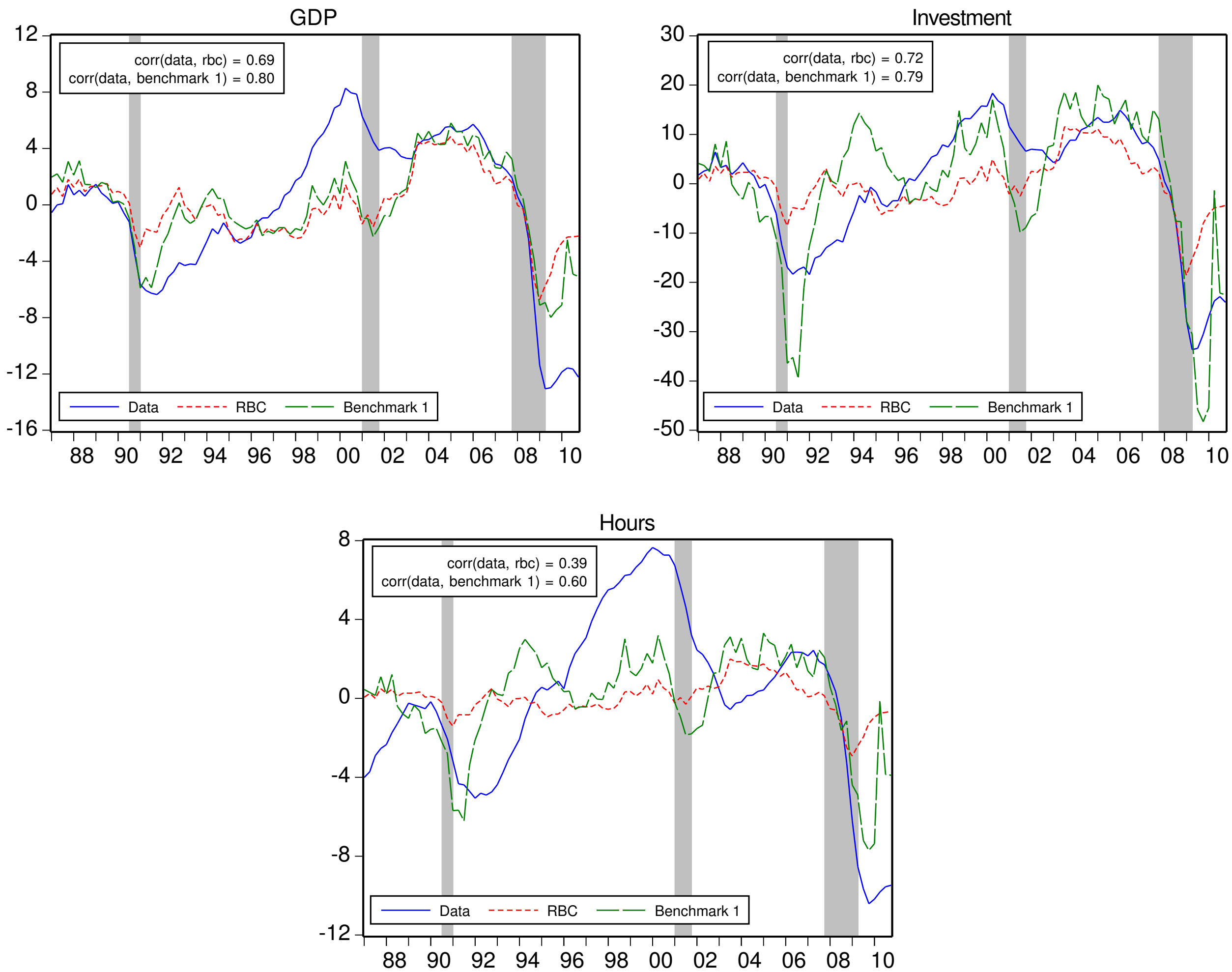


Figure 6: Real Fluctuations: Benchmark vs. RBC model

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.[26] I basically 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 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 series 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 all real variables, 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.

Figure 7 displays the quarterly time series of output, investment and hours 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 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

[26] 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 (53) and (54).

