Financial intermediaries, leverage ratios, and business cycles

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Financial Intermediaries, Leverage Ratios and Business Cycles ☆

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Abstract

I document cyclical properties of aggregate measures of liabilities, equity, and leverage ratio in the U.S. financial sector and those of credit spread. I find that (i) liabilities and equity are procyclical, leverage ratio is acyclical, and credit spread is countercyclical, (ii) financial variables are three to ten times more volatile than output, and (iii) financial variables lead the business cycle. I present a dynamic stochastic general equilibrium model with profit maximizing banks where bank equity mitigates a moral hazard problem between banks and their depositors. The driving sources of business cycles are shocks to bank equity as well as standard productivity shocks. The model generates real and financial fluctuations consistent with the U.S. data. The model also delivers some policy prescriptions about capital adequacy requirements of banks.

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

1. Introduction

In the last century, most of the U.S. economy's economic downturns are associated with banking crises. These crises are serious not only due to the meltdown that they created in one specific sector of the economy but because of the collapse that they caused in the whole economy.[1] Hellmann et al. (2000) argue that moral hazard in banking sector plays a crucial role in these crises.[2] However, the macro literature studying the role of the financial frictions in macroeconomic fluctuations emphasizes moral hazard in non-financial sector and models financial intermediaries as passive players that simply transfer funds from savers to firms.[3] This paper builds on the idea that the financial intermediaries themselves could be an important source of business cycle fluctuations since they are also dependent on external financing.[4] Moreover, the behavior of balance sheet items of financial intermediaries and how they interact with real variables over the business cycle have not been fully explored in the literature. Most previous studies on financial frictions have not tried to match fluctuations in both standard macro variables and aggregate financial variables at the same time. In this paper, I construct a model with a financial sector capable of matching both real and financial fluctuations.

I first systematically document the business cycle properties of aggregate liabilities, aggregate equity, and aggregate leverage ratio in the U.S. financial sector together with those of high yield bond spread (Baa-Aaa)

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[1] Hellman et al. (2000) suggest that banking crises over the past two decades cost up to 40 percent of GDP. In particular, the saving and loan crisis in the U.S. created losses estimated to be 3.2 percent of GDP.

[2] They also argue that abolishing formal deposit insurance systems does not solve this agency problem by itself. Kane (1989) and Cole et al. (1995) note that banks select a risky asset portfolio which earns high profits if the gamble succeeds, however depositors suffer from losses if it fails.

[3] Recent papers by Woodford and Curdia (2008), Gertler and Karadi (2010), Gertler and Kiyotaki (2010), Brunnermeier and Sannikov (2009) have attempted to model the financial sector as an active player.

[4] Carlson et al. (2008), Adrian and Shin (2009).

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using postwar data.[5] The following stylized facts emerge from the empirical analysis: (1) Aggregate financial leverage ratio and aggregate equity are three times more volatile than output, while credit spread is an order of magnitude more volatile. (2) Aggregate liabilities and aggregate equity are procyclical, aggregate leverage ratio is acyclical, and credit spread is countercyclical. (3) Aggregate leverage ratio, aggregate equity and credit spread lead output by three, two and one quarters, respectively, while aggregate liabilities contemporaneously move with output.

The model features two departures from an otherwise standard real business cycle framework in order to have a model where balance sheet fluctuations of financial sector matter for real fluctuations. The first departure is that I introduce a profit maximizing banking sector as in Gertler and Karadi (2010) – henceforth, GK. In particular, banks borrow funds from households and their ability to borrow is limited due to a moral hazard (costly enforcement) problem. This agency problem generates endogenous borrowing constraints for banks in obtaining funds from households. The second departure is that I incorporate empirically-disciplined shocks to bank net worth. These shocks capture disruptions in banks' health that originate solely in the financial sector. Following the recent literature, I interpret these shocks as loan losses, asset write-downs, reductions in banks' profits, or exogenous increases in the costs of financial intermediation.[6] 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.[7] Net worth shocks are transmitted to the real economy through their effects on credit supply and thus investment decisions of non-financial firms –henceforth, firms. These two departures generate the transmission mechanism by which fluctuations in bank equity induce sizeable movements in real and financial variables.

There are three main results. First, standard productivity and net worth shocks quantitatively account for almost all real and financial fluctuations in the data. Net worth shocks are transmitted to the real economy through a purely financial channel (bank capital channel): if there were no moral hazard problem between households and banks, hence no financial frictions, net worth shocks are not able to generate any fluctuations in real variables. Second, the absence of either shock or the absence of the agency problem between banks and households prevents the model from explaining the observed cyclical properties of real and financial variables simultaneously. Third, net worth shocks induces sizeable fluctuations in real variables. In particular, these shocks account for 29% of the fluctuations in output, 22% of the fluctuations in consumption, 72% of the fluctuations in investment, and 84% of the fluctuations in labor hours. However, productivity shocks can only partially explain the fluctuations in financial variables. Specifically, these shocks explain 23% of the variation in debt, almost zero percent of the variation in bank net worth, nearly 2% of the variation in leverage ratio and credit spreads.

[5] The leverage ratio is defined as the ratio of total liabilities to total shareholders' equity. Throughout the paper, I use the terms "bank net worth", "bank capital", or "bank equity" interchangeably, while I use the terms "bank liabilities" or "bank debt" interchangeably.

[6] Holmstrom and Tirole (1997), Brunnermeier and Pedersen (2009), Meh and Moran (2010), Mendoza and Quadrini (2010), and Curdia and Woodford (2010)

[7] The current paper is not the only paper that introduce net worth shocks. 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. Moreover, Brunnermeier and Pedersen (2009) introduce shocks to bank capital and interpret them as independent shocks arising from other activities like investment banking. They give as an example that Bear Stearns' clients terminated their brokerage relationships and ran on the investment bank in March 2008. 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. These shocks can be also attributed to the fluctuations in non-financial sector's equity holdings as banks' balance sheets include a non-trivial share of corporate equity. Finally, one might model this shock as a redistribution shock such that some portion of the wealth is transferred from financial intermediaries to households as suggested by Iacoviello (2010). Although the negative wealth transfer may distort the financial intermediaries' role of allocating resources inducing large real effects, the positive and negative wealth effects are likely to eliminate each other since households own financial intermediaries in the context of our model, which in turn implies that the impact of this shock on aggregate demand will not be very different from the net worth shock in our model.

This paper is related to recent empirical and theoretical literature on the role of financial intermediaries on business cycles. On the empirical side, the stylized facts about the financial variables documented in this paper are not widely known in the macro literature. To the best of my knowledge, the only related work is Adrian and Shin (2008, 2009), who provide evidence on the time series behavior of balance sheet items of some financial intermediaries using Flows of Funds data. However, they do not present standard business cycle statistics of financial variables.[8] They also 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 have significant forecasting power for total GDP growth. On the other hand, there are several papers documenting the behavior of the liabilities and equity of U.S non-financial corporate sector and a few papers providing empirical facts on the leverage ratio of the financial sector.[9] The closest available study is Chugh (2010), who computes standard business cycle statistics of the leverage ratio of U.S. non-financial firms using quarterly data from Compustat.[10]

Gilchrist, Yankov and Zakrajsek (2009) empirically shows that credit market shocks, which can result from deterioration in the supply of credit due to weak balance sheets of firms or the disruptions in the health of banks that supply credit, have played an important role for U.S. business cycle fluctuations during 1990-2008 period and account for more than 30% of the variation in economic activity measured by industrial production. In this paper, I focus on the effect of balance sheet fluctuations in financial sector on macroeconomic fluctuations.

