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A Real Business Cycle Model with Loan Securitization

by

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A thesis submitted in partial fulfillment for the degree of Master of Arts

in the

Graduate School of Social Sciences
Department of Economics

July 2010

Declaration of Authorship

I, İlhan Güner, declare that this thesis titled, 'A Real Business Cycle Model with Loan Securitization' and the work presented in it are my own. I confirm that:

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- Where I have consulted the published work of others, this is always clearly attributed.
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Abstract

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We document the importance and wide-spread popularity of loan securitization in the modern banking era. Instead of holding the loans on the balance sheets until maturity, banks pool the loans they made, create securities backed by these loans and sell to investors. We recognize the importance of securitization and we develop a real business cycle model, where banks endogenously "originate and distribute" the mortgage loans they administer. We calibrate the model against the US data. We solve the model by perturbation techniques. Our results show that the model is able to generate some important stylized facts of the business cycles and the cyclical properties of the bank balance sheet items.

Acknowledgements

I wish to thank Sumru Altug for encouraging me find a topic that is relevant to the real economy, helping to come with such topic, supervising me during writing my thesis and enhancing mu understanding of this topic.

I am grateful to Selva Demiralp and Cem Demiroglu for their valuable time to listen my thesis defense and being in my thesis committee. I owe a lot to my family for their presence. Very special thanks to my friends Ramazan Bora and Metin Uyanık for their friendship and their technical support in learning Matlab and Latex.

During my gradute study, Vehbi Koç Foundation and TUBITAK supported me with the financial assistance.

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To my family…

Chapter 1

Introduction

Fluctuations in the aggregate economic activity has long been an interest of the economists for decades. One of the main questions they try to answer is that relatively small shocks such as oil shocks in 1973, monetary shocks or sub-prime mortgage credit shock lead to large fluctuations in the aggregate economic activity. One answer proposed in the literature is that credit frictions among agents in the market could amplify and propagate the small shocks. Recent financial crisis that the world faces strengthens this idea because the relatively small shock in sub-prime mortgage market has devastating effects on the real economy, i.e. a small shock is amplified into a recession via securitization and leverage. In this paper, our main objective is to develop a dynamic stochastic general equilibrium (DSGE) model which includes a banking sector in a "modern way"-banks originate and distribute loans. Then we calibrate the model against the US data and show that the model is able to capture some important stylized facts of US business cycles.

One explanation that researchers come up with for the puzzle is the principal-agent approach to credit markets. In this approach, to acquire information about borrowers'(agents) balance sheet conditions lenders (principals) have to bear some costs, hence agents have to pay more to outside financing than internal financing, and the premium is inversely related to the agent's net worth. This premium is called the agency cost of external finance. A reduction in the net worth of an agent, which may be the result of a decrease in cash flow to the borrower or a lower value of collaterizable asset, increases the external funds required. It also increases the premium on external finance, and decreases the spending and production of borrowers [Bernanke et al. (1996)]. Generally consumers, small firms, and firms who have weak balance sheets (highly leveraged firms) face high agency costs when accessing to the credit market. Bernanke et al. (1996) argue that the endogenous changes in the credit conditions affect the borrowers who have high agency cost more, hence their access to credit markets decreases (the flight to quality). As a result they reduce their economic activity. The mechanism works as follow: first a negative shock comes and suppresses the agent's economic activity, but also, since their net worth is decreased, their ability to borrow also decreases. As a result the agent's economic activity is further suppressed. They refer to the amplification of initial shocks brought about by the endogenous changes in the credit market conditions as "financial accelerator." Also in the case of manufacturing firms, they found empirical evidence that firms with high agency costs are differentially affected by the downturns in terms of accessing to credit markets and the real economic activity.

Kiyotaki and Moore (1997) try to answer the same puzzle in a similar theoretical study. They argue that the dynamic interaction between credit limits and asset prices play an important role in transmission and amplification of shocks. They model an economy where land is used as a factor of production and as a collateral for borrowing. A negative productivity shock decreases the net worth of the borrower and her credit limits, hence in that period the credit constrained firm has to reduce its investment in output production and investment in land. Since the total supply of land is fixed, and the demand for the land decreases, the price of land decreases in the subsequent periods, which in turn effects the credit limits of the firm negatively since land is used as a collateral to borrowing, hence investment in the next periods.

In Bernanke et al. (1996) and Kiyotaki and Moore (1997) how the credit frictions on non-financial firms' borrowing affects the real economy and the role of financial intermediaries is not taken into account. However, the recent financial crisis has shown that the credit frictions on financial sector's borrowing might have devastating effects on the real economy. Gertler and Kiyotaki (2009) focuses on the credit frictions which affect the financial sectors' borrowing, assuming that there is no friction on non-financial sector borrowing. In their model, households deposit their savings to intermediaries and the intermediaries provide funds to the non-financial firms. Deposits of households is not the only source of funding of the financial firms. They can also borrow among each other (inter-bank market). They introduce an agency problem similar to Bernanke et al. (1996) and Kiyotaki and Moore (1997). If an exogenous decline in the asset values occurs, the net worths of banks decrease. If the banks are highly leveraged, the decline in asset values is enhanced with leverage. This decline tightens the banks' borrowing constraints which leads to fire sales of assets, and a fall in investment.

Instead of focusing on the role of financial sector as propagating the shocks that is originated in other sectors of the economy, Jermann and Quadrini (2009) introduce a model in which the financial sector is the originator of shocks to the economy. In their model, firms finance their investments with equity and debt.

However, the firms' ability to borrow is limited by the firms' expected lifetime profitability, which is also subject to random disturbances which they define as financial shocks. They argue that it is not possible to generate dynamic properties of the US business cycles with only productivity shocks, but a model with financial shocks and productivity shocks is able to capture the dynamic properties of the real activity and also the dynamics of financial flows.

In these models supply side of the financial intermediation is not stressed. Balance sheets of the banks could be the propagator of the shocks. Pierrard et al. (2009) investigate this issue. They develop a model with a heterogenous banking sector, endogenous default rates, and capital requirements for the banks set by the regulatory authority. Their model is micro founded in the sense that all the agents are maximizing their own utilities. They find that the productivity shocks alone cannot generate the dynamic properties of the US business cycle. On the other hand, introduction of a market book shock improves their results. We will follow this model since their way of identifying the banking sector helps us to implement our idea of incorporating securitization into the model. As we will explain below, securitization is an integral part of modern banking era.

