ESSAYS ON MONETARY POLICY AND FINANCIAL MARKETS

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ABSTRACT

How should a central bank conduct monetary policy in the presence of financial shocks? How is a financial shock identified? Using different economic models, my dissertation addresses these questions.

In Chapter 1, I construct a model with Iacoviello's (2005) heterogeneous agent structure, financial intermediaries, a risk-rating mechanism, and the Calvo-style sticky price formulation. I find that monetary policy should respond to the bank spread, which is the difference between the lending rate and the deposit rate. Additionally, I show that coordination of monetary and fiscal policy is necessary and that fiscal policy becomes more active when a financial shock is more volatile.

Motivated by an empirical VAR model (à la Christiano et al., 1999), Chapter 2 models an economy with financial intermediaries and a financial shock. There is a risk-rating mechanism based on firms' external finance dependence as firms need heterogeneous funds for a new investment. I propose a set of economic indicators to identify this financial shock. I again show that the conduct of monetary policy should pay attention to the financial market by negatively responding to the bank spread,

which is also the difference between the lending rate and the deposit rate. As a result, the cost of price rigidity is lower and the social aggregate welfare is higher.

The last chapter empirically examines a disturbance to the bank spread, the difference between the three-month prime rate and the three-month deposit rate. This spread is augmented into a standard VAR model as well as an ARIMAX model. I find that this disturbance has an estimated standard error of about 0.15 percent, which is relatively significant in comparison with a monetary shock's standard error of about 0.3 percent in the literature. In addition, a bank spread disturbance and a monetary shock have similar contributions to the fluctuations in economic activity. This shows that such a disturbance should be carefully observed.

PREFACE

This dissertation is dedicated to Mai, Anh, and Trí, who had given me the research space I needed and had suffered all my mess.

I am really indebted to Matthew Canzoneri, Robert Cumby, and Behzad Diba for infinite supports, guidances, and encouragements in every step of this dissertation. I could not finish this dissertation without their helps.

I wish to thank all of my friends, especially Beom Sock Park, Yuki Ikeda, Yoko Shinagawa, and Seong-Hoon Lim, for many useful discussions and research exchanges. I am grateful to the Department of Economics, Georgetown University, where I had enjoyed years doing research and learning economics, for academic and financial supports. Farooq Akram, David Amdur, Jinhui Bai, Bing Li, Zheng Liu, Douglas Pearce, and Federico Ravenna, and the participants at the Midwest Economics Conference, the Southern Economics Conference, and Georgetown Economics Seminar suggested insightful and useful comments.

Needless to say, I am responsible for all the remaining weakness and errors.

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INTRODUCTION

The current financial crisis has raised some questions for policy makers: How should a central bank conduct monetary policy in the presence of financial shocks? How is a financial shock identified? My dissertation uses different economic models to answer these questions and it has two main contributions.

First, the bank spread, which is the difference between the lending interest rate and the deposit interest rate, should be an economic indicator for policy makers. I show that the bank spread is a good proxy for a financial shock because a shock in the financial market would significantly contribute to the fluctuation in the bank spread. This is shown in the two theoretical models in Chapter 1 and Chapter 2 and the empirical model in Chapter 3.

Theoretically, to connect a financial shock to the bank spread, I construct financial intermediaries, which need labor effort to monitor loans. The amount of labor effort a bank needs depends on the amount of loans and the credit risk of borrowers. Banking labor effort is also subject to a shock. One could also interpret this banking labor effort as a type of information verification costs in Bernanke et al. (1999). Additionally, this financial structure helps prevent a "buffer stock" problem which may arise in Iacoviello (2005) and others where a borrowing constraint is assumed binding in an equilibrium.

Different from Cúrdia et al. (2009) who assume that a credit spread is dependent on aggregate private credit, the first two theoretical chapters show that the bank spread and a financial shock are directly connected. In addition, the bank spread could be

directly affected by other sources such as monetary and productivity shocks. These first two chapters show that a shock to banking labor effort noticeably fluctuates the bank spread, output, and inflation. In addition, the bank spread and interest rates would help distinguish a financial shock from a monetary one.

Empirically, a proxy for a financial shock has been investigated in the literature. Kashyap et al. (1993) and Taylor et al. (2010) find that interest rate spreads could be good indicators for financial shocks. I expand their empirical models by a standard Vector Autoregressive Regression (VAR) model by Christiano et al. (1999, 2005) with the bank spread added. I again show that a disturbance to the bank spread is significant.

Second, I show that policy makers should respond negatively to the bank spread. As said above, there is a close connection from a financial shock to the bank spread. This implies that monetary policy to respond to a financial shock might do the same to the bank spread. To show it, I use a loss function by Bernanke et al. (2001) and Filardo (2002) and the cost of price rigidity by Lucas (2003) and Canzoneri et al. (2007). I search a monetary rule which respond to the bank spread. I show that the loss function is lower and the cost of price rigidity decreases if the monetary authority negatively respond to the bank spread. This negative response still holds when fiscal policy is introduced and the financial market is more volatile. In addition, I show (in the first chapter) that coordination of monetary and fiscal policy is necessary.

A shock to banking labor effort, a "financial shock", would drain credit availability, increase the lending rate and the bank spread, reduce the savings (or deposit) rate, and decrease aggregate demand. As a result, both output and inflation are lower. To stimulate the whole economy, monetary policy needs to reduce the policy rate further in order to decrease the lending rate and push up investments and aggregate demand.

This means that monetary policy should negatively respond to the bank spread. This conclusion is complementary to Taylor et al. (2010) and Cúrdia et al. (2009).

The role of fiscal policy in terms of a transfer in Chapter 1 helps the whole economy in a different way. As a risk rating mechanism is modeled, a fiscal transfer would provide borrowers a new channel to insure against market risks. For example, if there is a bad shock, such a transfer would support borrowers in order to get a higher amount of collateral. Consequently, the market risk of borrowers is lower and the increase of banking labor effort is less. This definitely reduces the adverse effects of a bad shock.

In general, I show that policy makers have a persuasive reason to use the bank spread as a proxy for a financial shock since such a shock significantly contributes to the fluctuation in the bank spread and the bank spread in association with interest rates would help identify a financial shock. As a result, monetary rules should negatively respond to the bank spread. In addition, coordination of monetary and fiscal policy is necessary.

The structure of this dissertation is as follows. Chapter 1 is a model economy with financial intermediaries and Iacoviello's (2005) heterogeneous agent structure. Chapter 2 is another model economy with financial intermediaries and heterogeneous funds for new investments. Chapter 3 is an empirical econometric analysis of a disturbance to the bank spread.

CHAPTER 1

MONETARY POLICY AND FISCAL POLICY IN A MODEL WITH HETEROGENEOUS CONSUMERS AND FINANCIAL SHOCKS

1.1. Overview

In the first chapter, I address two questions which have been open and topical. The first is about the practical design of a monetary rule in the presence of financial shocks. The second is about coordination of monetary and fiscal policy.

I model a banking sector and Iacoviello's (2005) heterogeneous agent structure into the New Neoclassical Synthesis (NNS) framework. This banking sector needs labor effort to manage and monitor loans and contains a shock. Banks' labor effort depends on the amount of loans and durable goods (as collateral). This labor effort structure could be interpreted as a risk-rating mechanism. The banking system within Iacoviello's (2005) framework helps me not only document a financial shock without an assumption of a binding borrowing constraint but also eliminate worries about "buffer stock" issues[1].

For the first question, I find that monetary policy should negatively respond to the bank spread, the difference between the lending interest rate and the bond interest rate, as a proxy variable for a financial shock, regardless of the targets that the monetary

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[1]Some models use a borrowing constraint and assume that this constraint is always binding. "Buffer stock" is when the contraint is not binding. Iacoviello (2005) finds that in practice the aggregare shocks should increase four times to get that problem and "buffer stock" does not significantly affect calibration results. However, a shock could be high or the financial market could accelerate a shock to make the constraint more volatile. Additionally, there could be a direct financial shock to the constraint. There is also the case that the constraint is not hit during good times since borrowers want to save rather than borrow to protect their position in the future. If so, the borrowing constraint will often not be binding.

authority follows. A negative response is reasonable since a financial shock would drain aggregate credit, increase the lending interest rate and reduce aggregate demand, output, and the price level. Therefore, the monetary authority needs to reduce the policy interest rate in order to stimulate the economy.

In my model, the bank spread is the difference between the lending interest rate and the policy interest rate. Consistent with Taylor and Williams' (2010) empirical work, I theoretically propose a method to identify the presence of a financial shock using the bank spread. I show that the bank spread contains rich information concerning this shock. Therefore, a monetary rule should respond to it. This conclusion is also in the same vein with Cúrdia and Woodford (2009).