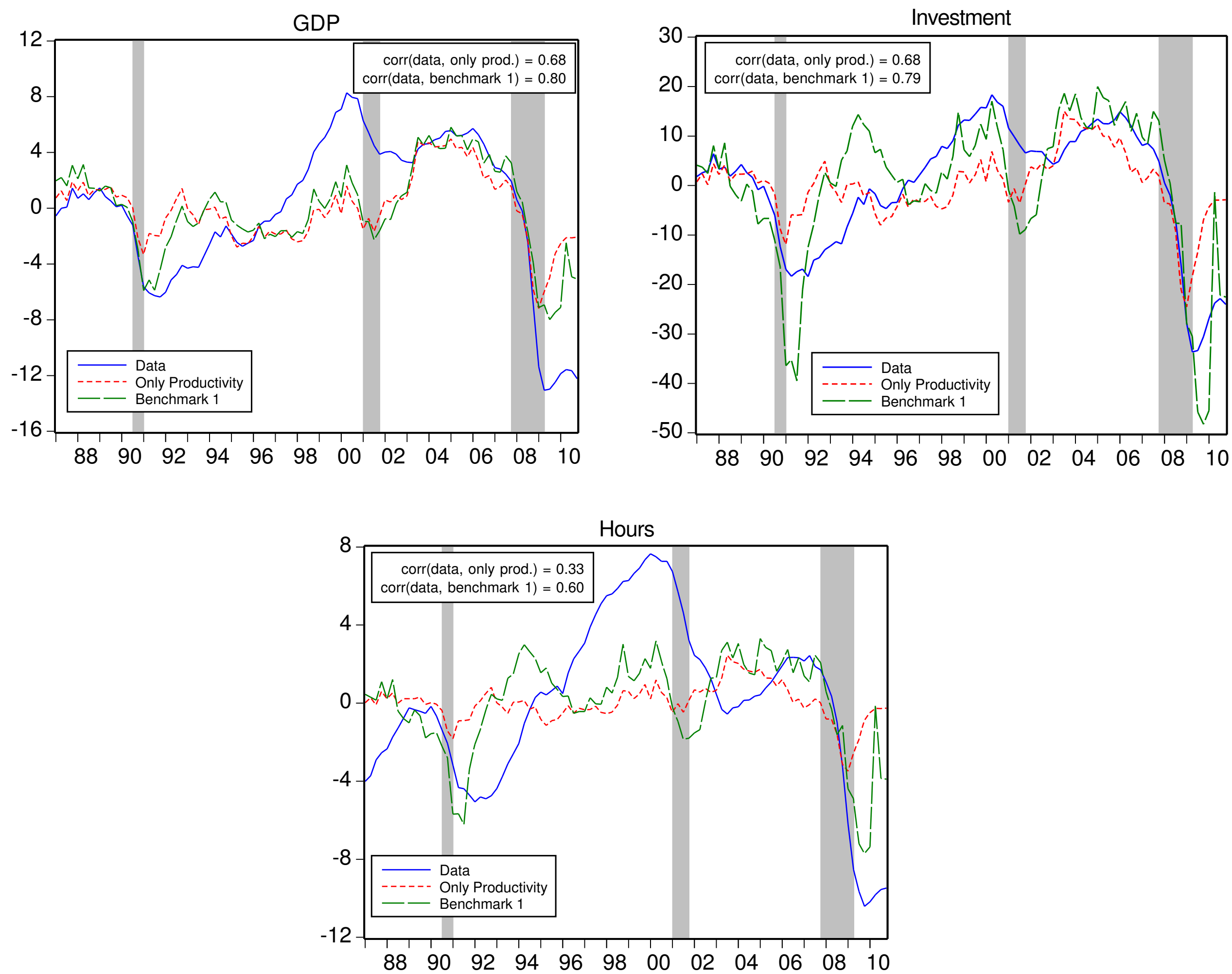


Figure 7: Real Fluctuations: Benchmark vs. Only Productivity

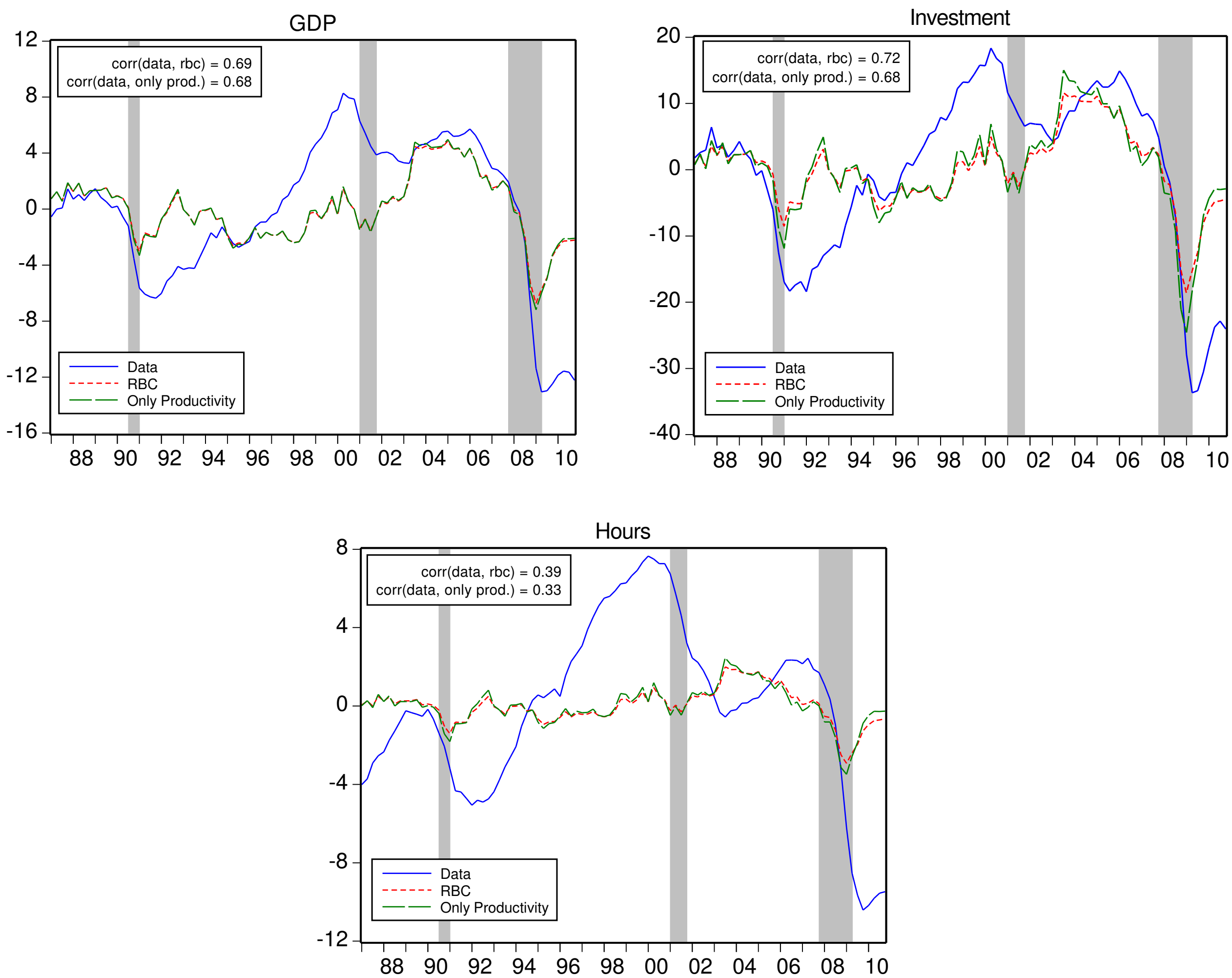


Figure 8: Real Fluctuations: RBC vs. Only Productivity

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 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, this figure suggests that financial shocks contribute significantly to explaining the observed dynamics of financial variables.

Figure 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 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 almost most of the fluctuations in the index. This figure establishes the second main result of the paper: U.S. banks experienced a significant deterioration in their lending ability in the last recessions, especially in 1990-91 and 2007-09 recessions.