In the last decade, the traditional banking transferred into ”originate and distribute” model. Previously, banks were maintaining their loans on their balance sheets until maturity. In such an environment, all the risk of the loans was born by the issuing bank. In the ”originate and distribute” banking model, banks give loans, make a portfolio of different loan types, tranche these loans according to risk levels of the loans and sell these loans to the investors via securitization. Therefore the risk is transferred to investors who have appetite to bear high risk then they would receive high return [Brunnermeier (2009)].

The popularity of the securitization can be attributed to the following reasons: First, banks can pass the risk otherwise they would hold to the investors who would like to bear it. Since the securitized loans are no longer on the balance sheets of the banks, the risk is dispersed to all of the agents in the market. This helps banks to increase the amounts of the loans they make. However, as the risk is passed to other agents, banks decrease their effort on screening and monitoring the borrowers. They even lend to the borrowers who have no chance to receive credit in normal times [Brunnermeier (2009)]. Contrary to what is expected, banks have too much exposure to these securitized products, the risk never left the banking system[Duffie (2008)].

Second, due to the bank capital requirements imposed by Basel accord, banks find it profitable to establish special purpose vehicles (SPVs) which invest in long term loans of the banks and finance their operations by issuing short term asset backed securities [Gorton (2009)]. Then, banks provide contractual and reputational credit lines to these SPVs. The capital requirements for contractual credit lines are much lower than on the balance sheet items, and there is no capital requirement for reputational credit lines [Brunnermeier (2009)]. With this method, banks decrease their capital requirements.

Third, because of the expansion in the collateralized borrowing, there is excess need for assets that could be used as collateral. Senior tranches of securitized assets serve this role since they are "informatively-insensitive" debt like the deposits [Gorton (2009)]. An asset is "informatively-insensitive" if investors cannot take position against the asset by gathering information. Since the securitized assets are highly complex and the senior tranches are considered to have very low risk, they are regarded as "informatively-insensitive"[Gorton (2009)].

Fourth, securitized assets are backed by mortgages who have historically low delinquency rates. Hence there were optimistic forecasts about the future of these products[Brunnermeier (2009)]. Because of all these reasons and many more, banks continued on securitization during the housing boom.

However, the securitization boom had some adverse effects on the market, especially on the credit quality. Since, banks are able to spread the credit risk, they decreased their lending standards. Mian and Sufi (2008) show empirically that, from 2001 to 2005, on the areas where there are relatively less income and employment growth, a relative decrease in denial rates for mortgage applications, an increase in mortgage originating and an increase in house prices are observed. Keys et al. (2010) also investigate how securitization affected the default rates and screening. They found that the default rates of the portfolio on which the securitizion is easier are around $10\% - 25\%$ higher than the default rates of the portfolio on which the securitization is harder. Also, they find that securitization adversely affects the screening of sub-prime mortgages. Demyanyk and Van Hemert (2009) find that the quality of mortgage loans deteriorated for 6 years before the crisis, and securitizers were aware of this.

Now there are two prominent views about securitization: one is in favor of it, the other is against it. On the former, securitization is favored since it enables to spread the risk among the market hence leads to more efficient functioning of the market. On the latter, securitization is regarded as evil, since it was just like putting the "hot-potato" to the most fool agent in the market[Shin (2009)]. In this case "hot-potato" is bad loans. However the most fool agents in the market are the leveraged financial intermediaries. Greenlaw et al. (2008) report that half of the sub-prime loss were borne by the leveraged financial institutions. Shin (2009) claims that the second view is as flawed as the first one, since the proponents of the second view could not distinguish between "selling a bad loan" and "selling a security backed by bad loans". In the first one, sellers get rid of the credit risk, however in the second one they continue to hold the credit risk on their balance sheets or on SPVs which are sponsored by them.

From all these,we can conclude that securitization plays an important role in the modern banking era. Hence, any DSGE model, which lacks the banking sector and the securitization activities of the banks, misses an important feature of the modern economy. In this paper, we incorporated a housing market and securitization process into the model of Pierrard et al. (2009). The model with securitization generates some important stylized facts of US business cycles. Chapter 2 presents the model, Chapter 3 explains the calibration of the model, chapter 4 shows the simulation results, and chapter 5 concludes.

Chapter 2

The Model

In our model, there is a representative firm, a representative bank and a continuum of households distributed on the interval $[0, 1]$. Following Pierrard et al. (2009) we depart from the standard RBC model by introducing a housing market, an endogenous banking sector, endogenous default rates for firms and households, and loan securitization for the bank. The firm may default on its loans and the households may default on their mortgages but they have to bear the cost of defaulting. The firm and households choose how much of their debt to pay back. We assume that the bank does not default on its obligation to the households. This is a reasonable assumption for the OECD countries.

The firm, owned by the households, produces not only the consumption/investment good, but also housing. It sells the house it builds to the households. The households deposit their savings to the bank and take mortgage loans from the bank. The bank also gives loans to firms.

We depart from the literature by introducing a bank which does not have to hold the mortgages until the maturity date. It may securitize some of the mortgages it makes, and sell these securities to the households. In our model, securitization is simply selling of the future mortgage receivables.

2.1 Mortgage and Securitization

In each period t, the representative bank lends M_t for 4 subsequent periods to the households at a price $1/(1+r_t^m)$, i.e. in real terms the bank lends $\sum_{i=1}^{4} M_t \left(\frac{1}{1+r_t^m}\right)^i$ at period t and receives M_t at periods $t+1, t+2, t+3, t+4$. Contrary to the traditional banking model, the bank "originates and distributes" the mortgages by securitization. Let S_t be the amount of the mortgage that the bank securitizes at period t. This means that the bank is selling the amount S_t from the future mortgage receivables M_t for the next 4 periods. We assume that the bank pools the mortgages that are given at the same period, and assume homogeneity of degree one for the securities. i.e. each security represents 1 unit of mortgage and the sum of these securities are equal to S_t. The bank holds a fraction, d, of these securities on its balance sheet. This is a reasonable assumption, and in accordance with the market, since exposure of the bank to its securities would give confidence to the investors [See Shleifer and Vishny (2009) for detailed explanation]. Then, the bank sells $1-d$ of the securities to the households at a price Q_t^4, and the households trade these securities among themselves, at a price Q_t^j,where j represents the remaining periods till maturity. Since the mortgages mature in 4 periods, and the securitization is simply the selling of these mortgage payments, the securities mature in 4 periods. $Q_t^0 = 0$ since there is no future payment.