On the theoretical side, the current paper differs from the existing literature on financial accelerator effects arising from the movements in the strength of borrowers' balance sheets.[11] This literature focused on the demand for credit. However, this paper focuses on supply of credit and features financial accelerator effects driven by fluctuations in the strength of lenders' balance sheets. Two other closely related works to this paper are Meh and Moran (2010), and Angeloni and Faia (2010). The former investigates 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. The latter studies the role of banks in the interaction between monetary policy and macroprudential regulations in a New Keynesian model with bank runs. Finally, this paper is different from GK and Gertler and Kiyotaki (2010) – henceforth, GNK. They focus on the normative implications of central bank's credit policy in a Christiano, Eichenbaum and Evans (2005) -type New Keynesian model with banks. However, in this paper, I address the positive implications of shocks to bank capital and the agency problem between households and banks.

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

This section documents stylized facts on aggregate measures of the leverage ratio, debt and equity of U.S. financial firms and the credit spread using quarterly data for the period 1952-2009.[12] In particular, I compute standard business cycle statistics of the aggregate financial variables, such as standard deviations, and cross-correlations with standard macro variables.

[8] They define leverage as the ratio of total assets to total equity. Moreover, their notion of "procyclical" is not with respect to GDP, but with respect to total assets of financial intermediaries. The notion of "procyclical" in the current paper is more standard in the sense that it is with respect to GDP. Hence, I undertake a more standard macro business cycle accounting exercise. In addition, they do not analyze the whole financial sector, as they omit bank holding companies, finance companies and insurance companies.

[9] Covas and den Haan (2006), and Jermann and Quadrini (2009) discuss non-financial firms, while Levin, Natalucci, and Zakrajsek (2004), and Korajczyk and Levy (2003) discuss the leverage ratio of the financial sector.

[10] He also studies the role of risk shocks in generating the observed real and financial fluctuations in a Carlstrom and Fuerst (1998) type financial accelerator model.

[11] Kiyotaki and Moore (1997), Carlstrom and Fuerst (1998), Bernanke, Gertler, and Gilchrist (1999)

[12] I perform the same business cycle analysis for the period 1984-2009, with results available upon request. Briefly, the volatilities of aggregate financial variables and credit spread are roughly the same compared to 1952-2009. Debt is strongly procyclical, and leverage ratio is mildly procyclical while equity is acyclical in this period. Credit spread is still countercyclical.

I use quarterly balance sheet data from the Flow of Funds Accounts of the Federal Reserve Board. The balance sheet data in the levels tables at the Flow of Funds Accounts are not seasonally adjusted and are nominal. I perform the seasonal adjustment using Census X12 and deflated the series using GDP deflator. Moreover, the balance sheet items at the Flow of Funds Accounts are market-value based. For credit spread, I use quarterly data from FRED.

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.[13] The debt measure I use is total liabilities, while the equity measure is total shareholder's equity. For each quarter, I compute the aggregate leverage ratio as the ratio of the aggregate liabilities of aforementioned financial institutions to their aggregate shareholders' equity. Finally, the spread measure I use the high yield bond spread computed as the difference between interest rate on Baa rated bonds and that on Aaa rated bonds.[14]

Figure 1 displays the time series of the aggregate leverage ratio of financial firms together with its HP trend component. The mean leverage ratio over the sample period is 13.68. The leverage ratio trends upward until 1988 and then falls down until the present. Note that the de-leveraging in the recent financial crisis is consistent with the longer term trend since 1988. In addition, the downward trend in the leverage ratio starting from 1988 is due to implementation of Basel Accord on capital requirements of banks.

Figure 2 shows the HP-filtered cyclical components of aggregate financial variables with NBER recession dates. Top-left panel of Figure 2 displays the cyclical components of aggregate leverage ratio. There are several sharp spikes evident in this figure: in 1974, in 1982, in 1991, in 1999 and 2000, and in 2006 and 2007. All of these spikes are associated with known economic and financial crises. The 1982 spike corresponds to Latin American debt crisis beginning in Mexico in 1982. The 1991 spike is associated with the Savings and Loan crisis in the U.S. between 1989 and 1991 and the burst of Japanese asset price bubble in 1990. The 1999 and 2000 episode is associated with the expansion and bursting of the tech bubble, while the final episode in 2006 and 2007 is due to recent global financial crisis preceded by the substantial leveraging before the crisis. Therefore, I can say that leverage cycles in U.S. financial sector are apparent and associated with major crises observed after 1952.

Top-right and bottom-left panels of Figure 2 display the cyclical components of aggregate liabilities and aggregate equity. The fluctuations in aggregate equity are much larger than those in aggregate liabilities. The quarterly standard deviation of aggregate equity is 5.76 % compared to 2.16% for aggregate liabilities. In addition, if we compare the top-left and bottom-left panels of Figure 2, we can observe that movements in the leverage ratio of U.S. financial firms are mainly due to fluctuations in their aggregate equity. The contemporaneous correlation between the leverage ratio and aggregate equity is -0.92. Finally, bottom-right panel of Figure 2 shows the cyclical component of credit spread. The fluctuations in credit spread is an order of magnitude larger than those in output. The quarterly standard deviation of credit spread is 21.70% compared to 1.97% for GDP.

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

[13]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.

[14]I choose the high yield bond spread among several different measures of credit spread since it is widely accepted that this bond spread is more reflective of default risk than other credit spreads and that it has a stronger forecasting power for real economic activity. Furthermore, I could also use the difference between 3-month commercial paper rate on financial firms and 3-month T-bill rate as a measure of credit spread, however, the longest available data on 3-month commercial paper rate is from 1997 to 2010.

of aggregate debt is roughly equal to that of output.[15] 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.[16] Moreover, the credit spread is ten times more volatile than output and the contemporaneous correlation with GDP is -0.56, showing that it is countercyclical.

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

The following facts emerge from the empirical analysis above: (1) Financial leverage ratio and equity are three times more volatile than output, liabilities are roughly as volatile as output, and credit spread is an order of magnitude more volatile, and (2) liabilities and equity are procyclical, financial leverage ratio is acyclical, and credit spread is countercyclical. (3) Financial leverage ratio, equity and credit spread lead output by three, two and one quarters, respectively, while liabilities contemporaneously move with output. I will assess the model below by its ability to match these facts.

3. A Business Cycle Model with Financial Sector

The model builds on GK and GNK. The 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 3 shows the sequence of events in a given time period in the theoretical model described below.

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

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

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.[17] 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

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

[16] 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.

[17] This assumption ensures independent decision-making. Depositors are not the owners of the bank, so the bank does not maximize their utility, but its own net worth.

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.[18]

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 firms, capital producers and banks net of the transfer that it gives to its new bankers.

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

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

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

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. The balance sheet identity of financial intermediary j at the end of period t is given by

$$q_t s_{jt} = \omega_t \widetilde{n}_{jt} + b_{jt+1} \tag{5}$$

where $\widetilde{n}_{jt}$ is the net worth of financial firm j at the beginning of period t before the net worth shock hits, b_{jt+1} is the amount of deposits that the intermediary obtains from the households, q_t is the price of firms' shares and s_{jt} is the quantity of these shares. 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).

ω_t is an i.i.d. net worth shock that I introduce into the model to capture exogenous movements in the net worth of financial intermediaries.[19] 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. Furthermore, even though the net worth shock is i.i.d., it endogenously persists through its effect on net worth accumulation.[20]

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} is the liabilities of the financial intermediary and n_{jt} is its equity or capital.[21]

[18] 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 Bernanke, Gertler, and Gilchrist (1999).

[19] I model this shock as an i.i.d. process because I assume that financial intermediaries immediately write off their losses in a given period when they realize it.

[20] This view is consistent with Woodford (2010). His paper suggests that if a shock induces a decrease (or increase) in the net worth of financial intermediaries, this new level of net worth persists for a while, resulting in real effects that are more persistent than the initial shock.

[21] In U.S. financial data, household deposits constitute 70% of total liabilities of banks.

The financial intermediaries receive 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 households (liabilities of financial intermediary). Thus the law of motion for the 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, $q_t s_{jt}$.