The second question is related to fiscal policy. In recent interventions in the financial market, central banks all over the world injected a huge quantity of money and governments used big fiscal packages to support borrowers in particular and consumers in general. Coordination of monetary and fiscal policy seemed to be extensively used. In this chapter, I find that fiscal policy is necessary and becomes more important when a financial shock is more volatile. These findings support the current policies to combat the financial crisis: lowering the policy interest rate and expanding fiscal spending to help "housing borrowers".

The way I set up banking labor effort creates room for coordination of monetary and fiscal policy. As the conduct of monetary policy should pay attention to a financial shock, I investigate how a fiscal automatic stabilizer in terms of a transfer from the government to borrowers interacts with a monetary rule.

In detail, I use a non-distortionary transfer in terms of a proportion of the change of lenders' durable goods. Therefore, borrowers are subject to a new type of a fiscal transfer, which would not create any distortion since this transfer, which is based on

lenders' conditions, is actually a lump-sum tax from borrowers' point of view. If there is a bad shock (e.g. a positive monetary or financial shock), borrowers receive a transfer, which helps them purchase more durable goods and reduce the risk of borrowing. As a result, banking labor effort per loan unit is less and the fluctuation of the bank spread is less[2]. This fiscal policy somewhat highlights the rationale of the U.S. 2008 tax transfer program during the dawn of the current financial crisis.

Obviously, if there is no new shock in a monetary model, a standard Taylor rule does not need a new factor and the bank spread in my model would be driven by a combination of inflation, output, and the policy interest rate. Therefore, this spread in a monetary rule would be redundant. As a financial shock is introduced in my model, I need to address it.

A financial shock has been documented in some previous works (e.g. Cúrdia et al., 2009, Calza et al., 2007, and Hafer et al., 2006). However, it has not been clear how monetary policy practically responds to a financial shock. There are two exceptions. One is Cúrdia et al. (2009), in which monetary policy could respond to a credit spread or aggregate private credit since these two variables could contain information of a financial shock. Another is Gertler et al. (2009), which consider a credit policy as an unconventional monetary rule[3]. I approach a financial shock in a different way.

Unlike Cúrdia et al. (2009) who assume that a credit spread depends on aggregate credit and it is subject to a shock, I construct a banking sector which needs labor effort, "banking labor effort", to monitor and manage loans. I assume that this labor effort is subject to a shock. Therefore, a financial shock in my model could come from a broad range of changes in banking labor productivity, lending practices, liquidity

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[2]This fiscal policy is not based on Mankiw's saver-spender framework in which spenders (borrowers) have a higher propensity-to-consume coefficient.

[3]Stracca (2007) directly augments the magnitude of a financial shock into a Taylor-style rule but empirically it is hard to observe/quantify this magnitude. Therefore, such a rule is impractical.

management, and default risks. For example, as shown in Figure 1.1, lending conditions are changeable.

Figure 1.1. Changes in lending conditions and lending willingness

Net Percentage of Domestic Respondents Tightening Standards for Consumer Loans

Net Percentage of Domestic Respondents Reporting Increased Willingness to Make Consumer Installment Loans

Source: The Federal Reserve
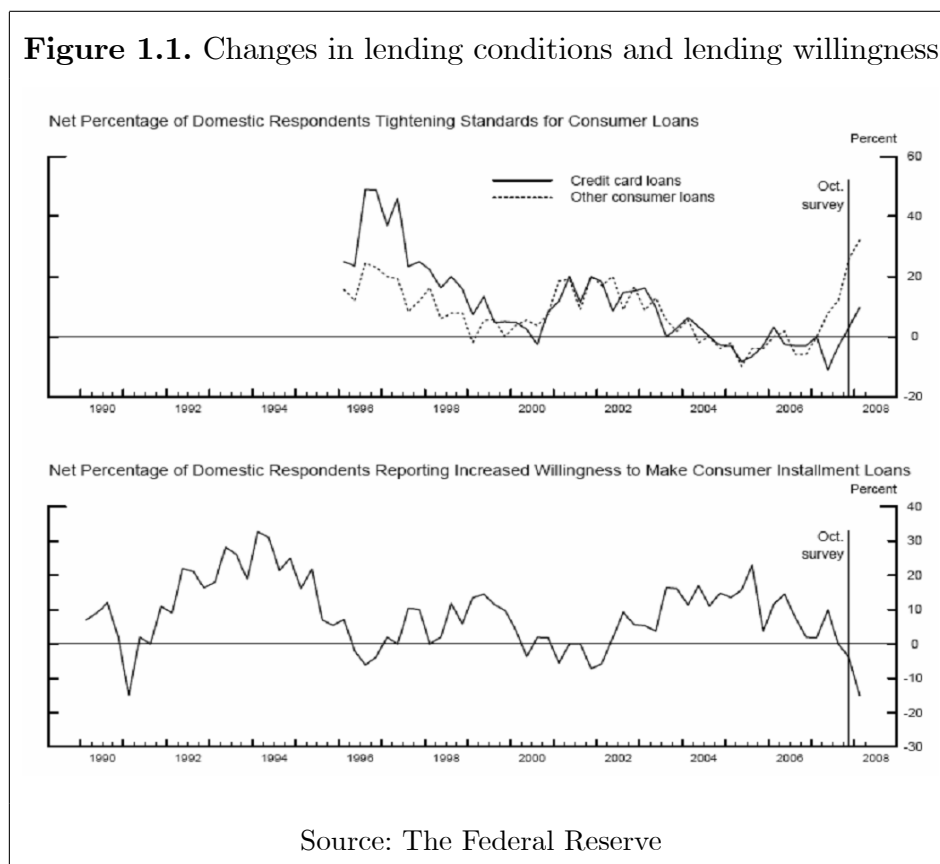
Unlike Gertler et al. (2009) and Bernanke et al. (1999) by constructing a framework of information verification costs and agency problems, I use banking labor effort to monitor and manage loans. One could interpret this labor effort as an indirect approach of information verification. In addition, I also use a risk-rating mechanism in which banking labor effort is dependent on the amount of loans and collateral. This collateral plays a role as a risk-rating element as a higher amount of collateral means a less monitoring cost[4].

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[4]One could see that in Cúrdia et al. (2009) aggregate credit also functions in a sense of a risk-rating mechanism.

With this banking sector I could explicitly show how a financial shock interacts with an interest rate spread (which I call the bank spread), real wage, durable goods, and banking labor effort per loan unit. Consequently, besides the bank spread used in my model as a proxy for a financial shock, one could use other proxies like banking labor effort or relative cost of the bank spread to real wage. (It shows how much net cash flow per loan unit covers for each labor effort unit.)

The rest of this chapter contains three other sections. Section 1.2 models an economy. Section 1.3 analyzes results and interprets policy implications. Section 1.4 concludes this chapter.

1.2. Model economy

The model is within the New Neoclassical Synthesis (NNS) framework augmented with banks. It contains patient and impatient consumers, intermediate and final good producers, banks, the monetary authority, and the government. Sticky price is of the Calvo-style formulation.

1.2.1. Consumers

A fixed proportion, ω, of consumers is patient with a high discount factor and the remaining proportion, $(1 - \omega)$, is impatient with a low discount factor. There are no idiosyncratic shocks. A competitive labor market in terms of a labor aggregator combines the total amount of available hours and supplies labor to producers and banks.

In each period, consumers get their wage, gross return from savings, gross return from bond-holding, money holding, firms' profit, banks' profit, and loans. They allocate their aggregate income to the lump-sum tax, the consumption of durable or non-durable

goods, the payment of previous loans, and the assets in terms of savings (or deposits), money holding, and bond holding.