2.2 Firm

There is a representative firm which produces the consumption/investment good and housing. The firm decides on the proportion of capital stock, v_t, and on the proportion of labor, u_t, to be used in the consumption/investment good production where $0 < v_t, u_t < 1$. The production functions for each sector are

$$Y_t = A_t[v_t K_{t-1}]^{\mu}[u_t N_t]^{1-\mu} \tag{2.1}$$

$$h_t = B_t[(1-v_t)K_{t-1}]^{\eta}[(1-u_t)N_t]^{1-\eta} \tag{2.2}$$

where Y_t is the amount of the consumption/investment good production, h_t is the housing production, K_t is the capital stock, N_t is the amount of available labor hour at time t. For the sake of simplicity we assume that the depreciation rates of capital stock used in the consumption/investment good and housing are the same, δ^K. In our model, the only financing source for investment is bank lending. Each period, the firm borrows the amount L_t at a price $1/(1+r_t^l)$ from the bank and next period repays $\alpha_{t+1}L_t$ to the bank. However, it has to bear a quadratic search cost, $\frac{\gamma}{2}\left[(1-\alpha_{t-1})L_{t-2}^b\right]^2$, for the defaulted amount. Also, the firm takes disutility, $d_f(1-\delta_t)$, from the defaulting. The maximization problem of the firm is:

$$\max_{K,N,L,\alpha,v,u} \sum_{s=0}^{\infty} E_t\left[\tilde{\beta}_{t+s}\{\pi_{t+s}^f - d_f(1-\alpha_{t+s})\}\right] \tag{2.3}$$

under the constraints:

$$K_t = (1-\delta^K)K_{t-1} + \frac{L_t}{1+r_t^l} \quad (2.4)$$

$$\pi_t^f = A_t[v_t K_{t-1}]^{\mu}[u_t N_t]^{1-\mu} + P_t B_t[(1-v_t)K_{t-1}]^{\eta}[(1-u_t)N_t]^{1-\eta} \quad (2.5)$$

$$- \alpha_t L_{t-1} - \frac{\gamma}{2}[(1-\alpha_{t-1})L_{t-2}]^2 - w_t^h(1-u_t)N_t - w_t^K u_t N_t$$

$$\tilde{\beta}_{t+s} = \beta^s \frac{\mathcal{U}_{C_{t+s}}}{\mathcal{U}_{C_t}} \quad (2.6)$$

where equation 2.4 is the law of motion for the capital stock, equation 2.5 is the profit function of the firm and equation 2.6 is the stochastic discount factor.

π_t^f = Profit of the firm.

L_t = The amount that the firm borrows from the bank at time t.

α_t = Loan repayment rate for the firm at time t.

r_t^l = The interest rate that the firm pays to bank at time t.

d_f = Parameter of disutility of not repaying the loan.

A_t = Total factor productivity.

B_t =Housing production technology parameter.

P_t = Price of housing relative to consumption/investment good.

w^h = Real wage paid to workers in house production sector.

w^K = Real wage paid to workers in consumption/investment good production sector.

2.3 Bank

In our model, there is a representative bank which takes deposits from the households, and gives loan to the firm and mortgages to the households. As explained in section 2.1 the bank securitizes some of its mortgages, and sells these securities to households. However, the bank has to obey the capital requirements which are set by the supervisory authority. The own funds, F_t^b, of the bank should be greater than or equal to a fraction, k, of the risk adjusted value of its portfolio, which consists of mortgage loans, securities, market book and loans to firms. Technically,

$$F_t^b \geq k\left[\bar{w}L_t^b + \tilde{w}(S^t + B) + \bar{\bar{w}}M^t\right] \tag{2.7}$$

As in Pierrard et al. (2009), we assume that the bank gets utility from the buffer of own funds, $d_{F^b}\left(F_t^b - k\left[\bar{w}L_t^b + \tilde{w}(S^t + B) + \bar{\bar{w}}M^t\right]\right)$, where M^t is the mortgage balance at time t and

$$M^t = \sum_{j=0}^{3}(M_{t-j} - S_{t-j})\sum_{i=1}^{4-j}\left(\frac{1}{1 + r_{t-j}^m}\right)^i.$$

The total balance of securities at time t is $S^t = d\sum_{j=0}^{4} S_{t-j}Q_t^{4-j}$. Each period, the bank puts a fraction of its own funds, ξ, to the insurance fund, then the fractions ζ_L and ζ_M of the defaulted amount of loans and mortgages respectively are repaid back by the insurance fund. We also assume that on the balance sheet of the bank there is fixed market book, B, which has constant return ρ.

The maximization problem for the bank is

$$\max_{D,L,M,S,F}\sum_{s=0}^{\infty} E_t\left[\tilde{\beta}_{t+s}\{ln(\pi_{t+s}^b) + d_{F^b}\left(F_{t+s}^b - k\left[\bar{w}L_{t+s}^b + \tilde{w}(S^{t+s} + B) + \bar{\bar{w}}M^{t+s}\right]\right)\}\right] \tag{2.8}$$

under the constraints:

$$F_t^b = (1-\xi)F_{t-1}^b + \upsilon_b \pi_t^b, \tag{2.9}$$

$$\pi_t^b = \alpha_t L_{t-1} - \frac{L_t}{1+r_t^l} + \frac{D_t}{1+r_t^d} - D_{t-1} + \zeta_L(1-\alpha_{t-1})L_{t-2} \tag{2.10}$$
$$-M_t \sum_{i=1}^{4} \left(\frac{1}{1+r_t^m}\right)^i + \delta_t \sum_{i=1}^{4} [M_{t-i} - (1-d)S_{t-i}] + S_t Q_t^4$$
$$+\zeta_M(1-\delta_{t-1}) \sum_{i=1}^{4} (M_{t-i-1} - S_{t-i-1}) + \rho B$$

where, equation 2.9 defines the law of motion for the own funds. Equation 2.10 defines the period t profits.

F_t^b = Own funds of the bank at time t.

d_{F^b} = Utility parameter that the bank gets from buffer of own funds above the capital requirement.

π_t^b = Profit of the bank at time t.

k = Coverage ratio of risky assets imposed by the financial supervisory authority.

$\bar{w}$ = Risk weight on loans.

$\bar{\bar{w}}$ = Risk weight on mortgage loans.

$\tilde{w}$ = Risk weight on mortgage backed securities and market book.

υ_b = The share of the profits that put to own funds.

ξ = The proportion of the own funds that are put to insurance fund.

ζ_L = The fraction of the firm's defaulted loan that the bank takes from the insurance fund.

ζ_M = The fraction of the defaulted mortgages that the bank receives from the insurance fund.