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

$$E_{t+i}\beta\Lambda_{t,t+1+i}(r_{kt+1+i} - r_{t+1+i}) \geq 0 \quad \vee\, i \geq 0 \tag{8}$$

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 below limits banks' ability to obtain deposits from the households, leading to a positive premium.

3.2.2. Profit Maximization

This section describes banks' profit maximization. The financial intermediary maximizes its expected discounted terminal net worth, given by[22]

$$V_{jt} = \max_{s_{jt}} E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^i \Lambda_{t,t+1+i}[(r_{kt+1+i} - r_{t+1+i})q_{t+i}s_{jt+i}] + (1 + r_{t+1+i})n_{jt+i}] \tag{9}$$

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.[23] 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: [24]

$$V_{jt} \geq \lambda q_t s_{jt} \tag{10}$$

[22]The detailed profit maximization problem of financial intermediaries is in Appendix A.

[23]If the financial intermediary diverts the funds, the assumed legal structure ensures that the households (depositors) are able to force the intermediary to go bankrupt and may recover the remaining fraction $1-\lambda$ of the assets. The depositors are not able to get the remaining fraction λ of the funds since, by assumption, the cost of recovering these funds is too high. Furthermore, 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.

[24]The incentive constraint binds when the value of K_{t+1} is decided at the end of period t.

The left-hand side of (11) is the value of operating for the bank 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 7.1

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

$$V_{jt} = \nu_t q_t s_{jt} + \eta_t n_{jt} \tag{11}$$

where

$$\nu_t = E_t[(1-\theta)\beta\Lambda_{t,t+1}(r_{kt+1} - r_{t+1}) + \beta\Lambda_{t,t+1}\theta\frac{q_{t+1}s_{jt+1}}{q_t s_{jt}}\nu_{t+1}] \tag{12}$$

$$\eta_t = E_t[(1-\theta)\beta\Lambda_{t,t+1}(1 + r_{t+1}) + \beta\Lambda_{t,t+1}\theta\frac{n_{jt+1}}{n_{jt}}\eta_{t+1}] \tag{13}$$

ν_t can be interpreted as the expected discounted marginal gain to the bank of obtaining one more unit of deposits and using it to buy 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 less unit of deposits and 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:

$$\nu_t q_t s_{jt} + \eta_t n_{jt} \geq \lambda q_t s_{jt} \tag{14}$$

When this constraint binds, the financial intermediary's assets are limited by its net worth.[25] 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 (16) 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 purchase more shares of firms. Conversely, de-leveraging or the deterioration in net worth in bad times will limit the bank's ability to buy firms' shares. Note that by manipulating this expression using the balance sheet, I can obtain the bank's leverage ratio as follows:

[25] As shown in Appendix A., the incentive compatibility constraint will bind as long as the risk premium $r_{kt+1} - r_{t+1}$ is positive. In numerical simulations, I ensure that the risk premium is always positive.

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

The leverage ratio increases in the expected marginal benefit of obtaining one more unit of deposits and using it to buy firms' shares, and in the expected marginal gain of having one less unit of deposits and 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.[26]

Using (16), I can re-write the law of motion for the banker's net worth as follows:

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

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 2 *Banks have an identical leverage ratio as none of its components depends on bank-specific factors.*
Proof: From (17), one can obtain the following:

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

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

The expressions above show that banks have identical expected growth rates of assets and net worth, thus have identical leverage ratios.[27]

By using Proposition 2, we can sum demand for assets across j to obtain the total intermediary demand for assets:

$$q_t s_t = \frac{\eta_t}{\lambda - \nu_t} n_t \quad (20)$$

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

$$\widetilde{n}_{t+1} = \widetilde{n}_{et+1} + \widetilde{n}_{nt+1} \quad (21)$$

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

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

[26] 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.

[27] This immediately implies that η_t and ν_t are independent of j. In Appendix 7.1, I use this result in explicit derivation of η_t and ν_t.

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 (22), (23), and (24), we obtain the following law of motion for $\widetilde{n}_{t+1}$:

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

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 K_{t+1} and H_{t+1} in order to maximize their profits. The profit maximization problem solved by a representative firm is given by

$$\max_{\{K_{t+1+j} H_{t+j}\}_{j=0}^{\infty}} E_t \sum_{j=0}^{\infty} \beta^j \Lambda_{t,t+j} \left[z_{t+j} F(K_{t+j}, H_{t+j}) + q_{t+j}(1-\delta)K_{t+j} - (1 + r_{kt+j})q_{t-1+j}K_{t+j} - w_{t+j}H_{t+j}\right] \tag{27}$$

Profit maximization with respect to K_t and H_t gives us the following capital and labor demand conditions:

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

$$w_t = z_t F_H(K_t, H_t) \tag{29}$$

Condition (28) states that the real rate of return on capital is equal to the marginal product of capital plus the capital gain from changed prices. Condition (29) states that the wage rate is equal to the marginal product of labor.

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.[28]

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:

$$\max_{I_t} q_t K_{t+1} - q_t(1-\delta)K_t - I_t \tag{30}$$

$$s.t.\ \ K_{t+1} = (1-\delta)K_t + \Phi\left(\frac{I_t}{K_t}\right)K_t \tag{31}$$

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:

$$q_t = \left[\Phi'\left(\frac{I_t}{K_t}\right)\right]^{-1} \tag{32}$$

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.

3.5. 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 $\{w_t, r_{kt}, r_t, q_t\}_{t=0}^{\infty}$ 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:

$$\frac{U_l(t)}{U_c(t)} = w_t \tag{33}$$

$$U_c(t) = \beta(1+r_{t+1})E_t U_c(t+1) \tag{34}$$

$$r_{kt+1} = \frac{z_{t+1}F_K(K_{t+1}, H_{t+1}) + q_{t+1}(1-\delta)}{q_t} - 1 \tag{35}$$

$$w_t = z_t F_H(K_t, H_t) \tag{36}$$

$$n_t = \omega_t \widetilde{n}_t \tag{37}$$

$$q_t s_t = \frac{\eta_t}{\lambda - \nu_t} n_t \tag{38}$$

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

$$\nu_t = E_t[(1-\theta)\beta\Lambda_{t,t+1}(r_{kt+1} - r_{t+1}) + \beta\Lambda_{t,t+1}\theta\frac{q_{t+1}s_{t+1}}{q_t s_t}\nu_{t+1}] \tag{39}$$

$$\eta_t = E_t[(1-\theta)\beta\Lambda_{t,t+1}(1 + r_{t+1}) + \beta\Lambda_{t,t+1}\theta\frac{n_{t+1}}{n_t}\eta_{t+1}] \tag{40}$$

$$\widetilde{n}_{t+1} = \theta[(r_{kt+1} - r_{t+1})\frac{\eta_t}{\lambda - \nu_t} + (1 + r_{t+1})]n_t + \epsilon n_t \tag{41}$$

$$q_t s_t = q_t K_{t+1} \tag{42}$$

$$K_{t+1} = (1-\delta)K_t + \Phi\left(\frac{I_t}{K_t}\right)K_t \tag{43}$$

$$q_t = \left[\Phi'\left(\frac{I_t}{K_t}\right)\right]^{-1} \tag{44}$$

$$L_t = H_t \tag{45}$$

$$C_t + I_t = z_t F(K_t, H_t) \tag{46}$$

$$log(z_{t+1}) = \rho_z log(z_t) + \epsilon^z_{t+1} \tag{47}$$

$$log(\omega_{t+1}) = \epsilon^\omega_{t+1} \tag{48}$$

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 first-order approximation to the equilibrium conditions using the perturbation algorithm developed by Schmitt-Grohe and Uribe (2004).