Assume that the utility from durable good consumption is subject to a quadratic adjustment $\frac{\vartheta}{2}\frac{(D_{i,t}-D_{i,t-1})^2}{D_{i,t}}$, which goes directly into utility[5]. Define

$$X_{i,t} = D_{i,t} - \frac{\vartheta}{2}\frac{(D_{i,t}-D_{i,t-1})^2}{D_{i,t}} \tag{1.1}$$

and each type of consumers will maximize their lifetime expected utility:

$$\max E_0\left\{\sum_{t=0}^{\infty}\beta_i^t[\mu_c\ln C_{i,t} + \mu_x\ln X_{i,t} + \mu_s\ln s_{i,t} + \mu_m\ln m_{i,t} - \frac{\mu_n}{2}N_{i,t}^2]\right\} \tag{1.2}$$

subject to the real budget constraint

$$C_{i,t} + (D_{i,t} - (1-\delta)D_{i,t-1}) + s_{i,t} + b_{i,t} + m_{i,t} + \frac{l_{i,t-1}R_{t-1}^l}{\Pi_t} + T_{i,t}$$
$$\leq \frac{W_t}{P_t}N_{i,t} + \frac{s_{i,t-1}R_{t-1}^s}{\Pi_t} + \frac{b_{i,t-1}R_{t-1}}{\Pi_t} + \frac{m_{i,t-1}}{\Pi_t} + l_{i,t} + \Gamma_{i,t}^p + \Gamma_t^b \tag{1.3}$$

where:

- $i = 1$ or 2 stands for high patience consumers or low patience consumers, respectively;

- $C_{i,t}$ are non-durable goods and $D_{i,t}$ is the stock of durable goods;

- $N_{i,t}$ is labor supply with real wage $\frac{W_t}{P_t}$;

- $s_{i,t}$ is real saving with a non-contingent gross interest rate R_t^s; $l_{i,t}$ is real loan with a non-contingent gross interest rate R_t^l; $b_{i,t}$ is real bond-holding which

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[5]This quadratic adjustment comes directly into the utility. It will not affect the aggregation of the durable goods. See Erceg and Levin (2006) for this formulation.

could be issued by the government or banks with a non-contingent gross inter-
est rate R_t; $m_{i,t}$ is real money holding; T_t is real lump-sum tax; $\Gamma_{i,t}^p$ is firms'
profit; Γ_t^b is banks' profit; and Π_t is gross backward inflation rate;

- β_i is the discount factor and β_1 is higher than β_2.

The first order conditions of both consumers' optimal problems are in Appendix
A.1. There are three notes. *First*, there are two types of consumers with heterogenous
patience rates in an economy without idiosyncratic shocks. *Second*, consumers suffer
some disutility from the adjustment of durable goods. This adjustment directly goes
into the utility of consumers, not through the consumers' budget constraints as in the
literature. *Third*, that consumers have some utility from savings (or deposits) implies
both types of consumers have some savings in their wealth allocation. Even though
savings in terms of certificates of deposits are not like money with respect to liquidity
levels, savings like money could provide some transaction services[6].

1.2.2. Producers

The production side is standard with the Calvo-style sticky price formulation. Inter-
mediate producers hire labor and produce differentiated goods. They have a fixed
probability of changing their price every period. Final producers use intermediate
goods to produce final composite goods. I assume that the profits from the production
side are paid as dividends to high patience consumers.

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[6]Canzoneri et al. (2005) propose an idea of the transaction services of bonds. Similarly, savings (or
deposits) could provide some transaction services too. It means that a deposit certificate could be
used to collaterize some purchases even though it has limited liquidity in the money market.

1.2.2.1. Final good producers

I use Dixit–Stiglitz aggregation in final good production $Y_t = \left(\int_0^1 Y_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}}$ where ε is the elasticity of substitution between differentiated intermediate goods $Y_t(i)$. Final goods could be used as durable goods or non-durable goods. The producers' cost minimization problem gives demand for differentiated goods and the aggregate price[7]:

$$Y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\varepsilon} Y_t \tag{1.4}$$

$$P_t = \left(\int_0^1 P_t(i)^{1-\varepsilon} di \right)^{\frac{1}{1-\varepsilon}} \tag{1.5}$$

1.2.2.2. Intermediate good producers

Intermediate good producer i employs labor $N_{p,t}(i)$ to produce differentiated good $Y(i)$:

$$Y_t(i) = z_t N_{p,t}(i) \tag{1.6}$$

where z_t is an aggregate productivity factor for all intermediate firms. Assume that $\ln(z_t)$ is autoregressive of order 1:

$$\ln(z_t) = \phi_z \ln(z_{t-1}) + u_{z,t} \text{ where shock } u_{z,t} \tilde{\ } i.i.d.\ N(0, \sigma_z^2) \tag{1.7}$$

As assumed in the Calvo-style sticky price structure, there is a fixed probability θ_p that an intermediate producer/firm will change its price in any period of time. If a firm does not get a chance to change its price, a new price will be updated from its previous price level:

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[7]Cost minimization problem is: $\min \int_0^1 P(i)Y(i)di$ subject to $\int_0^1 Y(i)^{\frac{\varepsilon-1}{\varepsilon}} di = Y_t$

$$P_t(i) = P_{t-1}(i) \tag{1.8}$$

If a firm gets a chance to change its price, it will set the price to maximize its expected discounted profit. This firm is to choose labor $N_{p,t}(i)$ and price $P_t(i)$ to solve the following maximization problem:

$$\max E_t \left\{ \sum_{s=0}^{\infty} \Lambda_{t,t+s}(1-\theta_p)^s \left[\frac{P_t(i)}{P_{t+s}} Y_{t+s}(i) - mc_{t+s} Y_{t+s}(i) \right] \right\} \tag{1.9}$$

where $Y_{t+s}(i) = z_{t+s} N_{p,t+s}(i)$, $Y_{t+s}(i) = \left(\frac{P_t(i)}{P_{t+s}} \right)^{-\varepsilon} Y_{t+s}$, $mc_{t+s} = \frac{W_{t+s}}{z_{t+s} P_{t+s}}$, $\Lambda_{t,t+s} = \tilde{\beta}^s \frac{\tilde{\lambda}_{t+s}}{\tilde{\lambda}_t}$ ($\tilde{\lambda}_t$ is the stochastic discount factor based on the patient rate and the marginal utility of high patience consumers' real income). Note that marginal cost mc is equal to real effective wage $\frac{W_{t+s}}{z_{t+s} P_{t+s}}$ due to the linear production technology (1.6). The first order condition for pricing $\overline{P}_t$ in a symmetric equilibrium where all pricing firms choose the same price is:

$$\frac{\overline{P}_t}{P_t} = \frac{\varepsilon}{\varepsilon - 1} \frac{E_t \left\{ \sum_{s=0}^{\infty} \Lambda_{t+s}(1-\theta_p)^s \prod_{j=1}^{s} \Pi_{t+j}^{\varepsilon} Y_{t+s} mc_{t+s} \right\}}{E_t \left\{ \sum_{s=0}^{\infty} \Lambda_{t+s}(1-\theta_p)^s \prod_{j=1}^{s} \Pi_{t+j}^{\varepsilon-1} Y_{t+s} \right\}} \tag{1.10}$$

The transition of the aggregate price should be:

$$P_t = \left(\int_0^1 P_t(i)^{1-\varepsilon} di \right)^{\frac{1}{1-\varepsilon}} = \left((1-\theta_p) P_{t-1}^{1-\varepsilon} + \theta_p \overline{P}_t^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}} \tag{1.11}$$

or

$$1 = (1-\theta_p) \frac{1}{\Pi_t^{1-\varepsilon}} + \theta_p \frac{\overline{P}_t^{1-\varepsilon}}{P_t^{1-\varepsilon}} \tag{1.12}$$

1.2.3. Banks

Banks as financial intermediaries need some labor effort to reallocate funds from savers to borrowers. The total labor effort needed for the banking sector depends on the amount of loans, the amount of borrowers' collateral, and an aggregate risk factor q_t:

$$N_{s,t} = q_t(\omega \frac{l_{1,t}}{D_{1,t}^{\alpha}} + (1 - \omega)\frac{l_{2,t}}{D_{2,t}^{\alpha}}) \tag{1.13}$$

The risk factor q_t has the steady state value q and contains a shock $u_{q,t}$.

$$\ln(\frac{q_t}{q}) = \phi_q \ln(\frac{q_{t-1}}{q}) + u_{q,t} \text{ where } u_{q,t} \text{ }^{\sim} \text{ } i.i.d. \text{ } N(0, \sigma_q^2) \tag{1.14}$$

Note that in an equilibrium near the steady state, high patience consumers would not take any loans. It means that the actual labor effort in the banking sector is $N_{s,t} = q_t(1 - \omega)\frac{l_{2,t}}{D_{2,t}^{\alpha}}$, that in turn helps show the existence of a stable steady state as long as α is positive (Appendix A.2).

There are two interpretations for q_t. *First*, q_t is a "productivity" factor in processing loan applications. It is similar to a productivity shock in the physical production sector, but the higher q_t implies the lower productivity in the financial market. *Second*, q_t along with α contains the information about financial market regulations and practices. The variance of q_t in comparison with other aggregate shocks mirrors how volatile and risky the financial market is.

Banks' labor-effort function has two roles. *First*, it shows how the financial market rates the risk of loans in terms of loan amount and collateral. The more collateral or the less amount of loans, the less banking labor effort is needed. *Second*, it helps create the different dynamics of the lending rate and the policy rate under a shock. These

different dynamics are shown later in terms of the dynamics of the spread between the lending rate and the policy rate.