2.4 Households

There is a continuum of identical households on the interval $[0,1]$. Each household deposits its savings to the bank and receives mortgage loans from the bank, and buys securities from the bank. The households trade these securities among each other. The households get utility from consumption, leisure, and housing stock, where housing stock evolves according to equation 2.13. The households also get disutility from depositing above the steady-state deposit level, and having securities different from their target security level. The households borrow mortgage loans from their bank, use the loans to finance their housing consumption and consumption/investment good consumption. Households have to repay this amount in four equal installments. They choose how much of these loans should be paid endogenously, but they have to bear a quadratic search cost based on the amount they defaulted. The maximization problem for each household is

$$\max_{c,\tilde{d},u,\tilde{h},m,s} U(c,n,h) = \sum_{s=0}^{\infty} \beta^s E_t \left[ln(c_{t+s}) + \bar{m} ln(1-n_{t+s}) + \bar{h} ln(\tilde{H}_{t+s}) \right] \tag{2.11}$$
$$- \sum_{s=0}^{\infty} \beta^s E_t \left[\sum_{i=1}^{4} \frac{\chi}{2} \left((s_{t+s,i} - \bar{s}) \sum_{j=1}^{i} \left(\frac{1}{1+r_t^m} \right)^i \right)^2 + \frac{\chi}{2} \left(\frac{\tilde{d}_{t+s}}{1+r_{t+s}^d} - \frac{\bar{\tilde{d}}}{1+\bar{r}} \right)^2 \right]$$

subject to

$$c_t + \frac{\tilde{d}_t}{1+r_t^d} + P_t \tilde{h}_t + \delta_t \sum_{i=1}^{4} m_{t-i} + (1-d) \sum_{j=1}^{4} Q_t^j s_{t,j} + \frac{\theta}{2} \left((1-\delta_{t-1}) \sum_{i=1}^{4} m_{t-i-1} \right)^2$$
$$= w_t^K u_t n_t + w_t^h (1-u_t) n_t + \tilde{d}_{t-1} + \tilde{\pi^f}_t + (1-\upsilon_b) \tilde{\pi}_t{}^b + m_t \sum_{i=1}^{4} \left(\frac{1}{1+r_t^m} \right)^i$$
$$+ (1-d) \sum_{j=1}^{4} Q_t^{j-1} s_{t-1,j} + \delta_t (1-d) \sum_{j=1}^{4} s_{t-1,j} \tag{2.12}$$
$$\tilde{H}_t = \tilde{h}_t + (1-\delta^h) \tilde{H}_{t-1} \tag{2.13}$$

where,

$s_{t,i}$ = The amount of securities bought by each household at time t which will mature in i periods. From the market clearing conditions $\int_i s_{t-1,j} di = S_{t+j-4}$ where i represents the households and $i \in [0,1]$.

c = Consumption of each household.

n = Labor supply of each household.

$\tilde{h}$ = Housing consumption of each household.

$\tilde{H}$ = Housing stock of each household.

$\tilde{\pi}^f$ = Profit received by each household from the ownership of the firm.

$\tilde{\pi}^b$ = Profit received by each household from the ownership of the bank.

$\bar{m}$ = Weight of the utility coming from the leisure.

$\bar{h}$= Weight of the utility coming from house owning.

$\frac{\chi}{2}\left(\frac{\tilde{d}_{t+s}}{1+r^d_{t+s}} - \frac{\bar{\tilde{d}}}{1+\bar{r}}\right)^2$ = The disutility of differing of the deposits from their long run equilibrium level.

$\tilde{d}_t$= The amount that each household deposits to bank at time t.

$\bar{\tilde{d}}_t$= The target deposit level for each household.

r^d_t= The deposit rate.

m_t= The amount of mortgage each household takes at time t.

r^m_t= The mortgage rate at time t.

$\bar{s}$ = The target security holding level.

P_t= The price of house at time t.

$\tilde{H}_t$= The house stock.

δ^h= Depreciation rate for house.

$\frac{\chi}{2}\left((s_{t+s,i} - \bar{s})\sum_{j=1}^{i}\left(\frac{1}{1+r^m_t}\right)^i\right)^2$ = The disutility of differing of the securities from their long run equilibrium level.

Chapter 3

Calibration

We calibrate our model against US data from 1985Q1 to 2008Q2. Since we followed the model of Pierrard et al. (2009), and extended the model with a housing market and securitization for the mortgages, our approach is to match as much as possible with this paper, and calibrate the rest according to aggregate balance sheet of the U.S. banks and the U.S. economy.

Following Pierrard et al. (2009), we set $r^d = 0.35\%$ and $r^l = 1.6\%$. These figures give a discount factor of $\beta = 1/(1 + r^d) = 0.9965$. Average return of Dow Jones index at the relative time period is 2.2%, and based on the assumption that banks have more profitable securities on their balance sheets other than the Dow Jones index, the authors set the return on market book, $\rho = 3\%$. From the aggregate balance sheet of the US banks, we impose D/L=2, B=L. According to Basel regulations, the ratio of own funds to the risk adjusted assets should be greater than 8%, and the risk weights for the loans to firms, market book, and mortgage loans are 0.8, 1.2, 0.35 respectively ($\bar{\omega} = 0.8$, $\tilde{\omega} = 1.2$, $\bar{\bar{\omega}} = 0.35$). We assume that the bank adopts a higher own funds to risk adjusted assets ratio in order to avoid any penalty, hence we set the effective ratio to 15%. Each period, the bank puts half of its profit to own funds($\upsilon_b = 0.5$), and distributes the rest to the households. Also 80% of the defaulted commercial loans to firms are reimbursed by the insurance fund($\zeta_L = 0.8$).

For the mortgage rate, we use the quarterly average 30 year fixed mortgage rate, $r^m = 2.01\%$. To be able to generate positive profits for the bank we set $S^t/L = 0.1$. We had problems to access the historical delinquency rate for the mortgage loans. The New York Fed provides only the 2009Q4 delinquency rate which is 5.6%. The time period we are interested in consists of the housing boom we set the average delinquency rate to 5% ($\delta = 0.95$).