4.1. Functional Forms, Parametrization and Calibration

The quantitative analysis uses the following functional forms for preferences, production technology and capital adjustment costs:[29]

$$U(c, 1-L) = log(c) + \upsilon(1-L) \tag{49}$$

$$F(K, H) = K^\alpha H^{1-\alpha} \tag{50}$$

$$\Phi\left(\frac{I}{K}\right) = \frac{I}{K} - \frac{\varphi}{2}\left[\frac{I}{K} - \delta\right]^2 \tag{51}$$

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 0.99 to match the 4% U.S. average annual real interest rate. I pick the relative utility weight of labor υ to fix hours worked in steady state

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

at one third of the available time, i.e. $\overline{L} = 0.33$. 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 investment to GDP in the U.S. data. The quarterly depreciation rate of capital is set to 2.26% 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 pick these parameters to match the following three targets: a steady-state interest rate spread of 97 basis points; a steady-state leverage ratio of 1.3, and an average survival time of 10 years for bankers.[30] The resulting values for $\overline{\lambda}$, ϵ and θ are 0.3437, 0.0017 and 0.967, respectively.

Finally, turning to the shock processes, the calibration of productivity shocks is standard. I set the persistence of TFP shocks to 0.95 as commonly used in the literature, i.e. $\rho_z = 0.95$, and I choose the standard deviation of shocks to TFP such that the benchmark model driven by productivity and net worth shocks generates a quarterly standard deviation of output equal to 1.97%, which is the volatility of GDP fluctuations over the past 58 years. The resulting value for σ_z is 0.0042. Furthermore, I assume that net worth shock, ω_t is an i.i.d. shock:

$$log(\omega_{t+1}) = \epsilon^{\omega}_{t+1} \tag{52}$$

with $\epsilon_\omega \sim$ N(0, σ_ω). I choose the standard deviation of the shock, σ_ω, such that in the benchmark model, the standard deviation of the leverage ratio relative to that of output is equal to 2.70, which is the relative volatility of the leverage ratio over the past 58 years.[31] The resulting value for σ_ω is 0.019.

Finally, I assume that productivity and net worth shocks are uncorrelated in the model since the theoretical model described above already features an endogenous mechanism in which productivity shocks affect banks' net worth and net worth shocks affect aggregate output.

4.2. Intermediary Capital and the Transmission of Shocks

I present the dynamics of the model in response to productivity and net worth shocks. The figures show the percentage deviations of the variables from their steady state values unless otherwise is noted.

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, lowering the value of firms' shares. This makes purchase of their shares less profitable for banks, which can also be observed from the fall in the expected marginal gain of increasing assets and the fall in the expected marginal benefit of increasing net worth. Thus, banks have difficulty in obtaining deposits from households since their equity investment becomes less attractive. This reduces the return to deposits, inducing countercyclical credit spreads. 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. This requires a fall in their leverage ratio. Hence, the model with productivity shocks generates a procyclical 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, inducing aggregate investment to fall. This creates the feedback loop of falling price of capital, deteriorating balance sheets of banks, and tightening financing conditions. Note that the fall in the balance sheet size of the banking sector is not only due to the fall in asset prices (price of capital) but also due to the fall in the quantity of risky asset holdings, namely firms' shares. This additional quantity adjustment increases the amplification effect of banks.

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 the net worth of banks. 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 generates a countercyclical

[30] The average survival time for bankers is taken from Gertler and Karadi (2010). Average interest rate spread is the historical average of high yield bond spread (Baa-Aaa) from 1952 to 2009).

[31] Calibrating the model to match the relative volatility of leverage ratio is crucial in explaining the financial fluctuations in the data.

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. This is why total liabilities (or deposits) first rise and then decline. Moreover, the fall in their net worth translates into a reduction in their equity investment on firms. The decline in equity investment is dramatic because banks are highly leveraged. Since firms finance their capital expenditures via equity purchases by intermediaries, they cut back their investment severely. The drop in investment reduces the price of capital, which lowers banks' net worth further. This generates the same feedback cycle of financial accelerator as above. Since the sharp fall in investment means that the economy eats up its capital, causing the rise in consumption. The expected marginal benefit of getting one more unit of deposits and buying firms' shares and the expected marginal gain of having one more unit of net worth rise as the rise in credit spread dominates the fall in the price of capital, which generates the increase in the banks' leverage ratios.

As apparent from Figures 4 and 5, both shocks affect both real and financial variables. However, net worth shocks generate larger fluctuations in financial variables. The rise in the credit spread is an order of magnitude higher in response to net worth shocks (10 basis points versus 2 basis points). The absolute change in the leverage ratio is six times larger in response to net worth shocks (3% versus -0.5%). Furthermore, net worth shocks induce sizeable fluctuations in real variables. The output falls by 0.5% after the net worth shock hits, which is nearly the same in response to productivity shocks. The fall in investment is more pronounced in response to net worth shocks (3% versus 2%). Moreover, net worth shocks create qualitatively different responses in some real and financial variables. Consumption, bank leverage ratio, and bank liabilities surge in response to negative net worth shocks while they shrink in response to negative productivity shocks.

4.3. Business Cycle Dynamics

This section presents numerical results from stochastic simulations of the economy with productivity and net worth shocks. I simulate the economy 1000 times for 1232 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 business cycle statistics using the simulated series.

Table 5 presents business cycle statistics of real and financial variables for the model economies with (1) both productivity and net worth shocks – henceforth, benchmark model, (2) only productivity shocks, and (3) only net worth shocks. The third column of Table 5 indicates that the benchmark model quantitatively accounts for almost all real and financial fluctuations in the data. Consumption is less volatile than output, investment is more volatile than output, and all real variables are highly persistent. In addition, debt is roughly as volatile as output, equity is two times more volatile than output, and credit spread is an order of magnitude more volatile than output. Moreover, debt and equity are procyclical, leverage ratio is mildly countercyclical or acyclical, and credit spread is countercyclical. Thus, I conclude that real and financial statistics produced by the benchmark model are all inline with the data, which is one of the main results of the paper.

The fourth and the fifth columns of Table 5 indicate that the absence of either shock prevents the model from explaining some important features of real and financial data. Productivity shocks can only explain 23% of the variation in debt, almost zero percent of the variation in bank net worth, nearly 2% of the variation in leverage ratio and credit spreads. This model overpredicts somewhat the observed degree of procyclicality in debt, and even more so the leverage ratio. It also generates an acyclical credit spread, contrary to the data. On the other hand, the model driven solely by net worth shocks creates strong countercyclicality in debt, leverage ratio and credit spreads, and highly procyclical net worth, neither of which is inline with the data. This model also generates counterfactual negative correlations between consumption and output, and consumption and investment.

Tables 6 and 7 report variance decompositions of real and financial variables in response to productivity and net worth shocks. In particular, it displays the percentage of variance of the k-step-ahead forecast error in real and financial variables due to productivity and net worth shocks. Table 6 shows that productivity shocks account for only small fractions of equity, leverage ratio and credit spread while accounting for a non-trivial fraction of debt. Moreover, Table 7 indicates that net worth shocks induce sizeable fluctuations in real variables. These shocks account for 29% of the fluctuations in output, 22% of the fluctuations in consumption, 72% of the fluctuations in investment, and 84% of the fluctuations in labor hours. The results suggest that the fluctuations in bank net worth are an important source for business cycle fluctuations.

Asset prices play an important role in generating financial fluctuations in the data. In order to quantify the importance of asset price movements for financial variables, I also solve the benchmark model with fixed asset prices.[32] Fixing the asset prices reduces the fluctuations in debt, equity, leverage ratio, and credit spreads by 12%, 13%, 19%, and 3.6 percentage points, respectively. This model also generates less procyclical debt, more procyclical net worth, more countercyclical leverage ratio and credit spreads.

Figure 6 displays the performance of the model in terms of cross-correlations of financial variables with 5 period leads and lags of output. The cross-correlations of financial variables with GDP generated by the model driven by productivity and net worth shocks are quite close to the data. This figure also suggests that the absence of either shock prevents the model from explaining the observed lead-lag relationships of financial variables. Overall, I conclude that the model's predictions about the cyclicality of financial variables are consistent with the data.