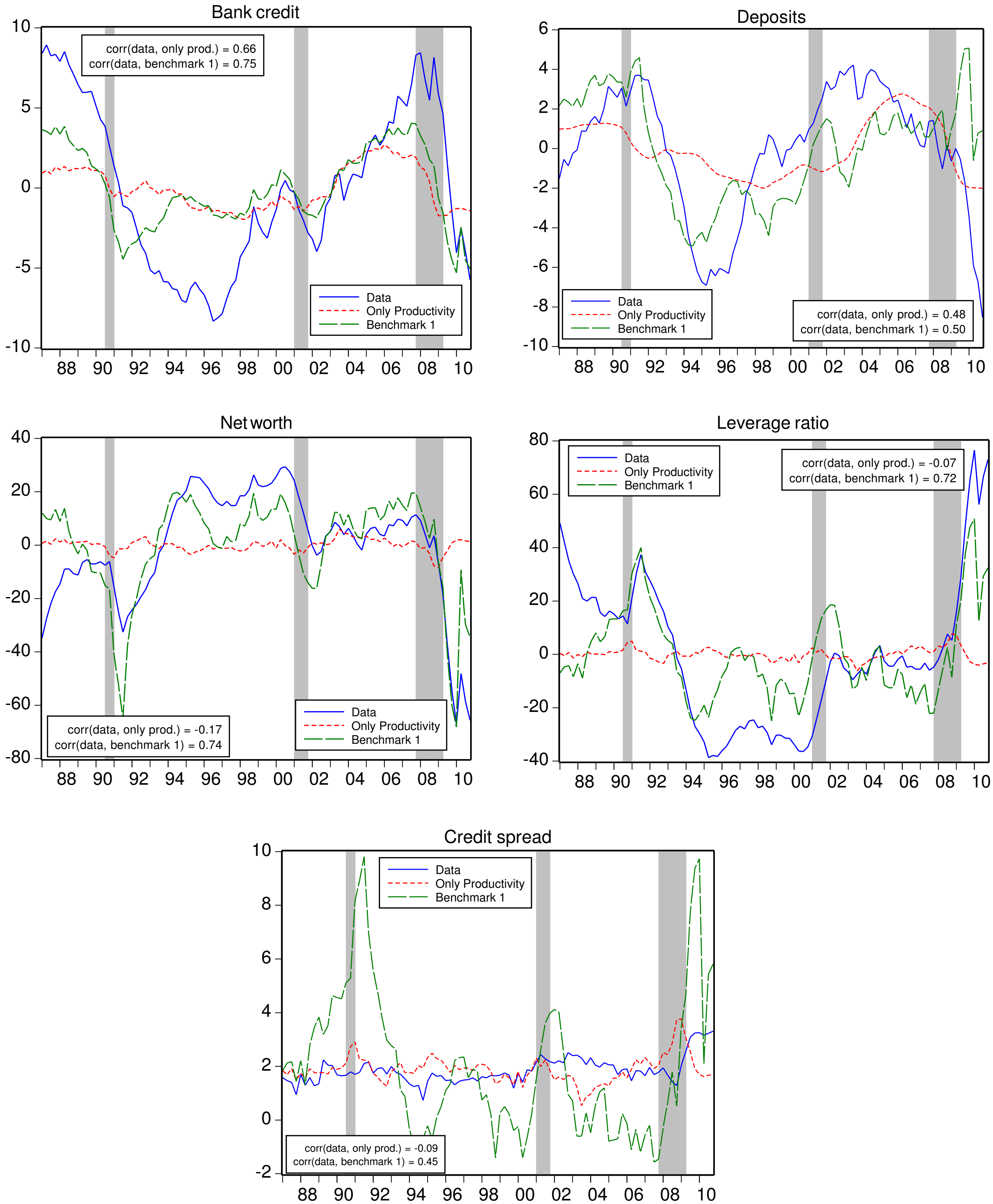


Figure 9: Financial Fluctuations: Benchmark vs. Only Productivity

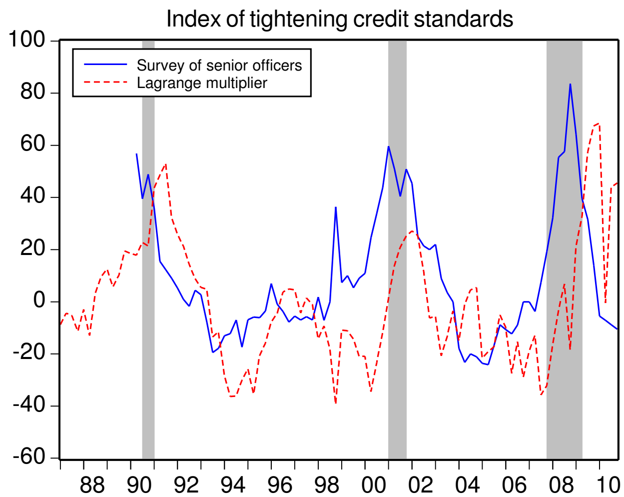


Figure 10: Tightness of Credit Conditions in the Benchmark Model

5 Conclusion

This paper quantitatively investigates the joint role of financial shocks and credit frictions affecting banking sector in driving the real and financial fluctuations in the 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 simple 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. Second, 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, I need a model capable of matching real and financial fluctuations simultaneously. I think that the model proposed in this paper is quite successful in this dimension.

References

[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] 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.

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

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

[9] 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.

[10] 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.

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

[12] 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.

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

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

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

[16] 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.

[17] Gertler, M., Karadi, P., 2011. "A Model of Unconventional Monetary Policy." *Journal of Monetary Economics*. forthcoming.

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

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

[20] 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.

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

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

[23] 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.

[24] 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.

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

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

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

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

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

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

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

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

[33] 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.

[34] 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.

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

[36] 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.

[37] 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.

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

Appendix A: 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.

Appendix B

B.1. Proof of Proposition 1

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

$$V_{jt} = \nu_t q_t s_{jt} + \eta_t n_t \tag{43}$$

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

$$\nu_t q_t s_{jt} = E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i}[(r_{kt+1+i} - r_{t+1+i})q_{t+i}s_{jt+i}] \tag{44}$$

$$\eta_t n_{jt} = E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i}(1 + r_{t+1+i})n_{jt+i} \tag{45}$$

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.

$$\nu_t = \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i}\left[(r_{kt+1+i} - r_{t+1+i})x_{t,t+i}\right] \tag{46}$$

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

$$\nu_t = (1-\theta)\beta\Lambda_{t,t+1}(r_{kt+1} - r_{t+1}) + \sum_{i=1}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i}\left[(r_{kt+1+i} - r_{t+1+i})x_{t,t+i}\right] \tag{47}$$

$$\nu_t = (1-\theta)\beta\Lambda_{t,t+1}(r_{kt+1} - r_{t+1}) + \beta\Lambda_{t,t+1}\theta x_{t,t+1} \sum_{i=0}^{\infty} (1-\theta)\theta^{i+1} \beta^{i+1} \Lambda_{t+1,t+2+i}\left[(r_{kt+2+i} - r_{t+2+i})x_{t+1,t+1+i}\right] \tag{48}$$

The infinite sum at the right-hand side of equation (64) is one period updated version of equation (62), given by

$$\nu_{t+1} = \sum_{i=0}^{\infty} (1-\theta)\theta^{i+1} \beta^{i+1} \Lambda_{t+1,t+2+i}\left[(r_{kt+2+i} - r_{t+2+i})x_{t+1,t+1+i}\right] \tag{49}$$

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 (64) with the expectations as follows:

$$\nu_t = E_t[(1-\theta)\beta\Lambda_{t,t+1}(r_{kt+1} - r_{t+1}) + \beta\Lambda_{t,t+1}\theta x_{t,t+1}\nu_{t+1}] \tag{50}$$

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

$$\eta_t = \sum_{i=0}^{\infty}(1-\theta)\theta^i\beta^{i+1}\Lambda_{t,t+1+i}(1+r_{t+1+i})z_{t,t+i} \tag{51}$$