The banking sector is perfectly competitive and a bank could issue a non-contingent bond, $b_{b,t}$, which is similar to a government bond, $b_{g,t}$. Since banks return their periodic profits to consumers (high patience consumers to be exact), they would get an expected profit of zero in a competitive financial market. (In Appendix A.4, I prove that any new banks would have an expected profit of zero.) Assume that a bank has to hold some reserves at ratio, r_t, on all savings (or deposits), which would be returned to the bank in the next period. Table 1.1 summarizes the cash flows of such a competitive bank.

Table 1.1. Bank's cash flows		
$Outflows$	$Inflows$	
bond $\quad \frac{b_{b,t-1}}{\Pi_t}R_{t-1}$	$b_{b,t}$	bond
loan $\quad \omega l_{1,t} + (1-\omega)l_{2,t}$	$\frac{\omega l_{1,t-1}+(1-\omega)l_{2,t-1}}{\Pi_t}R^l_{t-1}$	loan
deposit $\quad \frac{\omega s_{1,t-1}+(1-\omega)s_{2,t-1}}{\Pi_t}R^s_{t-1}$	$\omega s_{1,t} + (1-\omega)s_{2,t}$	deposit
reserve $\quad [\omega s_{1,t} + (1-\omega)s_{2,t}]r_t$	$\frac{[\omega s_{1,t-1}+(1-\omega)s_{2,t-1}]}{\Pi_t}r_{t-1}$	reserve
wage $\quad N_{s,t}\frac{W_t}{P_t}$		

A bank also faces a balance sheet constraint which equates the total assets to the total liabilities. The balance sheet constraint is:

$$\omega l_{1,t} + (1-\omega)l_{2,t} = (1-r_t)(\omega s_{1,t} + (1-\omega)s_{2,t}) + b_{b,t} \tag{1.15}$$

Since banks' profit (or loss) is transferred to consumers at the end of periods, their retained earning will not be in the balance sheet. This feature is different from Gertler et al. (2009), where banks could issue equity.

Subject to the balance sheet constraint, a bank will solve the following problem:

$$
\max E_0 \left\{ \sum_{t=0}^{\infty} \Lambda_t \left[\begin{array}{c} b_{b,t} - \frac{b_{b,t-1}R_{t-1}}{\Pi_t} + \\ \frac{\omega l_{1,t-1}+(1-\omega)l_{2,t-1}}{\Pi_t}R_{t-1}^l - [\omega l_{1,t} + (1-\omega)l_{2,t}] \\ +(1-r_t)(\omega s_{1,t} + (1-\omega)s_{2,t}) + r_{t-1}\frac{\omega s_{1,t-1}+(1-\omega)s_{2,t-1}}{\Pi_t}) \\ -\frac{\omega s_{1,t-1}+(1-\omega)s_{2t-1}}{\Pi_t}R_{t-1}^s - N_{s,t}\frac{W_t}{P_t} \end{array} \right] \right\} \tag{1.16}
$$

where $\Lambda_t = \beta_1^t \frac{\lambda_{1,t}}{\lambda_{1,0}}$ is high patience consumers' stochastic discount factor and $\lambda_{1,t}$, which is equal to $U_{C_{1,t}}$, is the Lagrange multiplier associated with high patience consumers' budget constraint. The first order conditions are:

$$
R_t^s = (1 - r_t)(R_t - 1) + 1 \tag{1.17}
$$

$$
R_t^l = R_t \left[q_t \frac{W_t}{P_t}\frac{1}{D_{2,t}^\alpha} + 1 \right] \tag{1.18}
$$

Equation (1.17) shows a nearly perfect correlation between risk-free interest rate R_t and savings interest rate R_t^s as long as the variation of reserve ratio r_t is little. This property displays an empirical correlation between these two rates to be about 0.98. Since banks need to reserve a proportion of savings, the actual cost of funds for banks is exactly the risk-free interest rate, the cost of bank bonds. Therefore, in this chapter, the interest rate spread as a measure of banks' lending margin should not be between

the lending and savings interest rates, but between the lending and risk-free interest rates.

As we will see, equation (1.18) implies an effect of a monetary shock to the bank spread, $R^l - R$. Tightening monetary policy would increase the cost of funds for banks. As the amount of loans is expected to fall, banks would scale down their operation. If the cost of durable good adjustment is high, implying that durable good D_t is relatively sluggish, the higher policy interest rate would be partially compensated by the lower real wage. The spread between the lending and policy interest rates is possibly lower.

Equation (1.18) shows that a positive shock to q_t, a "financial shock", raises the monitoring/screening cost for banks at every unit of loan, shifting up the supply curve of loans. As a result, the lending interest rate is higher with a lower amount of loans in equilibrium. Borrowers would reduce their borrowing and demand for final goods. A new equilibrium is reached at lower output and inflation.

1.2.4. Monetary policy and fiscal policy

I use a standard monetary rule, in which the policy interest rate responds to its previous level, current output, and current inflation:

$$\ln \frac{R_t}{R^*} = \phi_r \ln \frac{R_{t-1}}{R^*} + \phi_\pi \ln \frac{\Pi_t}{\Pi^*} + \phi_y \ln \frac{Y_t}{Y^*} + u_{rt} \qquad (1.19)$$

where monetary shock $u_{r,t}$ follows a normal distribution $N(0, \sigma_r^2)$, and R^*, Π^*, and Y^* are the steady state values of the policy interest rate, inflation, and total output, respectively.

The government budget constraint, in real terms, is:

$$\frac{R_{t-1}b_{g,t-1} + \omega m_{1,t-1} + (1-\omega)m_{2,t-1} + r_{t-1}(\omega s_{t-1} + (1-\omega)s_{2,t-1})}{\Pi_t} + G_t$$

$$= \quad b_{g,t} + \omega m_{1,t} + (1-\omega)m_{2,t} + r_t(\omega s_{1,t} + (1-\omega)s_{2,t}) + T_t \qquad (1.20)$$

where T_t and G_t are the lump-sum tax and the government spending, respectively. To simplify the model and evaluate different monetary rules, I fix the lump-sum tax at its steady state value and formulate a government spending rule as follows:

$$T_t = T^* \qquad (1.21)$$

$$\ln \frac{G_t}{G^*} = \phi_g \ln \frac{G_{t-1}}{G^*} - \phi_{bg} \ln \frac{b_{g,t-1}}{b_g^*} + u_{g,t} \qquad (1.22)$$

where fiscal shock $u_{g,t}$ follows a normal distribution $N(0, \sigma_g^2)$ and G^* and b_g^* are the steady state values of the government spending and the government bonds, respectively.

1.2.5. Market clearing conditions

Production is equal to consumption in the final good market:

$$Y_t = \omega[C_{1,t} + (D_{1,t} - (1-\delta)D_{1,t-1})] + (1-\omega)[C_{2,t} + (D_{2,t} - (1-\delta)D_{2,t-1})] + G_t \quad (1.23)$$

Bond supply is equal to bond demand in the bond market:

$$\omega b_{1,t} + (1-\omega)b_{2,t} = b_{b,t} + b_{g,t} \qquad (1.24)$$

Labor supply is equal to labor demand in the labor market:

$$\omega N_{1,t} + (1 - \omega)N_{2,t} = N_{p,t} + N_{s,t} \tag{1.25}$$

1.2.6. Equilibrium

An equilibrium is a state of the model economy such that:

- $\{C_{i,t}, D_{i,t}, l_{i,t}, s_{i,t}, N_{i,t}, m_{i,t}\}_{t=0,i=1,2}^{\infty}$ maximizes consumers' lifetime expected utility given price vector $\{P_t, W_t, R_t, R_r^s, R_t^l\}$, fiscal policy and monetary policy

- Intermediate firms will set price P_t to maximize their profit

- $\{l_{1,t}, l_{2,t}, b_{b,t}, N_{s,t}\}$ maximizes the lifetime expected profit of banks given price vector $\{P_t, W_t, R_t, R_r^s, R_t^l\}$

- Price vector $\{P_t, W_t, R_t, R_r^s, R_t^l\}$ adjusts to satisfy the market clearing conditions.

1.3. Results

In this section, I first state two remarks, which help me pin down the first order conditions and implement the simulation processes. Second, I evaluate the optimal simple monetary rules. Third, I examine a fiscal transfer in coordination with a monetary rule. The parameterization process is in Appendix A.3.

1.3.1. Remarks

I use the two following remarks in order to simplify the model economy, pin down the steady state solution, and simulate the effects of an economic shock.