4.4. Cyclical Properties of Capital Adequacy Ratio and Policy Implications

I close by presenting empirical observations on capital adequacy ratio (CAR) of U.S. financial sector and compares these observations with the model-generated CAR.[33] Figure 7 shows the cyclical component of CAR with NBER recession dates. The quarterly standard deviation of CAR is 4.92%, which is two and a half times more volatile than output. Its correlation with GDP is 0.08, implying that it is acyclical or mildly procyclical at best.

The benchmark model accounts for 61% of the variation in CAR. The contemporaneous correlation between the CAR and output is 0.21, suggesting that it is mildly procyclical. Furthermore, productivity shocks explain 19% of the fluctuations in CAR. Its contemporaneous correlation with output is -0.91, implying that it is strongly countercyclical, contrary to the data. The model driven solely by net worth shocks generates 58% of the observed volatility of the CAR. Its contemporaneous correlation with output is 0.98, implying that it is strongly procyclical, which is not inline with the data. Moreover, these results suggest that the cyclicality of the CAR depends on the sector that the shock originates from and are inline with the findings in Meh and Moran (2010). If the shock originates within financial sector, the CAR is strongly procyclical, while if it originates within non-financial sector, the CAR is countercyclical. Furthermore, these findings imply some important policy prescriptions about bank capital requirements. If the shock originates within the banking sector, banks should accumulate extra capital stock in booms. Excess bank capital increases bank lending to non-financial firms and these firms increase their demand for investment goods raising the asset prices. Higher assets prices improves the banks' balance sheets and break the feedback cycle. In addition, this result is consistent with recent demand of developed and developing countries' banks to mitigate their capital adequacy requirements, especially Basel III criteria. However, if the shock originates within the production sector, banks should reduce their extra capital stock in booms. This is the case because firms cannot find profitable investment opportunities due to lower productivity and asset prices fall. This worsens the banks' net worth. Hence, the capital requirements should be tightened so that banks set aside more capital in order to improve their balance sheet conditions. After the productivity shock mitigates and banks' net worth improves, bank lending increases, breaking the feedback loop.

5. Conclusion

This paper characterizes the cyclical behavior of aggregate financial variables of U.S. financial sector together with those of credit spread. Using a DSGE model augmented with profit maximizing banks in which banks' net worth mitigates an agency problem between financial intermediaries and its depositors, I quantitatively show

[32] Capital adjustment cost parameter is set to zero so that asset prices are always equal to one. The quantitative results of that model are not shown here, however they are available upon request.

[33] Capital adequacy ratio (CAR) is defined as the ratio of bank equity to bank assets.

that the model driven by productivity and net worth shocks accounts for almost all real and financial fluctuations in the U.S. data. Net worth shocks are transmitted to the real economy through a purely financial channel: if there were no financial frictions between households and banks, net worth shocks are not able to generate any real fluctuations. The absence of either shock or the agency problem prevents the model from explaining the observed dynamics of real and financial variables simultaneously. Moreover, net worth shocks induce sizeable fluctuations in real variables. However, productivity shocks can only partially explain the fluctuations in financial variables. Finally, the model driven by net worth shocks implies a policy prescription for banks in response to financial shocks. If net worth shock hits the economy, the capital adequacy ratio (CAR) is strongly procyclical, meaning that banks should build up more capital when the economy is in a boom, consistent with Basel III regime. These results suggest that the model in the current paper can be used for practical policy analysis.

In this paper, adverse macro shocks create an adverse feedback loop of falling asset prices, deteriorating balance sheets and tightening borrowing constraints for financial intermediaries. Banks do not internalize that changes in their net worth affect asset prices, which in turn determine the tightness of their borrowing constraints. As Jeanne and Korinek (2009) suggest, they do not internalize their contribution to aggregate volatility and take on excessive leverage inducing systemic externalities. The model can quantify the systemic externalities originating from excessive borrowing of bankers. Moreover, the following normative question arises in this environment: Which macroprudential regulations can be introduced to make the banks internalize the systemic externalities? What is the optimal tax rate to impose on borrowing by financial intermediaries to prevent them from taking on excessive leverage? For further research, in order to start thinking about how macroprudential regulations can be implemented in an environment in which the financial sector is crucial for business cycle fluctuations, 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.

Appendix A: Profit Maximization Problem of Banks

The profit maximization problem by a representative bank is given by

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

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

where μ_t is the Lagrange multiplier associated with the incentive compatibility constraint. The first order conditions w.r.t. s_{jt} and μ_t are given respectively by

$$(1-\theta)\theta\beta\Lambda_{t,t+1}(r_{kt+1} - r_{t+1})q_t - \mu_t \lambda q_t = 0 \tag{53}$$

$$V_{jt} - \lambda q_t s_{jt} = 0 \tag{54}$$

From (53), we establish that μ_t is greater than zero as long as $r_{kt+1} > r_{t+1}$. Since, by assumption, $\beta^i \Lambda_{t,t+i}[(r_{kt+1+i} - r_{t+1+i})]$ is greater than zero, the incentive compatibility constraint will hold with equality. Thus, we have

$$V_{jt} = \lambda q_t s_{jt} \tag{55}$$

Now, we will write V_{jt} in a recursive form to obtain the leverage ratio of financial intermediaries. Let's define the following variables:

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

$$\eta_t n_{jt} = E_t \sum_{i=0} (1-\theta)\theta^i \beta^i \Lambda_{t,t+1+i}(1+r_{t+1+i})n_{jt+i} \tag{57}$$

Thus, we have the following expression:

$$V_{jt} = \nu_t q_t s_{jt} + \eta_t n_{jt} \tag{58}$$

Now we need to write ν_t and η_t recursively in order to get rid of infinite sums. Let's begin with ν_t. To ease the notation, let's drop expectations for now.

$$\nu_t = \sum_{i=0} (1-\theta)\theta^i \beta^i \Lambda_{t,t+1+i}\left[(r_{kt+1+i} - r_{t+1+i})x_{t,t+i}\right] \tag{59}$$

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

$$\nu_t = (1-\theta)\Lambda_{t,t+1}(r_{kt+1} - r_{t+1}) + \sum_{i=1} (1-\theta)\theta^i \beta^i \Lambda_{t,t+1+i}\left[(r_{kt+1+i} - r_{t+1+i})x_{t,t+i}\right] \tag{60}$$

$$\nu_t = (1-\theta)\Lambda_{t,t+1}(r_{kt+1} - r_{t+1}) + \beta\Lambda_{t,t+1}\theta x_{t,t+1} \sum_{i=1} (1-\theta)\theta^{i-1} \beta^{i-1} \Lambda_{t+1,t+i}\left[(r_{kt+1+i} - r_{t+1+i})x_{t+1,t+i}\right] \tag{61}$$

By updating equation (59) one period, we obtain the following expression for ν_{t+1}

$$\nu_{t+1} = \sum_{i=0} (1-\theta)\theta^i \beta^i \Lambda_{t+1,t+i}\left[(r_{kt+1+i} - r_{t+1+i})x_{t+1,t+i}\right] \tag{62}$$

where $x_{t+1,t+i} = \frac{q_{t+i}s_{jt+i}}{q_{t+1}s_{jt+1}}$.