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

$$\eta_t = (1-\theta)\beta\Lambda_{t,t+1}(1+r_{t+1}) + \sum_{i=1}^{\infty}(1-\theta)\theta^i\beta^{i+1}\Lambda_{t,t+1+i}(1+r_{t+1+i})z_{t,t+i} \tag{52}$$

$$\eta_t = (1-\theta)\beta\Lambda_{t,t+1}(1+r_{t+1}) + \beta\Lambda_{t,t+1}\theta z_{t,t+1}\sum_{i=0}^{\infty}(1-\theta)\theta^{i+1}\beta^{i+1}\Lambda_{t+1,t+2+i}(1+r_{t+2+i})z_{t+1,t+1+i} \tag{53}$$

The infinite sum at the right-hand size of equation (69) is one period updated version of equation (67), given by

$$\eta_{t+1} = \sum_{i=1}^{\infty}(1-\theta)\theta^{i+1}\beta^{i+1}\Lambda_{t+1,t+2+i}(1+r_{t+2+i})z_{t+1,t+1+i} \tag{54}$$

where $z_{t+1,t+1+i} = \frac{n_{jt+1+i}}{n_{jt+1}}$
Hence, we can re-write equation (69) with the expectations as follows:

$$\eta_t = E_t[(1-\theta)\beta\Lambda_{t,t+1}(1+r_{t+1}) + \beta\Lambda_{t,t+1}\theta z_{t,t+1}\eta_{t+1}] \tag{55}$$

B.2. Proof of Proposition 2

The profit maximization problem by a representative bank is given by

$$V_{jt} = \max_{s_{jt}} E_t\sum_{i=0}^{\infty}(1-\theta)\theta^i\beta^{i+1}\Lambda_{t,t+1+i}[(r_{kt+1+i}-r_{t+1+i})q_{t+i}s_{jt+i} + (1+r_{t+1+i})n_{jt+i}] \tag{56}$$

$$s.t. \quad V_{jt} \geq \lambda q_t s_{jt} \qquad (\mu_t) \tag{57}$$

where μ_t is the Lagrange multiplier associated with the incentive compatibility constraint. Using the solution for V_{jt} in Proposition 2, I can re-write the intermediary's maximization problem using the Lagrangian,

$$Ł = \nu_t q_t s_{jt} + \eta_t n_{jt} + \mu_t[\nu_t q_t s_{jt} + \eta_t n_{jt} - \lambda q_t s_{jt}] \tag{58}$$

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

$$(1+\mu_t)\nu_t q_t = \mu_t \lambda q_t \tag{59}$$

$$V_{jt} - \lambda q_t s_{jt} = 0 \tag{60}$$

Rearranging (75) gives us the following expression,

$$\nu_t = \frac{\mu_t \lambda}{(1+\mu_t)} \tag{61}$$

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

$$E_t[(1-\theta)\beta\Lambda_{t,t+1}(r_{kt+1} - r_{t+1}) + \beta\Lambda_{t,t+1}\theta\frac{q_{t+1}s_{jt+1}}{q_t s_{jt}}\nu_{t+1}] = \frac{\mu_t \lambda}{(1+\mu_t)} \tag{62}$$

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

$$\frac{(1-\theta)\beta(r_k - r)}{(1-\beta\theta)} = \frac{\mu\lambda}{(1+\mu)} \tag{63}$$

Rearranging gives us

$$(r_k - r) = \frac{(1-\beta\theta)\mu\lambda}{(1-\theta)\beta(1+\mu)} \tag{64}$$

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.

Appendix C: Competitive Equilibrium

A competitive equilibrium of this model economy consists of sequences of allocations $\{c_t, L_t, K_{t+1}, s_t, n_t, \widetilde{n}_t, I_t, \eta_t, \nu_t, H_t\}_{t=0}^{\infty}$, 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 firm's and the financial intermediary's problems at the equilibrium prices and (ii) markets for factor inputs clear. The following equilibrium conditions must be satisfied:

$$\frac{U_l(t)}{U_c(t)} = w_t \tag{65}$$

$$U_c(t) = \beta(1 + r_{t+1})E_t U_c(t+1) \tag{66}$$

$$r_{kt+1} = \frac{z_{t+1}F_K(K_{t+1}, H_{t+1}) + q_{t+1}(1-\delta)}{q_t} - 1 \tag{67}$$

$$w_t = z_t F_H(K_t, H_t) \tag{68}$$

$$n_t = \omega_t \widetilde{n}_t \tag{69}$$

$$q_t s_t = \frac{\eta_t}{\lambda - \nu_t} n_t \tag{70}$$

$$\nu_t = E_t[(1-\theta)\beta\Lambda_{t,t+1}(r_{kt+1} - r_{t+1}) + \beta\Lambda_{t,t+1}\theta\frac{q_{t+1}s_{t+1}}{q_t s_t}\nu_{t+1}] \tag{71}$$

$$\eta_t = E_t[(1-\theta)\beta\Lambda_{t,t+1}(1 + r_{t+1}) + \beta\Lambda_{t,t+1}\theta\frac{n_{t+1}}{n_t}\eta_{t+1}] \tag{72}$$

$$\widetilde{n}_{t+1} = \theta[(r_{kt+1} - r_{t+1})\frac{\eta_t}{\lambda - \nu_t} + (1 + r_{t+1})]n_t + \epsilon n_t \tag{73}$$

$$q_t s_t = q_t K_{t+1} \tag{74}$$

$$K_{t+1} = (1-\delta)K_t + \Phi\left(\frac{I_t}{K_t}\right)K_t \tag{75}$$

$$q_t = \left[\Phi^{'}\left(\frac{I_t}{K_t}\right)\right]^{-1} \tag{76}$$

$$L_t = H_t \tag{77}$$

$$C_t + I_t = z_t F(K_t, H_t) \tag{78}$$

$$log(z_{t+1}) = \rho_z log(z_t) + \epsilon^z_{t+1} \tag{79}$$

$$log(\omega_{t+1}) = \rho_\omega log(\omega_t) + \epsilon^\omega_{t+1} \tag{80}$$

Appendix D: 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.[27] 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 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.[28] *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

[27] 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.

[28] 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.

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 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 5: 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 5 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.[29] 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.[30] Moreover, the contemporaneous correlation with between credit spread and GDP is -0.56, showing that it is countercyclical.

Table 6 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 leverage ratio and equity are three times more volatile than output, liabilities are a little more volatile than

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

[30] 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.

Table 6: 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.

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.