Banks			
k =0.08	$\bar{\omega} = 0.8$	$\bar{\bar{\omega}} = 0.35$	$\tilde{\omega} = 1.2$
$d_F = 1.5$	$B = 0.18$	$\zeta_L = 0.8$	$\zeta_M = 0.24$
$\xi = 0.04$	$\upsilon = 0.5$	$\rho = 0.03$	$d = 0.01$
Firms			
$d_f = 0.1$	$\mu = 0.33$	$\eta = 0.11$	$\gamma = 50.8$
$\delta^K = 0.03$	$\beta = 0.9965$	$\sigma = 0.01$	
Households			
$\bar{m} = 4.5$	$\bar{h} = 4.4$	$\chi = 0.01$	$\theta = 4.6$
$\delta^H = 0.016$	$\bar{M} = 0.87$	$\bar{S} = 0.18$	

Table 3.1: Parameter values

For the firm side, capital share of production is set to 0.33, average working time to 0.2 as usual in RBC literature ($\mu = 0.33$, $N = 0.2$). To match with Pierrard et al. (2009) we set average default ratio of firm to 5% ($\alpha = 0.95$), capital to output ratio is set to 10 ($K/F = 10$), and depreciation rate for capital stock to 3% ($\delta^K = 0.03$). Empirically we see that the depreciation rate of housing stock is less than the depreciation rate of capital stock, then $\delta^H = 0.016$ [Davis and Heathcote (2005)]. From the data of Bureau of Economic Analysis, the ratio of hours worked on construction industry to hours worked on domestic industry is 0.055, proportion of capital used in construction industry to capital used in nonresidential capital stock is 0.014 ($u = 0.944$ and $v = 0.986$).

From these impositions, we are able to derive the other parameters which are given in Table 3.1

Chapter 4

Results

4.1 Simulation Results

As usual in RBC tradition, we made simulations based on the shocks to the technology parameter in the Cobb-Douglas production function which evolves as $A_t = (A_{t-1})^{\rho_\epsilon} exp(z_t)$ where $\rho_\epsilon = 0.95$ and $z_t \sim N(0, \sigma^2)$. By looking at the second moments of the variables, we check whether we are able to generate some stylized facts about business cycles. In table 4.1 the moments of real data and the model are reported, and our model is able to generate some important stylized facts which are summarized in Altug (2010).

In the data, consumption is strongly pro-cyclical as our model. Investment in residential structures is pro-cyclical and highly volatile. We are able to capture the high volatility of residential structures (relative standard deviation of h is 13.5). In our model, residential investment is pro-cyclical, but its correlation with output is low, 0.018. This can be explained as follow: in our model there is only one shock which comes only to the consumption/investment good producing sector. As can be seen by the IRFs of u, v, h investment in consumption goods increases but investment in housing decreases. In our model, employment is strongly pro-cyclical, real wages and productivity vary less than the output, which are in accordance with the stylized facts. Real wages are strongly pro-cyclical, but the data does not show clear tendency for pro-cyclicality. Moreover, in the data, profits are highly volatile which is captured by our model, as we show the relative standard deviations of firm profit and bank profit are 50.5 and 8 respectively. However, in the data correlation between the hours worked and the productivity is near zero or negative, therefore we were not able to generate this fact. In our model these two variables are highly correlated. Also, capital stock fluctuates less than the output and is largely uncorrelated with the output [Cooley (1995)]. We could not generate these two facts. In our model capital stock fluctuates almost the same as output and it is strongly correlated with output.

	Mean		Relative Standard Deviation		Correlation With Output		First Order Autocorrelation	
	Data	Model	Data	Model	Data	Model	Data	Model
r^d	1.7	1.40	1.2	4.85	0.47	0.04	0.88	0.97
r^l	6.61	6.49	1.2	1.29	0.36	0.18	0.9	0.96
α	95.4	95.08	0.52	0.025	0.52	-0.55	0.82	0.85
L	0.67	0.32	4.03	1.96	0.36	0.93	0.79	0.89
D	1.59	0.80	1.38	23.30	-0.11	0.16	0.87	0.95
F	0.22	0.71	4.62	0.79	0.01	-0.08	0.64	0.99
C	0.69	0.66	0.82	0.72	0.81	0.9	0.83	0.99
GDP	1	1	1	1	1	1	0.86	0.94
N	0.2	0.2	1.03	1.79	0.77	0.68	0.96	0.964
M	0.8	11.9	0.90	0.37	0.44	0.21	0.995	0.997

Table 4.1: Cyclical Properties

In addition to real economic variables, we were able to generate some cyclical properties of interest rates and balance sheet components. In the data the interest rates tend to be pro-cyclical and we are able generate this; however correlations with the output is stronger in the data. The relative standard deviation of loan rate, r^l, in the model is almost matched with the data. Also, in our model we capture the volatility of the deposit rate, r^d. However, the volatility in our model is higher than the data. Also, the interest rates are more persistent than the data. Similar to the indications by the data, the correlation between r^l and r^d is high. But for the repayment rate, we were not able to replicate the pro-cyclicality and volatility of α. Balance sheet components are volatile in the data. In our model both the loans and the deposits are volatile. The former is more volatile in the data, whereas the latter is more volatile in the model. The bank loans is pro-cyclical contrary to the deposits which is counter-cyclical. We were able to generate pro-cyclicality of bank loans, but we could not replicate the counter-cyclicality of deposits. As seen in table 4.1, the correlation between the bank loans and the output is high, and we have a small correlation between the output and the deposits. However, the sign of the correlation with output is positive, whereas there is a negative correlation in the data. As seen in the first-order autocorrelations part of table 4.1, almost all of the variables are highly persistent. Overall, it can be said that our model works quite well in terms of generating the stylized facts of the business cycles and the cyclical properties of the balance sheet component in the US.

4.2 Impulse Response Functions

Figures B.1, B.2 and B.3 show the response of the variables in the model to a one standard deviation shock to the technology parameter. In figure B.2 we see that capital stock, consumption and real wage rate are hump-shaped. After the initial shock, the marginal productivity of capital increases followed by an increase in the investment in capital stock. Also, the marginal productivity of labor increases, and this leads to an increase in the wage rate. Similarly, the total hours worked and output increase first and then decrease. However, in the data, the output is hump-shaped, but we cannot not generate this fact.

For the house production side, since we give a shock to the marginal productivity of capital in the consumption/investment good, the firm switches its resources to the shocked sector, then u and v increases, which leads to a reduction in house production and house stock. However, at the same time the house price increases which leads to the reduction of u and v in the subsequent periods. This can also be seen in equation A.5. The antecedent of $P_t = \frac{\mu A_t[v_t K_{t-1}]^{\mu-1}[u_t N_t]^{1-\mu} K_{t-1}}{\eta B_t[(1-v_t)K_{t-1}]^{\eta-1}[(1-u_t)N_t]^{1-\eta} K_{t-1}}$ increases hence P rises. Then, investment in housing increases. As seen in the figure B.2, housing and house stock first decrease followed by a rise, then return to steady-state levels. In figure B.1, we see that the house price first increases and gradually decreases to its steady-state level.