We can write (62) in the following way:

$$\nu_{t+1} = \sum_{i=1} (1-\theta)\theta^{i-1}\beta^{i-1}\Lambda_{t+1,t+i}\left[(r_{kt+1+i} - r_{t+1+i})x_{t+1,t+i}\right] \tag{63}$$

Thus, (63) is equal to the expression in the second term of RHS of equation (61). Hence, we can re-write (61) with the expectations as follows:

$$\nu_t = E_t[(1-\theta)\Lambda_{t,t+1}(r_{kt+1} - r_{t+1}) + \beta\Lambda_{t,t+1}\theta x_{t,t+1}\nu_{t+1}] \tag{64}$$

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

$$\eta_t = \sum_{i=0} (1-\theta)\theta^i\beta^i\Lambda_{t,t+i}(1 + r_{t+1+i})z_{t,t+i} \tag{65}$$

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

$$\eta_t = (1-\theta)\Lambda_{t,t+1}(1 + r_{t+1}) + \sum_{i=1} (1-\theta)\theta^i\beta^i\Lambda_{t,t+i}(1 + r_{t+1+i})z_{t,t+i} \tag{66}$$

$$\eta_t = (1-\theta)\Lambda_{t,t+1}(1 + r_{t+1}) + \beta\Lambda_{t,t+1}\theta z_{t,t+1} \sum_{i=1} (1-\theta)\theta^{i-1}\beta^{i-1}\Lambda_{t+1,t+i}(1 + r_{t+1+i})z_{t+1,t+i} \tag{67}$$

By updating equation (65) one period, we obtain the following expression for η_{t+1}

$$\eta_{t+1} = \sum_{i=0} (1-\theta)\theta^i\beta^i\Lambda_{t+1,t+i}(1 + r_{t+1+i})z_{t+1,t+i} \tag{68}$$

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

We can write (68) in the following way:

$$\eta_{t+1} = \sum_{i=1} (1-\theta)\theta^{i-1}\beta^{i-1}\Lambda_{t+1,t+i}(1 + r_{t+1+i})z_{t+1,t+i} \tag{69}$$

Thus, (69) is equal to the expression in the second term of RHS of equation (51). Hence, we can re-write (67) with the expectations as follows:

$$\eta_t = E_t[(1-\theta)\Lambda_{t,t+1}(1 + r_{t+1}) + \beta\Lambda_{t,t+1}\theta z_{t,t+1}\eta_{t+1}] \tag{70}$$

When the incentive constraint binds, we have

$$\nu_t q_t s_{jt} + \eta_t n_{jt} = \lambda q_t s_{jt} \tag{71}$$

$$q_t s_{jt} = \frac{\eta_t}{\lambda - \nu_t} n_{jt} \tag{72}$$

By manipulating this expression using the balance sheet of financial firm, we can obtain the leverage ratio of financial firms as follows:

$$b_{jt+1} + n_{jt} = \frac{\eta_t}{\lambda - \nu_t} n_{jt} \tag{73}$$

$$\frac{b_{jt+1} + n_{jt}}{n_{jt}} = \frac{\eta_t}{\lambda - \nu_t} \tag{74}$$

$$\frac{b_{jt+1}}{n_{jt}} = \frac{\eta_t}{\lambda - \nu_t} - 1 \tag{75}$$

Therefore, $\frac{\eta_t}{\lambda - \nu_t}$ - 1 is the leverage ratio of the financial sector.

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Tables and Figures

Table 1: Business Cycle Statistics, Quarterly U.S. Data, 1952-2009

		GDP	C	I	Leverage R.	Debt	Equity	Spread
Standard deviation (%)		1.97	0.89	5.56	5.33	2.16	5.76	21.70
Quarterly autocorrelation		0.83	0.86	0.82	0.74	0.92	0.79	0.75
Correlation matrix	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
	I	–	–	1	-0.10	0.63	0.33	-0.62
	Leverage R.	–	–	–	1	-0.03	-0.92	0.14
	Debt	–	–	–	–	1	0.40	-0.51
	Equity	–	–	–	–	–	1	-0.32
	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 2: 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}
LeverageR.	0.00	0.00	0.00	0.00	-0.03	-0.08	-0.14	-0.18	**-0.18**	-0.10	0.00
Debt	0.01	0.13	0.27	0.41	0.52	**0.57**	0.57	0.50	0.39	0.26	0.12
Equity	0.00	0.04	0.09	0.14	0.21	0.28	0.34	**0.35**	0.31	0.20	0.05
Spread	0.28	0.17	0.03	-0.15	-0.34	-0.56	**-0.67**	-0.60	-0.46	-0.29	-0.11

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

Table 3: The Sequence of Events in a Given Time Period

1. Aggregate productivity shock z_t is realized.
2. Firms hire labor H_t and production for period t takes place, $Y_t = z_t\mathrm{F}(K_t,\, H_t)$.
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. Net worth shock 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.

Table 4: Model Parameterization and Calibration

Description	Parameter	Value	Target	Data	Moment
Preferences					
Quarterly discount factor	β	0.99	Annual T-bill rate (inflation adjusted)	4%	4%
Relative utility weight of leisure	υ	2.4375	Hours worked	0.33	0.33
Production Technology					
Share of capital in output	α	0.36	Labor share of output	0.64	0.64
Capital adjustment cost parameter	φ	3.7	Relative volatility of investment to GDP	2.82	2.82
Depreciation rate of capital	δ	0.026	Average annual ratio of investment to capital	9.35%	9.35%
Steady-state total factor productivity	$\overline{z}$	1	Normalization	N/A	N/A
Financial Intermediaries					
Steady-state fraction of assets that can be diverted	λ	0.3437	Average financial leverage ratio	1.3	1.3
Proportional transfer to the entering bankers	ϵ	0.0017	Average high yield bond spread (Baa-Aaa)	0.97%	0.97%
Survival probability of the bankers	θ	0.967	Average survival time of banks in years	10	10
Steady-state level of net worth shock	$\overline{\omega}$	1	Normalization	N/A	N/A
Shock Processes					
Persistence parameter of productivity shock	ρ_z	0.95	Quarterly persistence of TFP	0.95	0.95
Standard deviation of productivity shock	σ_z	0.0042	Quarterly standard dev. of output	1.97%	1.97%
Standard deviation of net worth shock	σ_ω	0.019	Relative volatility of leverage ratio to GDP	2.70	2.70