Remark 1.1. *From the steady state position, aggregate shocks do not change the status of consumers. High patience consumers are savers and low patience consumers are borrowers.*

As shown in Appendix A.2 there is only one steady state solution, in which high patience consumers are savers and low patience consumers are borrowers. From the steady state position, if aggregate shocks increase the wealth of low patience consumers, they would increase the wealth of high patience consumers who have more types of assets to insure against risks. This remark simplifies some equations for both types of consumers: high patience consumers will not take loans and low patience consumers will not invest in bonds.

Remark 1.2. *The expected profit of banks in the beginning of periods is zero.*

The proof of Remark 1.2 is in Appendix A.4. Remark 1.2 holds because banks are perfectly competitive within the rational expectation framework where perfect competition means zero profit and free entrance for all participants.

1.3.2. Financial shock

Figure 1.2. Impulse responses of variables to a financial shock

Y is output; C is aggregate consumption; Rl is lending interest rate; R is policy interest rate; S is aggregate saving; inflation is gross backward inflation rate
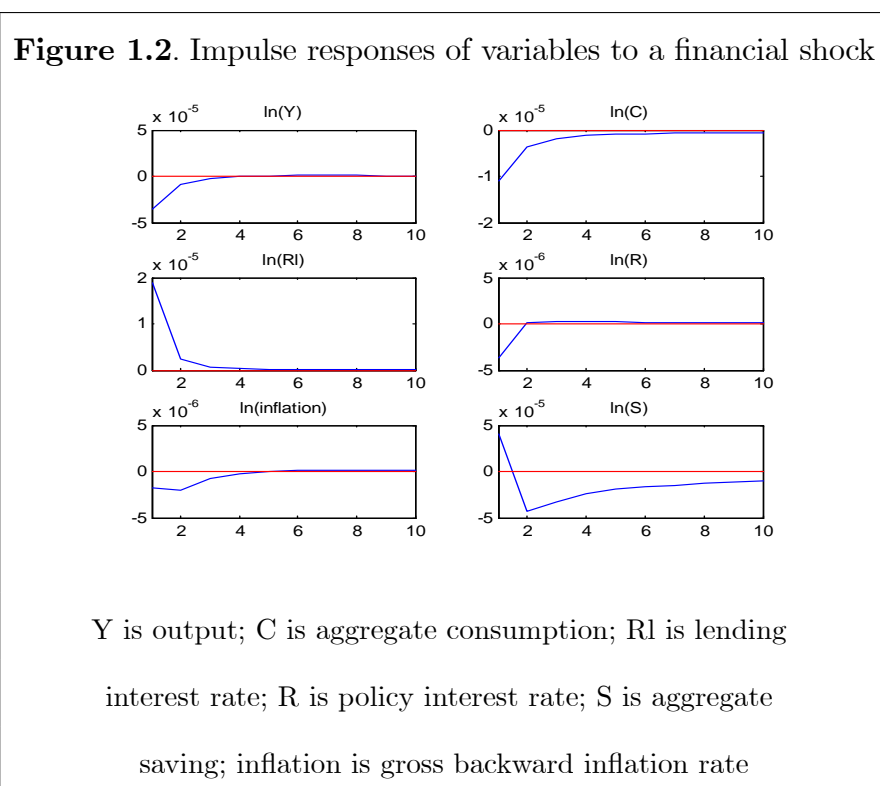
As seen in the model economy, a financial shock to the banking sector and a monetary shock seem to have similar effects on inflation and output. Figure 1.2 contains the impulse responses of some main economic variables to a financial shock. Such a shock would drain the aggregate loan and increase the lending rate. Therefore, borrowers lower their demand, causing the aggregate demand to decrease. Consequently, inflation and output go down.

Figure 1.3. Impulse responses of variables to a monetary shock
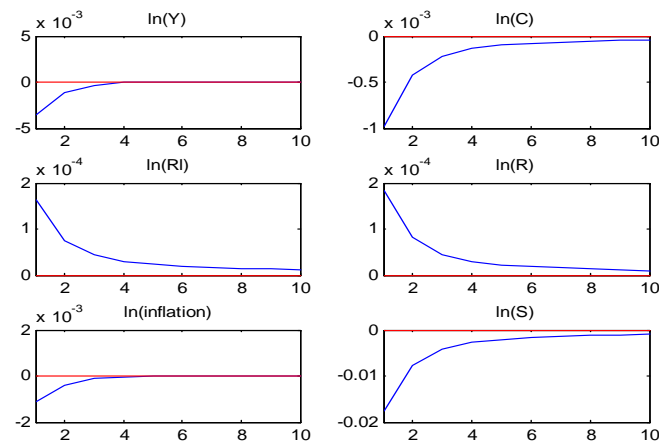
Y is output; C is aggregate consumption; Rl is lending interest rate; R is policy interest rate; S is aggregate saving; inflation is gross backward inflation rate

Figure 1.3 presents the responses of some variables to a monetary shock. Comparing Figure 1.2 and Figure 1.3, one would see that, to some degree, the responses of the lending rate, output, consumption, and inflation to a financial shock are similar to their responses to a monetary shock.

1.3.3. Bank spread

In this sub-section, I show that the bank spread is a good economic indicator and a proxy for a financial shock. The interactions between the bank spread and the lending rate distinguish a financial shock from a monetary one. Therefore, it is reasonable to use this spread to design monetary rules later on.

In my model, the actual cost of funds for banks is not the savings rate since savings are subject to a reserve requirement, which does not give banks any return. Equation (1.17) shows that the actual cost of banks' funds is equal to the interest rate of banks' bonds. Therefore, one could see that the bank spread in this chapter is the difference between the lending rate and the policy interest rate. This spread is equivalent to the credit spread in Cúrdia et al. (2009).

Bank spread is a good proxy for a financial shock because a financial shock significantly contributes to the fluctuation in the bank spread.

Table 1.2. Variance decomposition (%)	
Shock type	$\ln(spread)$
Financial shock	16.95
Monetary shock	4.39
Productivity shock	78.46
Fiscal shock	0.02

Table 1.2 reports the variance decomposition of the bank spread. A monetary shock and a fiscal shock do not explain the variance of the bank spread very much. Two important explanatory forces are a productivity shock and a financial shock.

Let's take a closer look at equation (1.13) of banking labor effort, $N_{s,t} = (1 - \omega)q_t \frac{l_{2,t}}{D_{2,t}^\alpha}$, and equation (1.18), $R_t^l - R_t = R_t q_t \frac{W_t}{P_t} \frac{1}{D_{2,t}^\alpha}$, equation (1.18) is rewritten by:

$$spread_t = R_t^l - R_t = \frac{1}{(1-\omega)} R_t \frac{W_t}{P_t} \frac{N_{s,t}}{l_{2,t}} \tag{1.26}$$

Given the relatively high sluggishness of durable goods, a financial shock would directly increase the labor effort per loan unit, $\frac{N_{s,t}}{l_{2,t}}$. Consequently, the bank spread increases. However, the increase of the bank spread may be compensated partially by the decrease of the policy interest rate and the real wage.

Observation 1.1. *Given that there is a shock from monetary policy or the banking sector, the co-movements of the bank spread and the lending rate signal a financial shock. Otherwise, there is a monetary shock.*

Figure 1.4. Impulse responses of ln(bank spread) to shocks
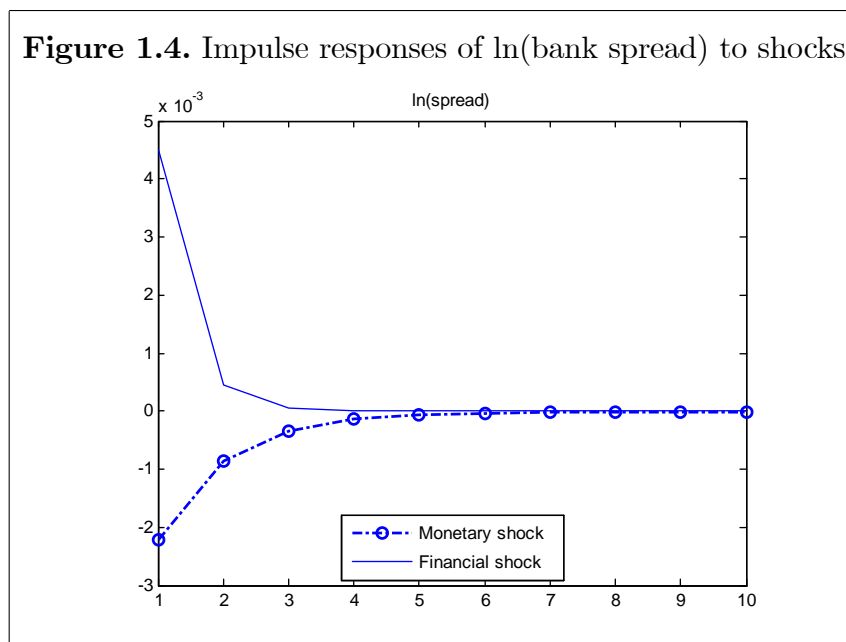
Figure 1.4 shows the impulse responses of the bank spread to a financial shock and a monetary shock. A financial shock increases the bank spread in order to mirror a rising risk in the financial market.