The IRFs of interest rates and bank balance sheet items are depicted in figure B.3. In our model, the only financing source for capital investment for the firm is bank lending. Since marginal productivity of capital increases, capital investment increases, hence we see that loans to the firm goes up. Since the demand for loans rises the loan rate, r^l, increases first and then decreases as the demand for capital investment decreases. Then we see that the loan rate goes below its steady-state level and after that it converges to its steady state level. We also see that other interest rates, r^d and r^m move almost the same as r^l. The IRF of mortgage repayment rate, δ, first decreases, and then increases, and finally goes below the steady-state level. In equation A.14, since C increases, δ has to decrease to satisfy the equation. As time passes the cost of defaulting exceeds the benefit of it, therefore the repayment rate rises. We observe that M and S follow similar paths with the mortgage repayment rate. As the shock increases the marginal productivity of capital, loan demand and loan rate increases, hence the bank uses its resources to supply the loan demand, hence supply of the mortgages decreases then M decreases. In our model, the bank actually decides on how much mortgage loan to hold on its balance sheet, hence S follows M. However, due to the reduction in δ it is profitable for the bank to increase securitization and pass the risk to the households at the first periods. Also, the price of the security is the expected future discounted value of the cash flows, and the cash flow is determined by the repayment rate, Q^j follows δ.

Chapter 5

Conclusion

In the last decade we have witnessed the transformation of the traditional banking model into "originate and distribute" banking model. With widespread popularity of securitization, banks do not have to hold the loans they made until maturity. They pool the loans, tranche according to their risk level and sell to investors. Via securitization, they were able to expand their balance sheets, disperse the risk on their loans, and make money. However, with the help of global financial conditions, which are out of the scope of this paper, there occurred a bubble in the housing market, and it eventually burst.

In this paper, we attempted to incorporate this important phenomenon of the modern banking model into the DSGE model of Pierrard et al. (2009), calibrated the model against the US data and we were able to generate some important stylized facts of the US economy.

However, we solved the model with the perturbation techniques, this does not allow us to make crisis experiment. Since we are making Taylor approximation around the steady-state, we cannot model the over-accumulation of the mortgage loans and the securities on the balance sheets of the banks. The model gives us a $d = 0.01$ value, which is very low, since the financial institutions on the US were holding half of the securitized loans on their balance sheets or on the SPVs which are sponsored by them. One possible extension of this paper is to solve this model with non-linear techniques and make a crisis experiment by putting a financial shock into the model, letting the bank to over accumulate the securities.

Appendix A

First Order Conditions

A.1 F.O.C.s for the firm

$$K_t : -\lambda_t^f + E_t \left\{ \tilde{\beta} \left[\lambda_{t+1}^f (1-\delta^K) + \mu A_{t+1} [v_{t+1} K_t]^{\mu-1} [u_{t+1} N_{t+1}]^{1-\mu} v_{t+1} \right] \right\}$$
$$+E_t \left\{ \tilde{\beta} \left[\eta P_{t+1} B_{t+1} [(1-v_{t+1})K_t]^{\eta-1} [(1-u_{t+1})N_{t+1}]^{1-\eta} (1-v_{t+1}) \right] \right\} = 0 \quad \text{(A.1)}$$

$$N_t : (1-\mu) A_t [v_t K_{t-1}]^{\mu} [u_t N_t]^{-\mu} u_t + (1-\eta) P_t B_t [(1-v_t)K_{t-1}]^{\eta} [(1-u_t)N_t]^{-\eta} (1-u_t)$$
$$-w_t^h (1-u_t) - w_t^K u_t = 0 \quad \text{(A.2)}$$

$$L_t : \frac{\lambda_t^f}{1+r_t^l} - E_t \left\{ \tilde{\beta} \alpha_{t+1} + \tilde{\beta}^2 \gamma [(1-\alpha_{t+1})^2 L_t] \right\} = 0 \quad \text{(A.3)}$$

$$\alpha_t : d_f - L_{t-1} + E_t \left\{ \tilde{\beta} \gamma [(1-\alpha_t) L_{t-1}^2] \right\} = 0 \quad \text{(A.4)}$$

$$v_t : \mu A_t [v_t K_{t-1}]^{\mu-1} [u_t N_t]^{1-\mu} K_{t-1}$$
$$-\eta P_t B_t [(1-v_t)K_{t-1}]^{\eta-1} [(1-u_t)N_t]^{1-\eta} K_{t-1} = 0 \quad \text{(A.5)}$$

$$u_t : (1-\mu) A_t [v_t K_{t-1}]^{\mu} [u_t N_t]^{-\mu} N_t - P_t B_t [(1-v_t)K_{t-1}]^{\eta} (1-\eta) [(1-u_t)N_t]^{-\eta} N_t$$
$$+w_t^h N_t - w_t^K N_t = 0 \quad \text{(A.6)}$$

A.2 F.O.C.s for the representative household

$$C_t : \frac{1}{C_t} = \lambda_t \tag{A.7}$$

$$u_t : w_t^K = w_t^h \tag{A.8}$$

$$N_t : \frac{\bar{m}}{1-N_t} = \lambda_t(w^k u_t + w_t^h(1-u_t)) \tag{A.9}$$

$$M_t : \lambda_t \sum_{i=1}^{4} \left(\frac{1}{1+r_t^m}\right)^i = \sum_{i=1}^{4} E_t\left[\beta^i \lambda_{t+i}\delta_{t+i} + \beta^{i+1}\lambda_{t+i+1}\theta(1-\delta_{t+i})^2 M_t\right] \tag{A.10}$$

$$h_t : \frac{\bar{h}}{h_t + (1-\delta^h)H_{t-1}} = \lambda_t P_t \tag{A.11}$$

$$D_t : \chi(\frac{D_t}{1+r_t^d} - \frac{\bar{D}}{1+r^d}) + \lambda_t = E_t\left[\beta(1+r_t^d)\lambda_{t+1}\right] \tag{A.12}$$

$$S_{t,j} : \chi(S_{t,j} - \bar{S}) \sum_{j=1}^{i} \left(\frac{1}{1+r_t^m}\right)^i + \lambda_t Q_t^j = E_t\left[\beta\lambda_{t+1}\left(Q_{t+1}^{j-1} + \delta_{t+1}\right)\right] \text{ j=1,2,3,4} \tag{A.13}$$

$$\delta_t : -\lambda_t \sum_{i=1}^{4}(M_{t-i} - (1-d)S_{t-i}) + \lambda_{t+1}\beta\theta(1-\delta_t)\left(\sum_{i=1}^{4} M_{t-i}\right)^2 = 0 \tag{A.14}$$