Figure 1: Leverage ratio of U.S. financial firms, 1952-2009

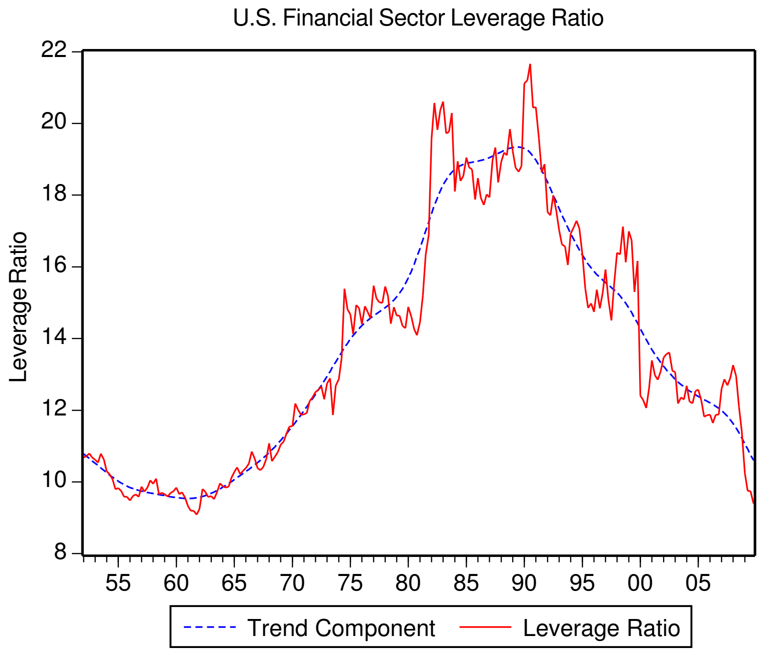

Table 5: Real and Financial Statistics

Statistic	Data	Benchmark	Only Productivity Shocks	Only Net Worth Shocks
σ_Y	1.97	1.97*	1.70	0.95
$\frac{\sigma_C}{\sigma_Y}$	0.45	0.77	0.80	0.61
$\frac{\sigma_I}{\sigma_Y}$	2.82	2.82*	1.87	4.76
$\frac{\sigma_L}{\sigma_Y}$	0.88	0.62	0.30	1.17
ρ_Y	0.83	0.94	0.95	0.89
ρ_C	0.86	0.95	0.96	0.90
ρ_I	0.82	0.85	0.88	0.83
ρ_L	0.76	0.83	0.84	0.82
$\rho_{Y,I}$	0.96	0.82	0.91	0.92
$\rho_{Y,C}$	0.54	0.72	0.93	-0.11
$\rho_{Y,L}$	0.81	0.65	0.73	0.87
$\rho_{C,I}$	0.29	0.27	0.81	-0.48
$\frac{\sigma_{Debt}}{\sigma_Y}$	1.10	1.21	1.08	1.51
$\frac{\sigma_{Equity}}{\sigma_Y}$	2.92	2.11	0.48	4.28
$\frac{\sigma_{LeverageR.}}{\sigma_Y}$	2.70	2.70*	0.96	5.35
$\frac{\sigma_{Spread}}{\sigma_Y}$	11.01	10.01	1.80	23.13
ρ_{Debt}	0.92	0.91	0.97	0.82
ρ_{Equity}	0.79	0.90	0.99	0.90
$\rho_{LeverageR.}$	0.74	0.87	0.97	0.86
ρ_{Spread}	0.75	0.92	0.84	0.92
$\rho_{Y,Debt}$	0.57	0.41	0.90	-0.65
$\rho_{Y,Equity}$	0.28	0.50	0.15	0.99
$\rho_{Y,LeverageR.}$	-0.08	-0.20	0.91	-0.98
$\rho_{Y,Spread}$	-0.56	-0.44	0.01	-0.94

[a] The numbers with * are the calibration targets.
[b] The correlation coefficients greater than 0.13 are statistically significant at 5% significance level.

Table 6: Percentage Variance Due to Productivity Shocks

	4 Quarters Ahead	8 Quarters Ahead	12 Quarters Ahead	20 Quarters Ahead
Output	71.60	72.85	74.34	76.20
Consumption	78.01	88.67	91.38	90.62
Investment	28.42	30.91	32.61	34.28
Hours	16.41	16.87	17.09	17.16
Debt	22.91	39.52	51.96	63.75
Equity	0.02	0.02	0.02	0.02
Leverage R.	2.07	3.88	5.49	7.43
Credit Spread	2.14	1.32	1.26	1.48

Table 7: Percentage Variance Due to Net Worth Shocks

	4 Quarters Ahead	8 Quarters Ahead	12 Quarters Ahead	20 Quarters Ahead
Output	28.40	27.15	25.66	23.80
Consumption	21.99	11.33	8.62	9.38
Investment	71.58	69.09	67.39	65.72
Hours	83.59	83.13	82.91	82.84
Debt	77.09	60.48	48.04	36.25
Equity	99.98	99.98	99.98	99.75
Leverage R.	97.93	96.12	94.51	92.57
Credit Spread	97.86	98.68	98.74	98.52

Figure 2: Cyclical Components of GDP and Aggregate Financial Variables, 1952-2009

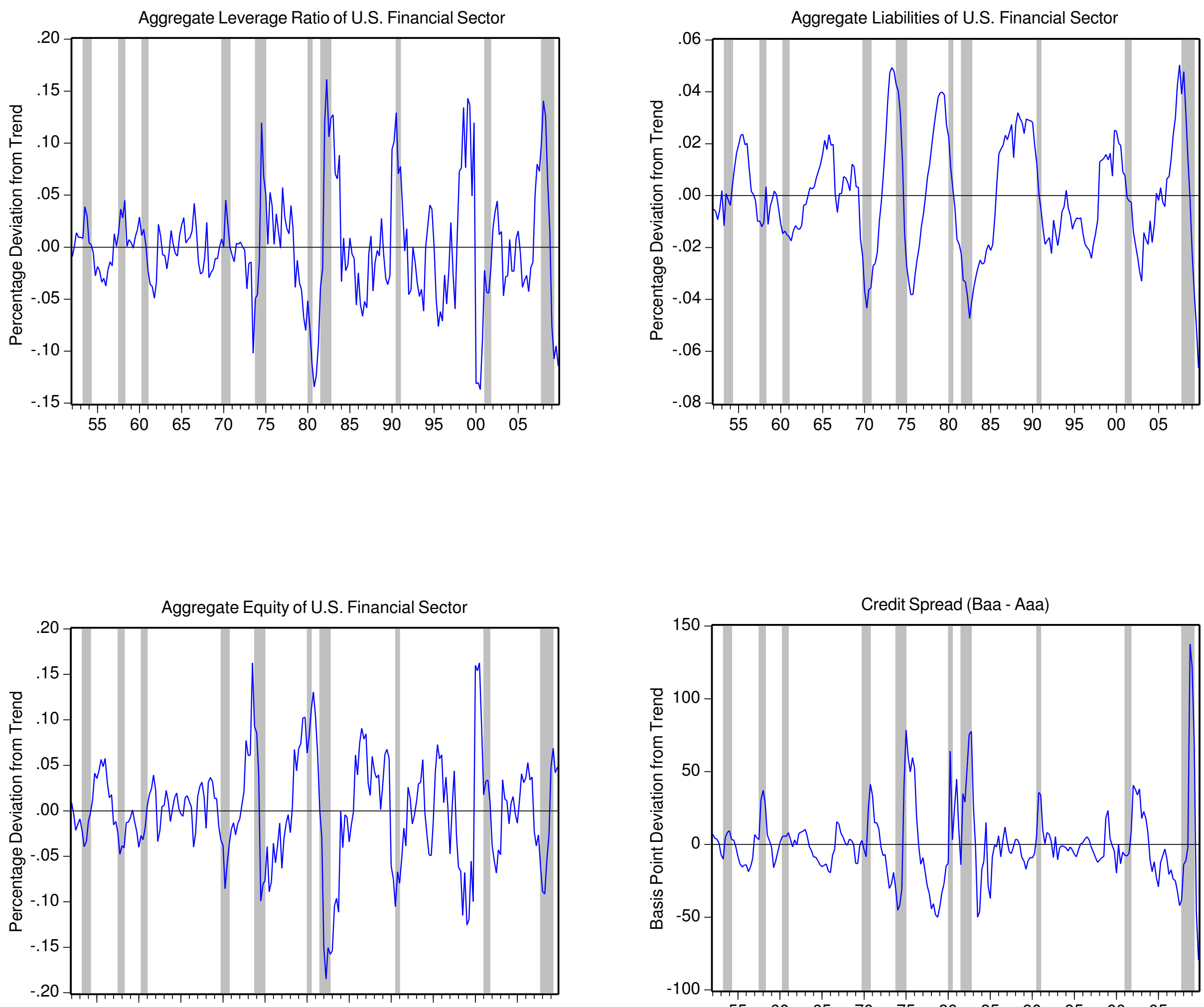

Figure 3: Impulse responses to a negative one-standard-deviation productivity shock