Appendix E: Alternative 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:

$$\omega_t = \frac{(1 - Loanlossrates) * Outstandingloans}{Networth} \tag{81}$$

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 (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 11. 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 ρ_z = 0.9467, $\rho_{z,\omega}$ = -0.0142, $\rho_{\omega,z}$ = 0.9129, ρ_ω = 0.2824, σ_z = 0.006378, and σ_ω = 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 7: Real and Financial Statistics

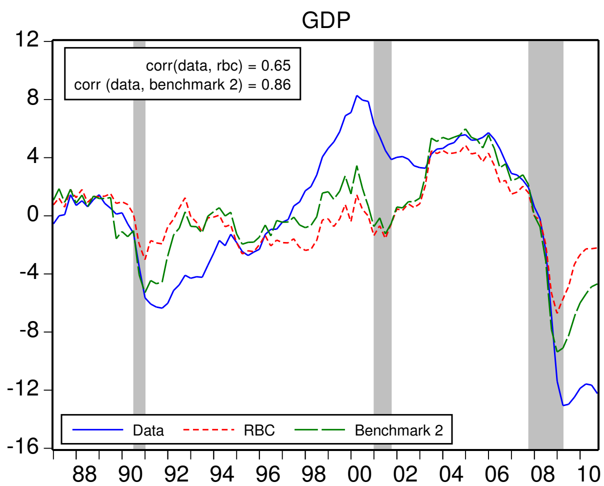
Statistic	Data	Benchmark 1	Benchmark 2	Benchmark 3	Benchmark 4
σ_Y	1.80	1.81	1.65	1.83	2.75
σ_C	0.45	0.75	0.52	0.77	0.57
σ_I	2.73	4.64	3.77	4.68	5.13
σ_L	0.91	0.84	0.64	0.88	0.94
$\rho_{Y,I}$	0.97	0.87	0.92	0.88	0.97
$\rho_{Y,C}$	0.82	-0.03	0.34	-0.09	-0.70
$\rho_{Y,L}$	0.83	0.81	0.86	0.81	0.96
σ_{Assets}	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

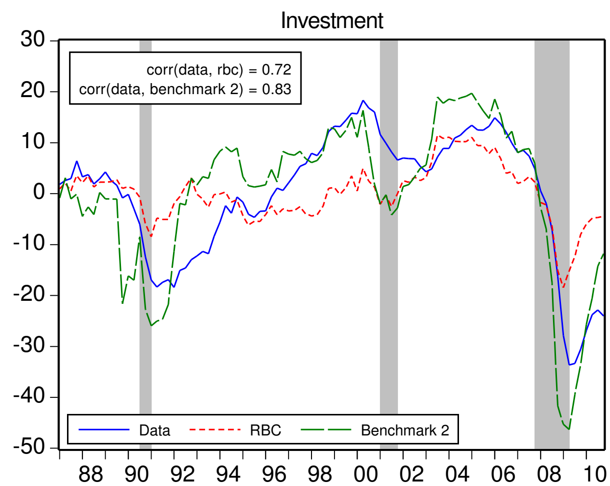
[a] Business cycle statistics in the table are based on HP-filtered cyclical components of quarterly simulated time series (smoothing parameter:1600).
[b] The standard deviation of output is expressed in percent; standard deviations of the remaining variables are normalized by the standard deviation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

Table 7 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 (Figure 12 - 19) 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 11: Time Series of Shocks to Productivity and Credit Conditions