Let's take a look at equation (1.18) again. A monetary shock increases the policy interest rate R and reduces the real wage $\frac{W_t}{P_t}$. In my model, a monetary shock drives down the bank spread because the durable goods as collateral are quite sluggish and the aggregate effect from the increase of R and the decrease of $\frac{W_t}{P_t}$ is negative.

In general, I show that the bank spread is a good proxy for a financial shock. Its interaction with other variables helps identify the presence of a financial shock. Therefore, the bank spread could be a good economic indicator.

1.3.4. Monetary policy evaluation

In this subsection, I first discuss the criterion for policy evaluation and the method to compute the optimal simple rules. I then show the optimal simple monetary rules.

1.3.4.1. Loss function

For policy evaluation, I do not use the welfare in the Ramsey policy problem. Neither would I use the welfare loss criterion in terms of consumption percentage needed to get out of the sticky price framework (Lucas, 2003). There are two reasons for not using welfare criteria. First, the social planner has no reasonable discount factor. Second, the monetary authority may use different weights rather than the proportion of high patience consumers in maximizing the aggregate welfare.

My choice for a policy evaluation criterion is a loss function like Filardo (2002) and Bernanke et al. (2001). This criterion is also based on the frontier of the variances of some economic variables by Iacoviello (2005). This means the monetary authority minimizes a linear combination of the unconditional variances of output, inflation, and the policy interest rate.

Let's define a loss function as follows:

$$LF = \Delta_\pi \ \text{var}(\ln(\Pi_t)) + \Delta_y \ \text{var}(\ln(Y)) + \Delta_r \ \text{var}(\ln(R)) \qquad (1.27)$$

where var stands for variance; and subjective positive coefficients Δs are assigned by the monetary authority (and/or the government). In order to investigate inflation targeting, I fix two coefficients $\Delta_y = 0.1$ and $\Delta_r = 0$. I then change coefficient Δ_π and see how monetary policy rules change to minimize the loss function. If the monetary authority targets inflation, it would consider Δ_π a relatively high value to the other weights Δs. A strict inflation targeting policy is the one in which Δ_π is unit and all the other weights Δs are zero.

1.3.4.2. Monetary rules

The general monetary rule is

$$\ln \frac{R_t}{R^*} = \phi_r \ln \frac{R_{t-1}}{R^*} + \phi_y \ln \frac{Y_t}{Y^*} + \phi_\pi \ln \frac{\Pi_t}{\Pi^*} + \phi_{spread} \ln \frac{spread_t}{spread^*} + u_{rt} \qquad (1.28)$$

where $spread_t$ is the bank spread in period t, ϕ_{spread} is the coefficient responding to the bank spread in the monetary rule, and the other variables and coefficients are from equation (1.19). My strategy of computation for the optimal simple rules is as follows:

- Step 1: I fix two coefficients ϕ_r and ϕ_y. This is mainly because I fix the weights of output Y_t and policy interest rate R_t in the loss function.
- Step 2: For each value Δ_π, I search for ϕ_{spread} in order to minimize the loss function.

1.3.4.3. Optimal simple rules with the bank spread

In this subsection, I examine what an optimal simple rule should be. I show that: (i) monetary policy should respond to the bank spread; and (2) how much monetary policy responds to the bank spread depends on the response coefficient of inflation. Figure 1.5 shows the different values of the coefficient of the bank spread for the different pre-determined values of the coefficient of inflation in monetary rule (1.28).

Figure 1.5. Optimal simple rules: response to the bank spread and inflation $(\Delta_y = 0.1; \Delta_r = 0; \Delta_\pi = 0.9)$
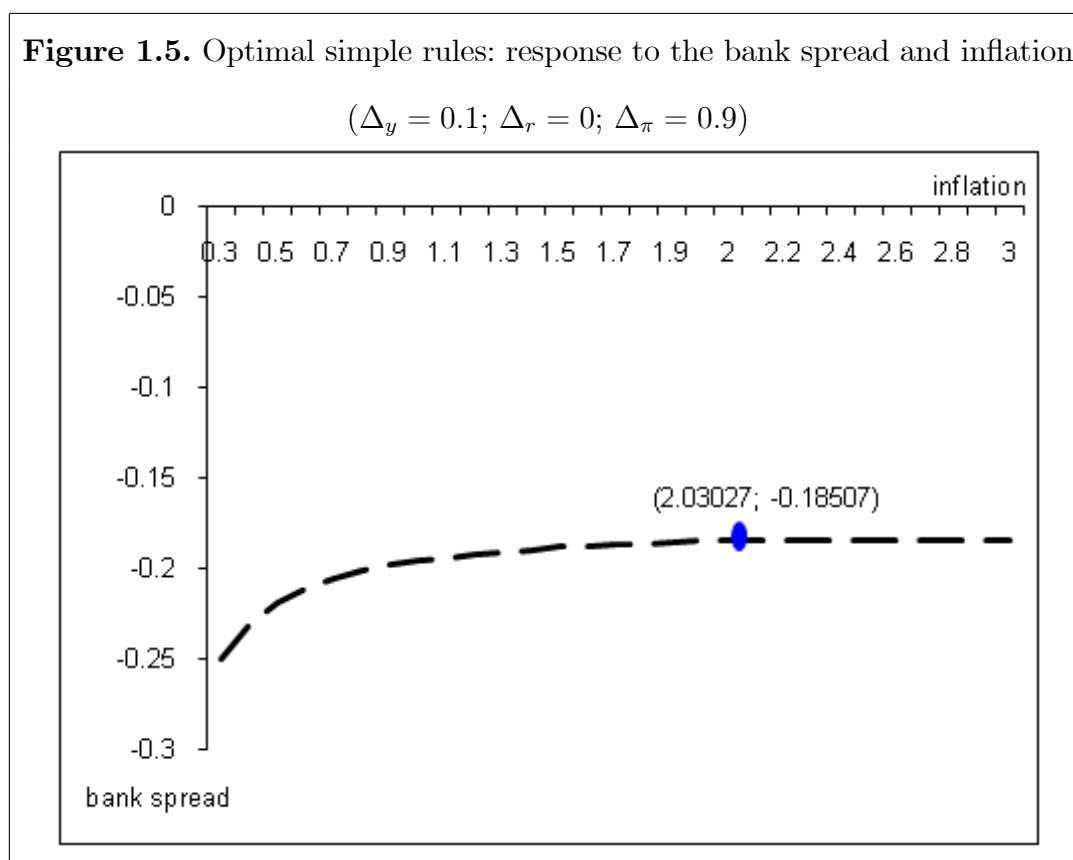
If both the coefficients of the bank spread and inflation in the monetary rule are allowed to change, the optimal simple rule is $(\phi_r, \phi_{spread}) = (2.03027; -0.18507)$. If the coefficient of inflation in the monetary rule is fixed, the optimal coefficient of the bank spread in the monetary rule is still negative but it decreases when the coefficient of

inflation increases. The negative coefficient of the bank spread in the monetary rule still holds when I change the weight of inflation Δ_π in the loss function.

A negative response to the bank spread in the monetary rule (1.28) is understandable. As shown above, the bank spread is a good proxy for a financial shock and a financial shock drives down inflation and output. Therefore, the policy interest rate should be lower in order to stimulate the whole economy when the economy is under a positive financial shock.