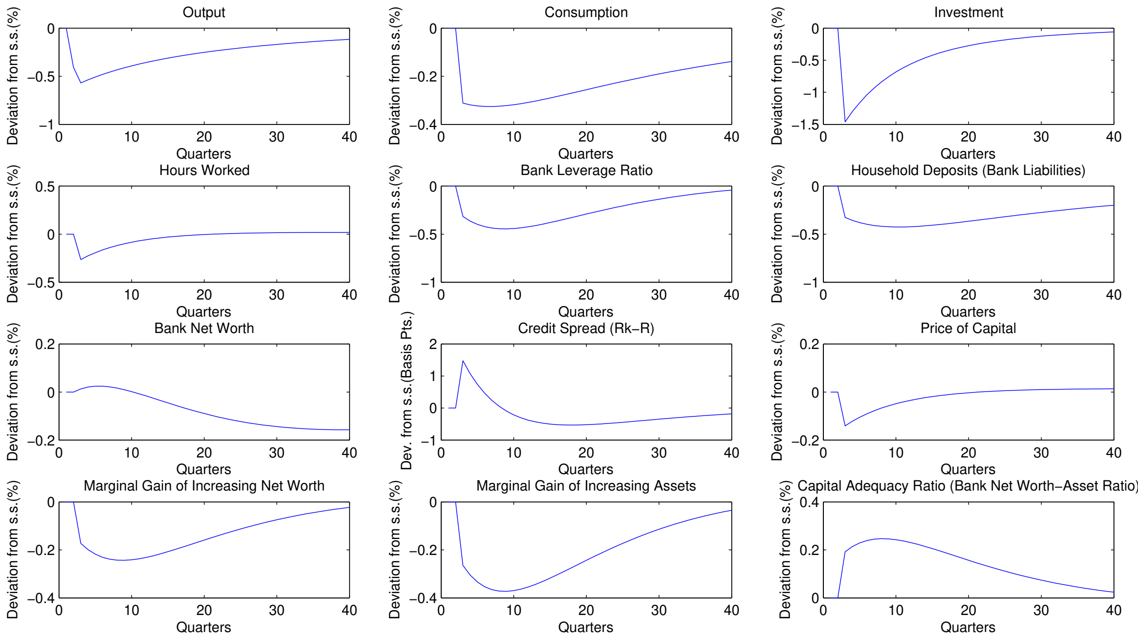

Figure 4: Impulse responses to a negative one-standard-deviation net worth shock

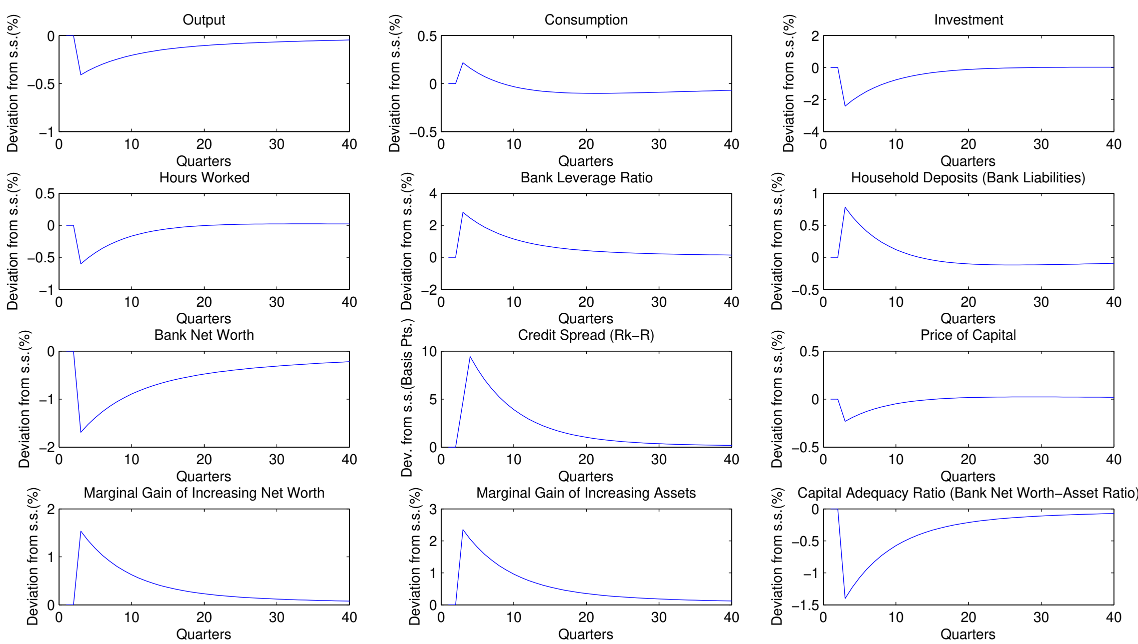

Figure 5: Cross-correlations between GDP and aggregate financial variables

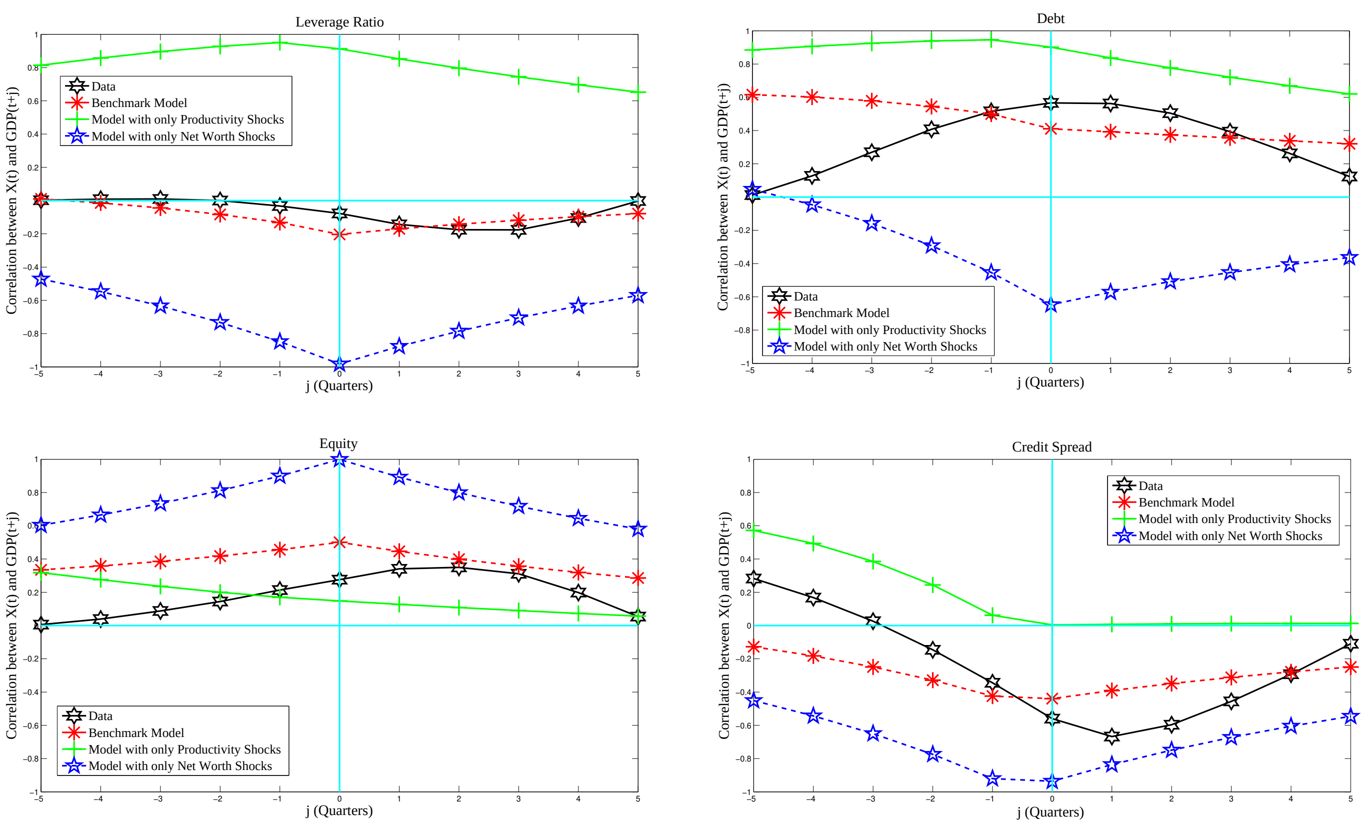

Figure 6: Cyclical Component of Capital Adequacy Ratio of U.S. Financial Sector, 1952-2009