A.3 F.O.C.s for the bank

$$D_t : \lambda_t = \left[E_t \tilde{\beta}_{t+1}\lambda_{t+1}(1+r_t^d)\right] \tag{A.15}$$

$$L_t : -d_F k\bar{w} - \frac{\lambda_t}{1+r_t^l} + E_t\left[\tilde{\beta}_{t+1}\lambda_{t+1}\alpha_{t+1} + \tilde{\beta}_{t+2}\lambda_{t+2}\zeta_L(1-\alpha_{t+1})\right] = 0 \tag{A.16}$$

$$F_t : d_F \upsilon_b = \left(\lambda_t - \frac{1}{\pi_t^b}\right) - E_t\left[\tilde{\beta}_{t+1}(1-\xi_b)\left(\lambda_{t+1} - \frac{1}{\pi_{t+1}^b}\right)\right] \tag{A.17}$$

$$M_t : -d_F k\bar{\bar{w}} E_t\left[\sum_{j=0}^{3}\tilde{\beta}_{t+j}\sum_{i=1}^{4-j}\left(\frac{1}{1+r_t^m}\right)^i\right] - \lambda_t \sum_{i=1}^{4}\left(\frac{1}{1+r_t^m}\right)^i + E_t\left[\sum_{j=1}^{4}\tilde{\beta}_{t+j}\lambda_{t+j}\delta_{t+j}\right]$$

$$+E_t\left[\zeta_M \sum_{i=1}^{4}\tilde{\beta}_{t+i+1}\lambda_{t+i+1}(1-\delta_{t+i})\right] = 0 \tag{A.18}$$

$$S_{t,4} : -d_F k E_t\left\{\sum_{j=0}^{3}\tilde{\beta}_{t+j}\left[dQ_{t+j}^{4-j}\tilde{w} - \bar{\bar{w}}\sum_{i=1}^{4-j}\left(\frac{1}{1+r_t^m}\right)^i\right]\right\} - (1-d)E_t\left[\sum_{j=1}^{4}\tilde{\beta}_{t+j}\lambda_{t+j}\delta_{t+j}\right] + \lambda_t Q_t^4$$

$$-E_t\left[\zeta_M \sum_{i=1}^{4}\tilde{\beta}_{t+i+1}\lambda_{t+i+1}(1-\delta_{t+i})\right] = 0 \tag{A.19}$$