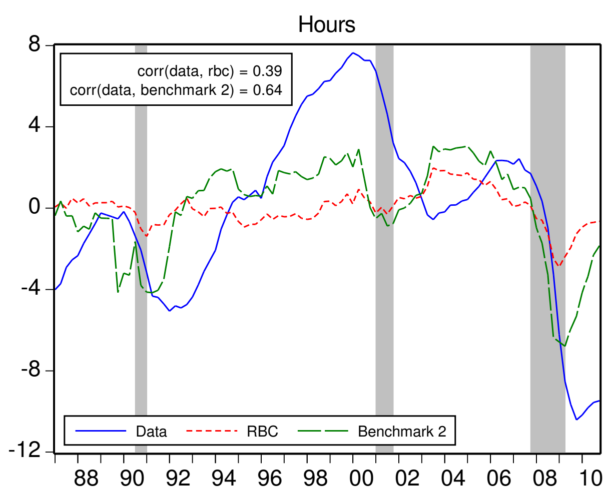


Figure 12: Real Fluctuations: Benchmark 2 vs. RBC model

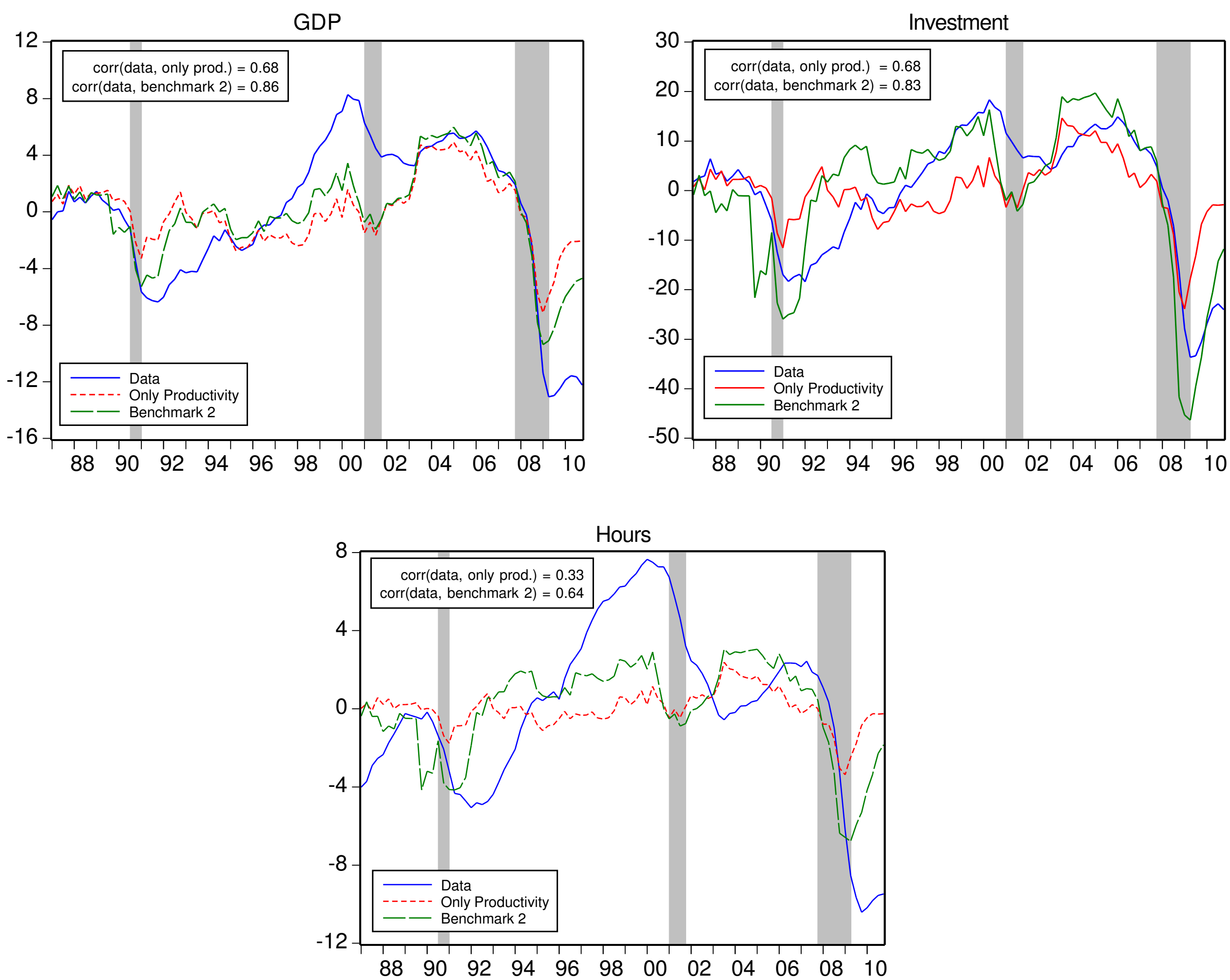


Figure 13: Real Fluctuations: Benchmark 2 vs. Only Productivity

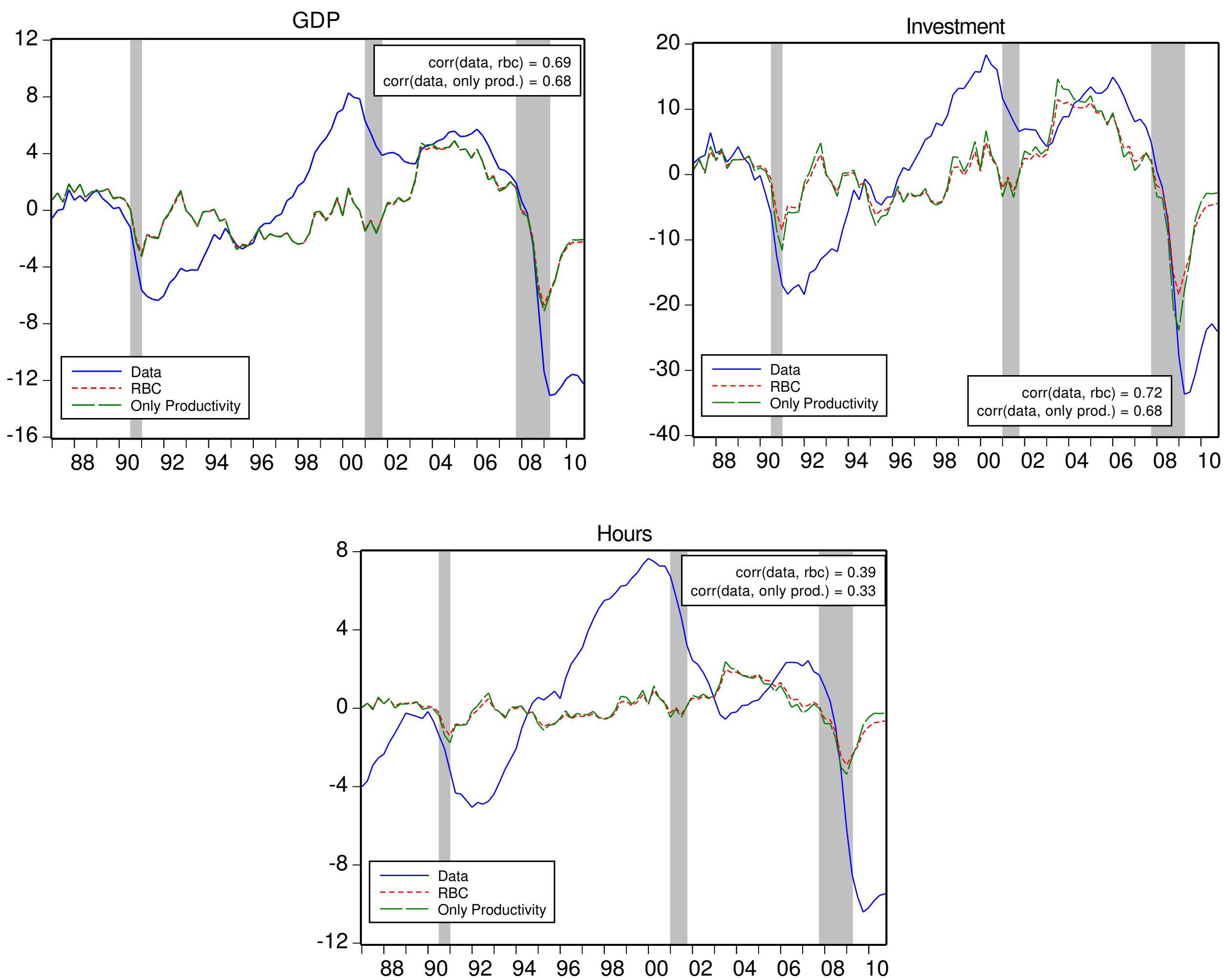


Figure 14: Real Fluctuations: RBC vs. Only Productivity with Benchmark 2 calibration