1.3.5. Monetary rules in coordination with a fiscal transfer

1.3.5.1. Fiscal transfer

I consider coordination of monetary and fiscal policy. As there are two separate types of consumers, I propose a transfer program from the government to borrowers (or low patience consumers). Each period, borrowers get some income $\tau(D_1^* - D_{1,t})$, a proportion of the change of high patience consumers' aggregate durable good. Borrowers' budget constraint becomes:

$$
\begin{aligned}
& C_{2,t} + (D_{2,t} - (1-\delta)D_{2,t-1}) + s_{2,t} + m_{2,t} + \frac{l_{2,t-1}R_{t-1}^l}{\Pi_t} + T_{2,t} \\
\leq\ & \frac{W_t}{P_t}N_{2,t} + \frac{s_{2,t-1}R_{t-1}^s}{\Pi_t} + \frac{m_{2,t-1}}{\Pi_t} + l_{i,t} + \tau(D_1^* - D_{1,t})
\end{aligned}
\tag{1.29}
$$

The government budget constraint becomes:

$$\frac{R_{t-1}b_{g,t-1} + \omega m_{1,t-1} + (1-\omega)m_{2,t-1} + r_{t-1}(\omega s_{t-1} + (1-\omega)s_{2,t-1})}{\Pi_t}$$

$$+G_t + \tau(1-\omega)(D_1^* - D_{1,t}) \tag{1.30}$$

$$= b_{g,t} + \omega m_{1,t} + (1-\omega)m_{2,t} + r_t(\omega s_{1,t} + (1-\omega)s_{2,t}) + T_t$$

In this fiscal transfer, the government but borrowers observes lenders' durable goods. Consequently, borrowers consider $\tau(D^* - D_{1,t})$ as a lump-sum tax and there is no distortion from this fiscal transfer. Even though this fiscal transfer is partial, it affects lenders through the government spending and the policy (or bond) interest rate.

A bad shock decreases the durable goods in both types of consumers. However, the government would support borrowers in order to stabilize their collateral in terms of durable goods. As borrowers' durable goods decrease by a lesser amount, the increase of banks' labor effort should be less. However, there is an opposite force from the fiscal transfer on the government budget, causing the bond rate to increase. In order to reduce this fiscal pressure, monetary policy needs to expand.

1.3.5.2. Quantifying the necessary coordination

The conclusions about monetary rules with the bank spread, addressed in previous sub-sections, still hold with this fiscal transfer. I do not show the results here. Instead, I show that: (i) the coordination of fiscal policy and monetary policy is necessary, and (ii) fiscal policy needs to be more active when the financial market is more volatile.

I use the same structure of the loss function (1.27) and I assume that the monetary authority pre-determines the response coefficient of inflation in the monetary rule. To

consider how the coordination works, I allow the coefficients of the bank spread ϕ_{spread} and fiscal transfer τ to change.

Table 1.4 reports the coefficients of the bank spread (ϕ_{spread}) and fiscal transfer (τ). It shows that coordination of monetary and fiscal policy is necessary. However, I see that fiscal policy is quite small, lower than 4 percent of the fluctuation in lenders' durable good. It means the burden on the government budget with this transfer is possibly small.

Table 1.3. Coordination of monetary and fiscal policy
$(\Delta_y = 0.1; \ \Delta_r = 0; \ \Delta_\pi = 0.9)$
$(\phi_r = 0.8; \ \phi_\pi = 2; \ \phi_y = 0.2)$

ϕ_{spread}	-0.64142
τ	0.0374528

I continue to check how this coordination changes when the magnitude of a financial shock is different.

Table 1.4. Coordination of monetary and fiscal policy: robust check
$(\Delta_y = 0.1; \ \Delta_r = 0; \ \Delta_\pi = 0.9)$
$(\phi_\pi = 2; \ \phi_y = 0.2; \ \phi_r = 0.8)$

	variance of a financial shock		
	$\frac{\sigma_q^2}{4}$	σ_q^2	$4\sigma_q^2$
ϕ_{spread}	-0.6534	-0.64142	-0.6084
τ	0.0342731	0.0374528	0.0473955

Table 1.4 shows two cases in which I cut in half or make double the magnitude of a financial shock. The results show that the fiscal transfer is more active while monetary policy responds less to the bank spread. It implies that if a monetary rule predetermines the responsive levels to inflation, output, and the policy interest rate, the magnitude of a financial shock would change the roles of fiscal transfer policy and monetary policy. However, it is always the case that monetary policy should negatively respond to the bank spread while borrowers should get more support from the government in order to better insure their wealth against more volatile financial shocks.

1.4. Conclusion

I show that the presence of a financial shock could change the analyses of a monetary model. The current model helps shed light on the practical design of a monetary rule in order to respond to a financial shock. It also proposes a lump-sum tax in terms of a fiscal transfer in coordination with monetary policy to better stabilize the whole economy.

Monetary rules should negatively respond to the bank spread, which is a good proxy for a financial shock. A fiscal transfer program, in which borrowers get some financial support from the government during bad shock periods, helps stabilize the whole economy as borrowers have some additional income sources to insure against risks. This fiscal policy becomes more active when the volatility in the financial market increases.

CHAPTER 2

MONETARY POLICY AND INTEREST RATE SPREAD IN A MODEL WITH HETEROGENEOUS FUNDS AND FINANCIAL SHOCKS

2.1. Overview

This chapter focuses on two questions: Do financial intermediaries significantly change and contribute to the fluctuations in macroeconomic variables? How does the monetary authority responds to a financial shock?

The first question has been addressed in the context of models with a financial accelerator (e.g. Bernanke et al., 1999, Iacovielo, 2005). This chapter sets aside the role of a financial accelerator and ask if the addition of financial intermediaries to a standard monetary model change the effects of a shock. A reasonable answer may depends on how different the dynamics of interest rates are.

In a standard New Neoclassical Synthesis (NNS) model, all interest rates are identical. However, they are not the same in reality and they have different dynamics[1]. Previous theoretical studies with financial intermediaries often generate these different dynamics but have diversified conclusions about the magnitude of the effects of an aggregate shock in comparison with models without a financial sector. While Christiano, Motto, and Rostagno (2007) say that a financial market does not change the effects of

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[1]Empirically, the three-month savings rate and the effective Fed-fund rate are nearly perfectly correlated. Therefore, bank spread, the difference between the prime rate and the savings rate, has similar properties to the spread between the prime rate and the effective Fed-fund rate. Some studies (e.g. Curdia et al., 2009) assume or model the three-month savings rate to be identical to the effective Fed-funds rate.

a shock much, Christiano, Trabandt, and Walentin (2007) and others claim that the different dynamics of interest rates make significant changes to economic outcomes.

To create a financial market, this chapter does not use a heterogeneous consumer framework (e.g. Iacoviello, 2005, Cúrdia et al., 2009, Stracca, 2007 and others). Nor does it use the credit channel in which a firm could use some funds to finance its operations (e.g. Bernanke et al., 1999 and Christiano, Motto, and Rostagno, 2007). I assume instead that firms need bank loans and retained earnings to produce new investments. It means that the fund in terms of bank loans is not a perfect substitute for the fund in terms of retained earnings.

The model with banks in this chapter is in the same vein of a series of interesting studies which augment a financial component into a standard monetary model (e.g. Dellas, Diba, and Loisel, 2010, Cúrdia and Woodford, 2009, Goodfriend and McCallum, 2007). Particularly, it examines a banking system in a standard menu-cost model with two new features: costly financial intermediation and a risk-rating framework. In order to manage and monitor loans, banks need labor effort. The amount of banks' labor effort depends on the amount of loans and intermediate good firms' risk, measured by the relative level of the firms' external finance. Banks' labor effort could be interpreted as a cost of information verification as in Bernanke et al. (1999). It could also be understood as the cost to screen debtors, monitor loans, and manage banking businesses.

Due to heterogenous funds to produce new investments and a banking sector which needs labor to observe and manage loans, there are different dynamics of the lending rate, the savings rate, and the policy rate. As a result, the effect of a shock on investment decisions, which depend on the lending rate, changes in comparison with a standard model without a financial sector. Similarly, the effects of a shock on output,

inflation and consumption are different. This chapter shows that the model with banks generates more fluctuations in macroeconomic activities and a higher cost of price rigidity.

Previous studies claim that financial disturbances, if any, do not contribute much to the variances of economic activity. This chapter still sees that given the policies that the NNS framework proposes, a financial disturbance does not contribute much to economic fluctuations in comparison with other common shocks such as fiscal shocks, monetary shocks, and productivity shocks. However, in terms of the level of responsive effects, a financial shock significantly affects economic activity.

The next question "*Are financial disturbances important in the conduct of monetary policy?*" has become extremely topical. This question has been investigated in Chapter 1. Under a different model, I want to examine it again. To address this question, I first analyze the effect of a shock to the banking sector and a set of economic indicators to identify this shock. I then evaluate the conduct of monetary rules with the bank spread.

This chapter introduces a financial disturbance to the banking sector. The labor effort that banks need to manage and observe loans is subject to a shock. Such a shock may come from changes in labor productivity, liquidity management, risk-rating strategies, and a broadly interpreted default risk. I consider the persistent process of a financial shock to be similar to the persistent process of a productivity shock. In reality, these processes are not identical.

Many studies have qualitatively tried to identify the presence of a financial shock. Taylor et al. (2010) investigate "*a Black Swan*" in the money market during the recent crisis. They claim that the spreads, measured by the differences between LIBOR rate

and Fed-funds rates, rise quickly during financial crises[2]. In an elegant setup, Cúrdia et al. (2009) model a direct disturbance to this spread. Kashyap et al. (1993) also empirically argue that a spread between the short-term commercial paper rate and the effective Fed-funds rate could be in a set of economic indicators to help identify a shock in the credit channel.