Appendix B

Impulse Response Functions

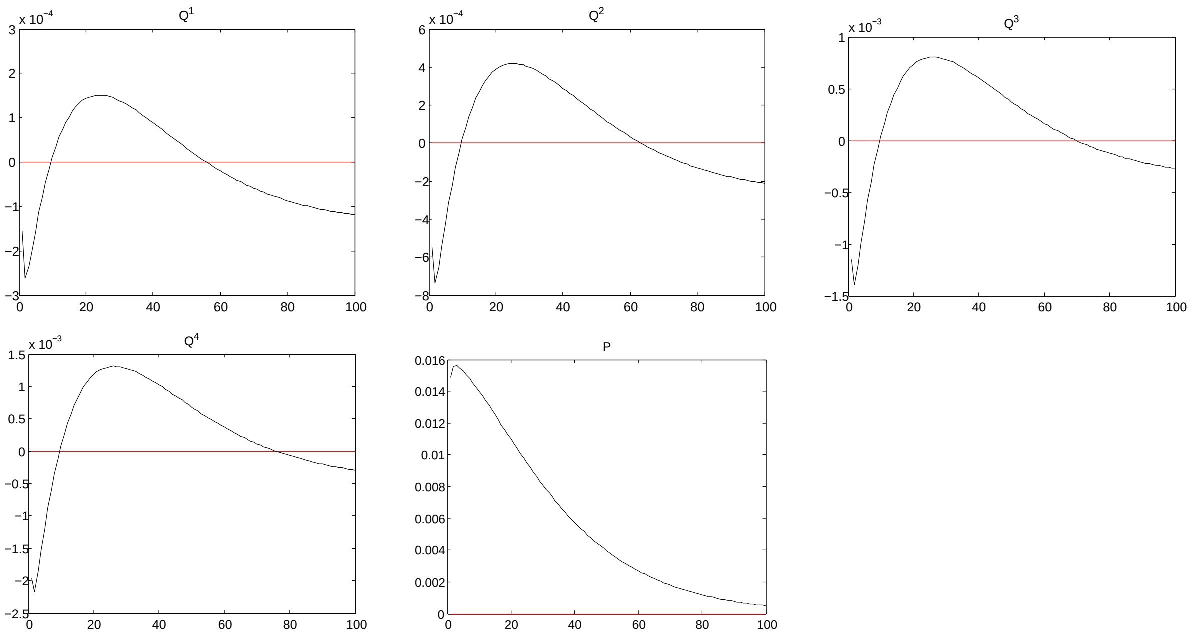

Figure B.1: IRFs for asset prices and house prices

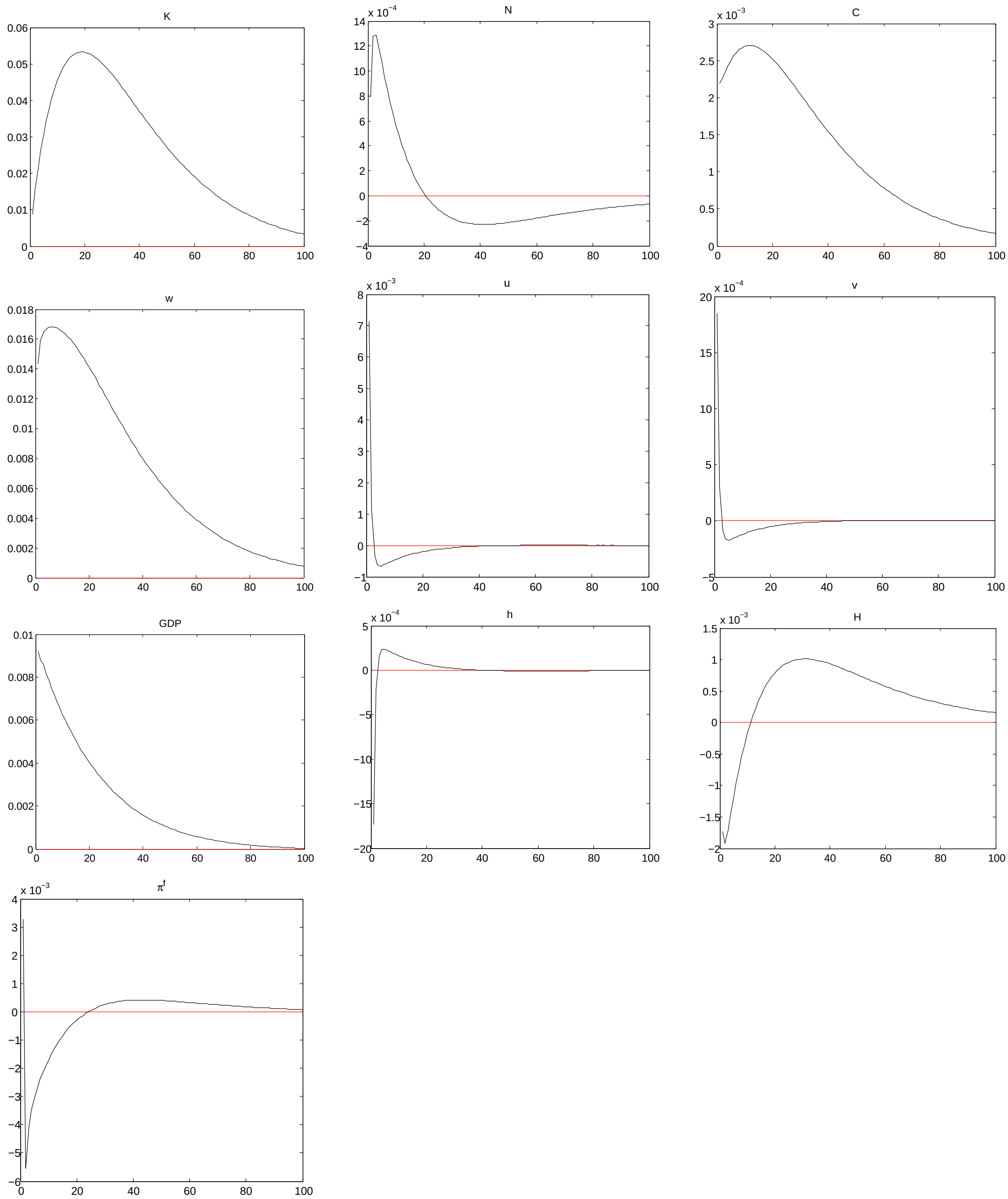

Figure B.2: IRFs of the real variables

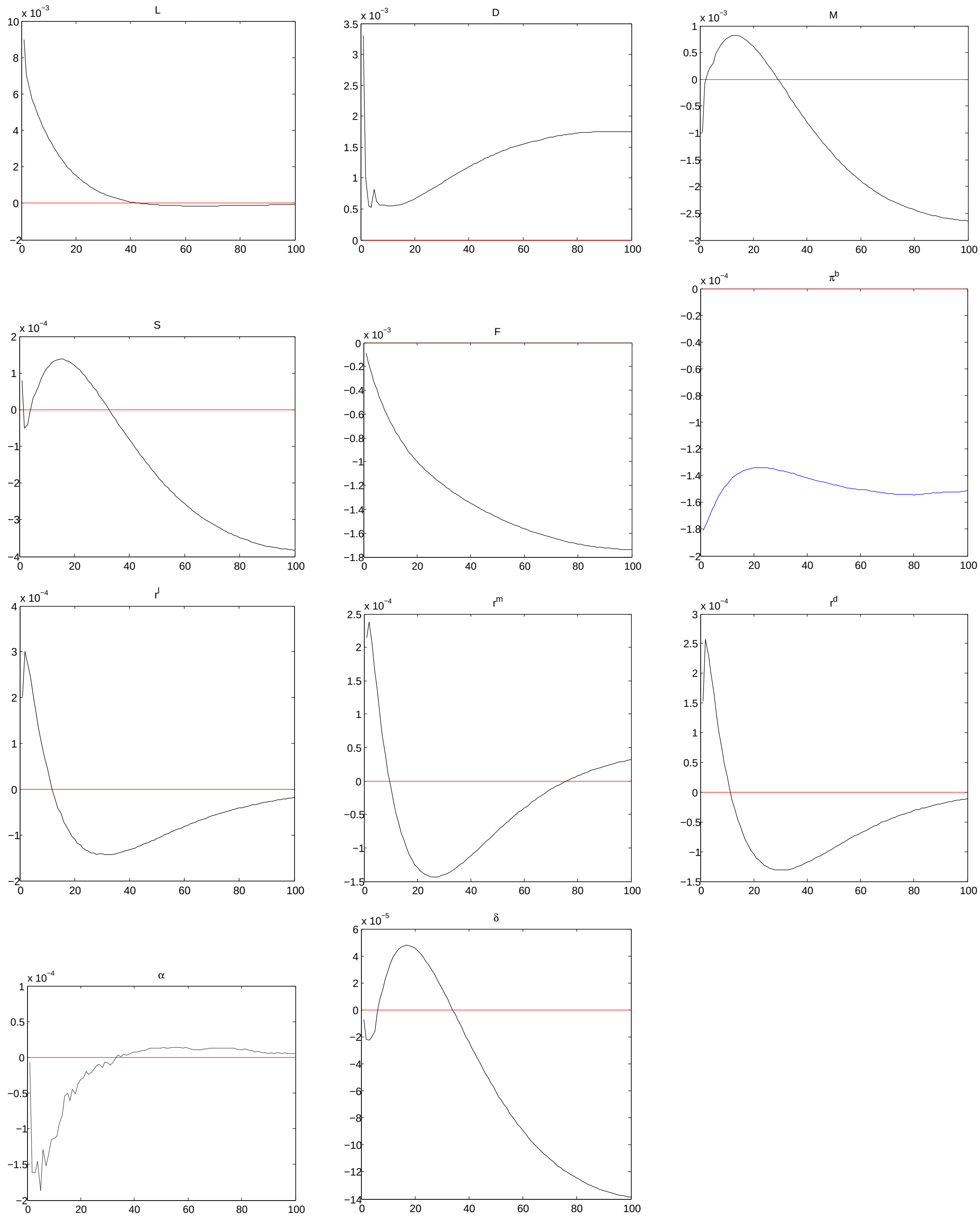

FIGURE B.3: IRFs for the bank's balance sheet items, interest rates, and default rates

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