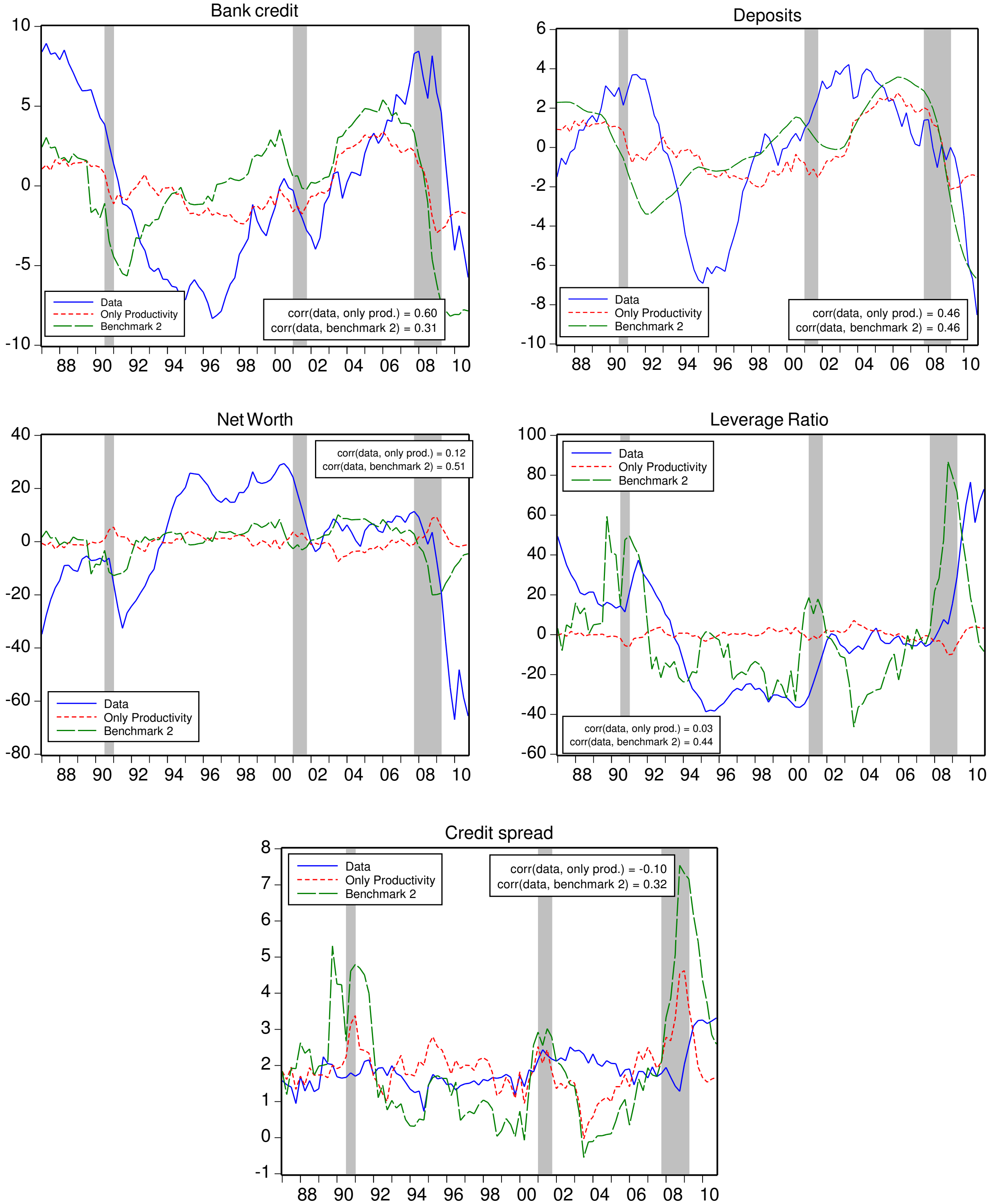


Figure 15: Financial Fluctuations: Benchmark 2 vs. Only Productivity

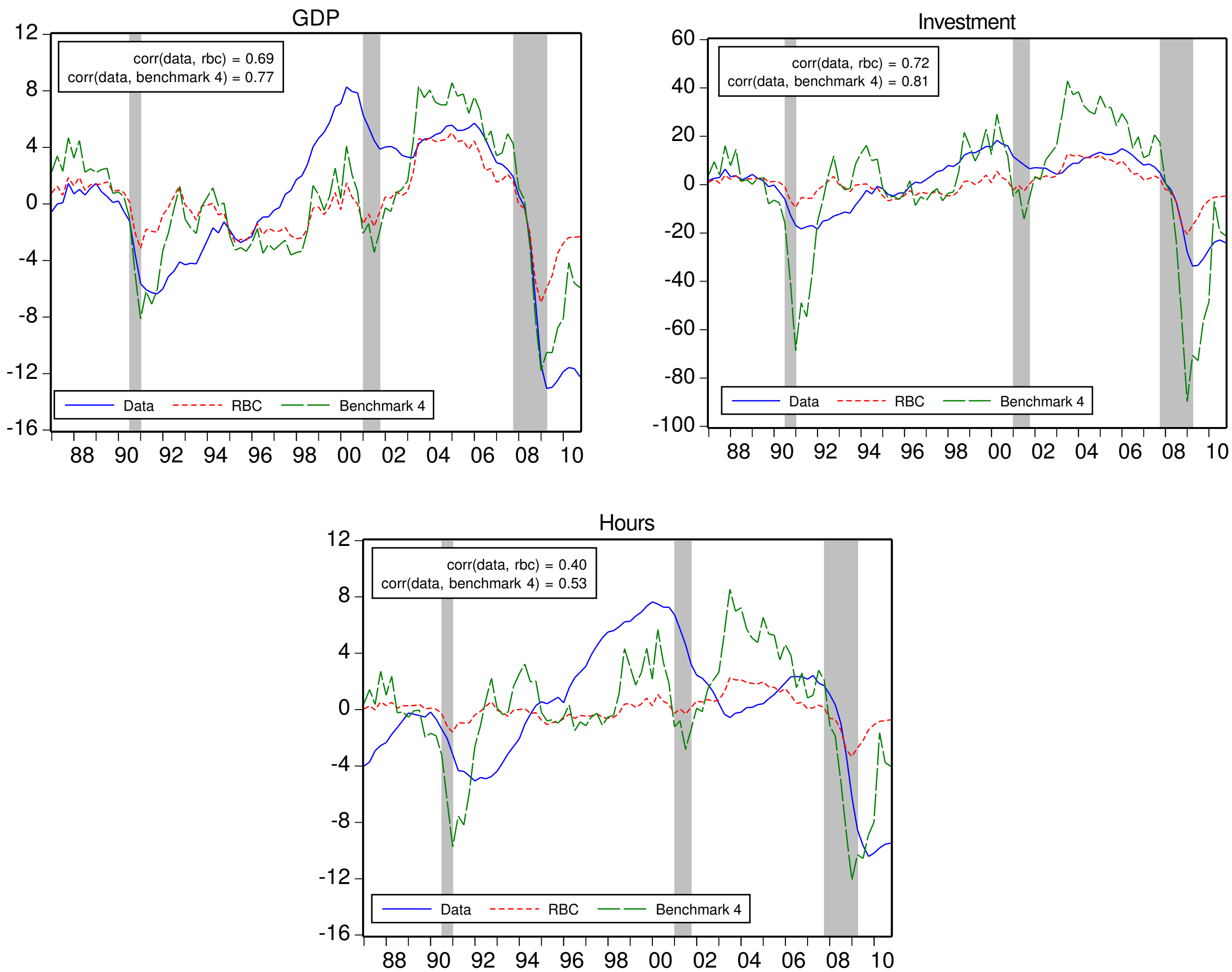


Figure 16: Real Fluctuations: Benchmark 4 vs. RBC model

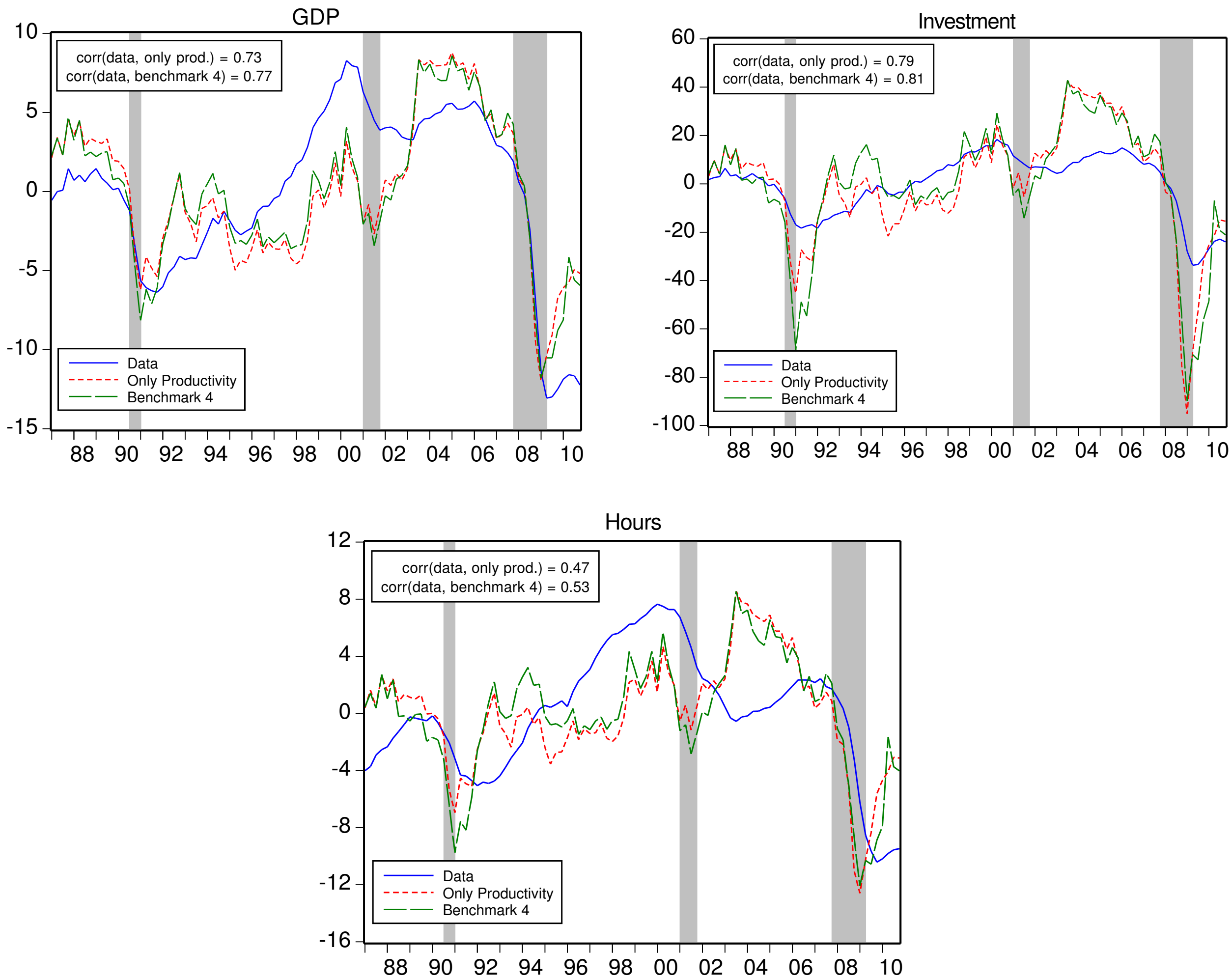


Figure 17: Real Fluctuations: Benchmark 4 vs. Only Productivity

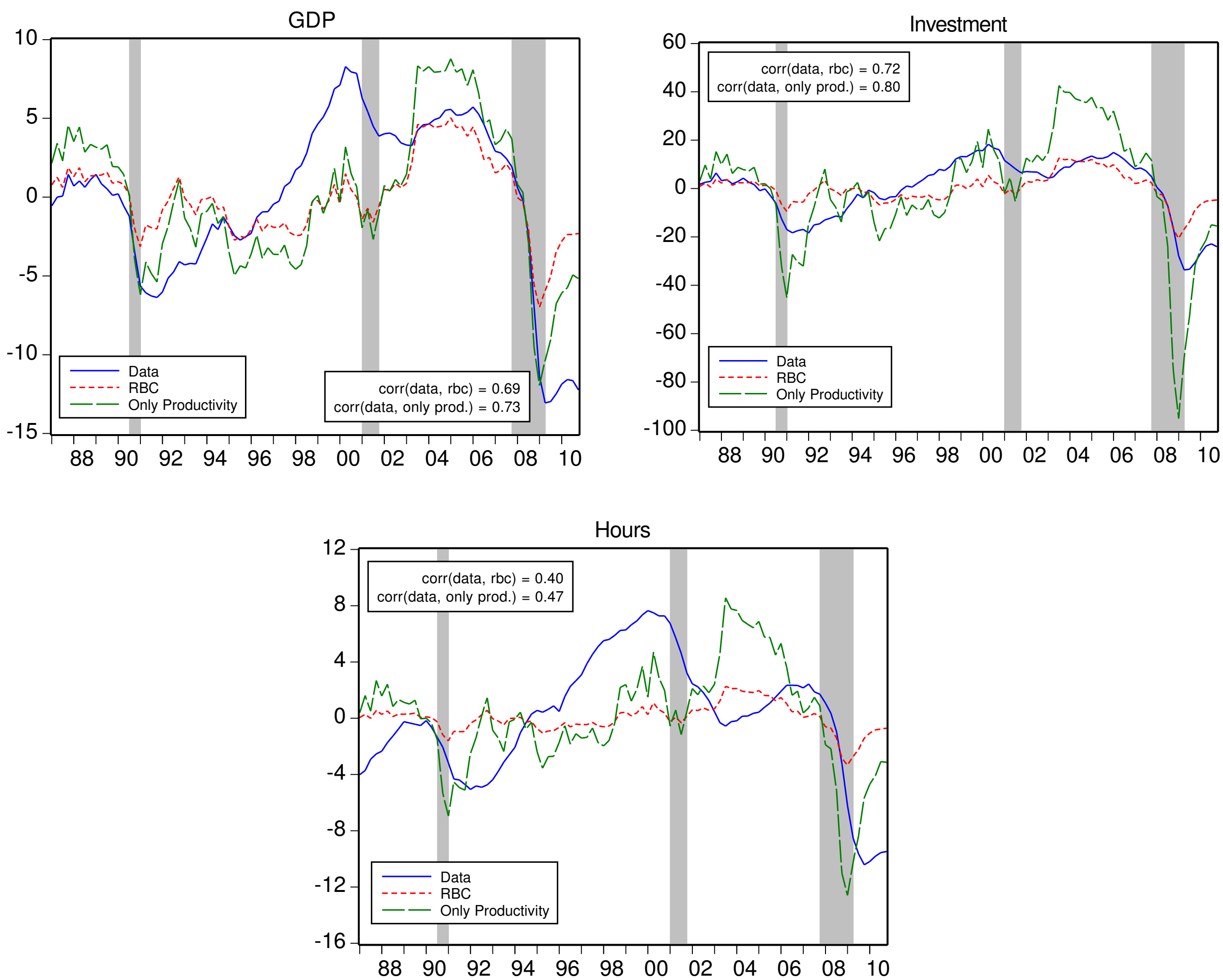


Figure 18: Real Fluctuations: RBC vs. Only Productivity with Benchmark 4 calibration

Figure 19: Financial Fluctuations: Benchmark 4 vs. Only Productivity