I theoretically construct a set of economic indicators including interest rates and the bank spread in order to identify the presence of a financial shock. In my model, a financial shock to banks' labor effort affects the bank spread. In order to further motivate the important role of the bank spread in connection to a financial disturbance, this chapter employs a simple vector autoregressive (VAR) model from Christiano et al. (1999, 2005) to initially see how the bank spread interacts with other economic variables. The set of indicators to identify such a shock is quite consistent with the model economy and the initial results from a simple VAR regression.

This chapter then analyses the conduct of monetary policy under the presence of a financial shock. It shows that the monetary authority should pay attention to this shock. If the monetary authority responds to a financial shock, this shock would account significantly for the fluctuations in economic activity in comparison with other shocks. In addition, the cost of price rigidity decreases significantly, signalling that this avenue is worthy of consideration.

In practice, one needs to use an observable proxy for the presence of a financial shock. In this chapter, the bank spread and the asset price as proxies for such a shock are used in standard Taylor-style rules in order to evaluate how well these augmented rules compensate for a financial disturbance. A difference from Cúrdia et al. (2009)

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[2]They also consider other money market rates including the Overnight Indexed Swap and Repo Rates. In addition, they consider the spread between the asset-backed rate and the dealer placed commercial paper rate.

is that the bank spread in this chapter is dependent on market return, firms' position in terms of relative external finance, and real wage. The credit spread in Cúrdia et al. (2009) is solely dependent on aggregate credit.

Using the optimal simple rule computation to minimize the cost of price rigidity, an optimal simple rule should negatively and partially respond to the bank spread. This result is again complimentary to Cúrdia et al. (2009) and Taylor et al. (2010). In addition, the switch of monetary policy to responding to the bank spread increases the role of a financial disturbance in the fluctuations of economic variables. This chapter also shows that, to some degree, a monetary rule with the bank spread is equivalent to a monetary rule with the asset price. However, these two rules would not result in the same patterns of economic responses under a financial shock.

This chapter contains four other sections. Section 2.2 provides some stylized facts. Section 2.3 describes the model economy. Section 2.4 presents the results. Section 2.5 concludes this chapter.

2.2. Empirical evidence

I document two facts: (i) the different dynamics of interest rates and; (ii) a disturbance to the bank spread.

2.2.1. Interest rates and the bank spread

Figure 2.1 contains three interest rates: the effective Fed-funds rate as the policy rate, the prime rate as the lending rate and the three-month deposit rate as the savings rate[3]. These three interest rates seem to follow closely together.

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[3]Defined by the Federal Reserves, the prime rate is the short-term (3-month) lending rate that banks charge for AAA-rated firms' loans.

Figure 2.1. Policy rate, R, prime rate, Rl, and savings rate, Rs
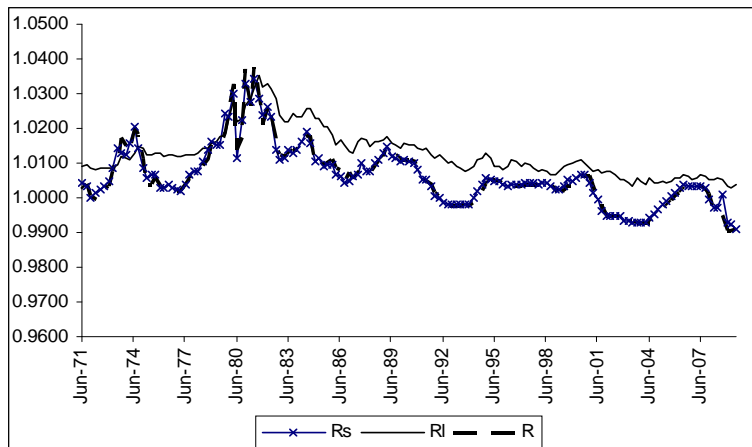
Table 2.1 shows that the correlations of these interest rates are strong and positively significant.

Correlation	Corr. with R	Corr. with R^l	*Mean*	*S.E*
Table 2.1. Some statistics				
R	1	0.9592(*)	1.0061	0.0088
R^l	0.9592(*)	1	1.0115	0.0080
R^s	0.9857(*)	0.9408(*)	1.0063	0.0084
Bank Spread	-0.2045(*)	0.0405	0.0052	0.0028

R - effective Fed-funds rate; R^s- three-month deposit rate;

R^l-three-month prime rate; SE - standard error; Corr: correlation.

(*) - significance at significance level of 5%.

Figure 2.2. Bank spread versus effective Fed-funds rate

Bank spread=$(R^l - R^s)$; R: effective Fed-funds rate

R^l : prime rate; R^s: savings rate
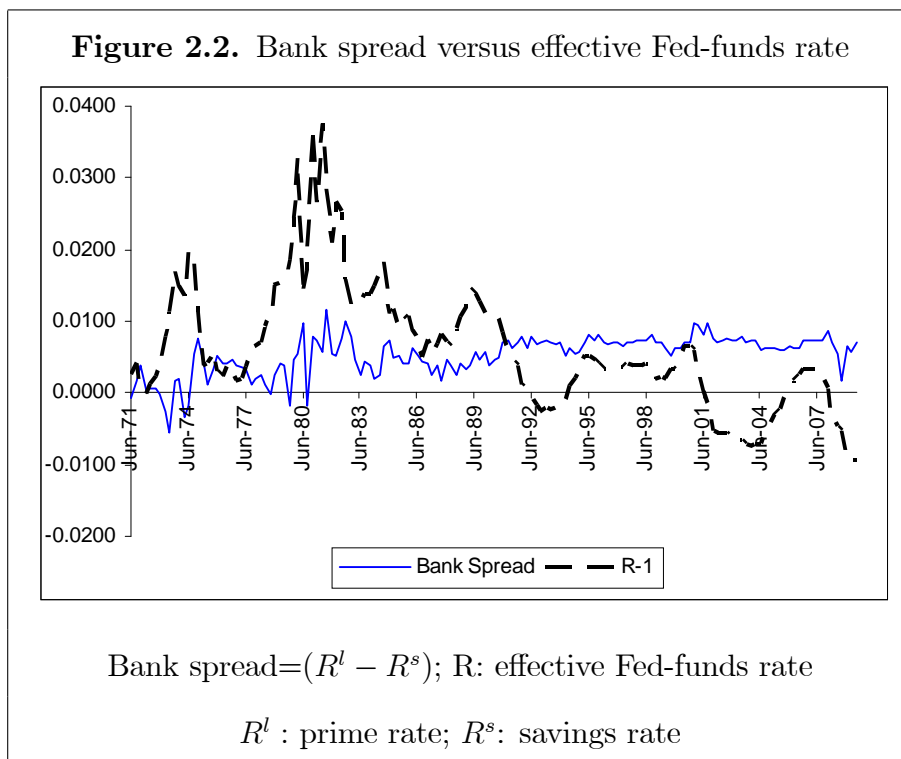
Figure 2.2 contains the spread between the lending rate and the savings rate, - henceforth, the bank spread. In some periods, the bank spread and the policy rate move in opposite directions. This pattern seems to repeat in the recent financial crisis. Table 2.1 also reveals that the bank spread is negatively correlated with the policy rate and not correlated with the lending rate. This means that the lending rate and the policy rate could have different dynamics.

2.2.2. Disturbance to the bank spread

In this subsection, I use the simple VAR model by Christiano, Eichenbaum and Evans (CEE, 1999, 2005), which includes output (y_t), inflation (π_t), and the policy interest rate (r_t) and I add the government expenditure (g_t) and the bank spread ($spread_t$). I use the VAR model to examine how the bank spread responds to shocks and how

common macroeconomic variables change when there is an exogenous shock to the bank spread. The VAR model is as follows:

$$X_t = \sum_{i=1}^{4} A_i X_{t-i} + \Omega \epsilon x_t \qquad (2.1)$$

where $X_t = [g_t, \pi_t, y_t, r_t, spread_t]'$; ϵx_t is a 5-dimension vector of zero-mean, uncorrelated shocks; Ω is a 5 x 5 lower triangular matrix with unit diagonal terms. Details of the data are in Appendix B.3.

To identify the shocks, I use the Cholesky decomposition of residuals. The proper ordering of this decomposition should have the most endogenous variable in the last position and the most exogenous variable in the first position. I assume that new information about shocks in period 't' is sequentially ordered in X_t from the government expenditure to the bank spread (Hamilton 1994). Therefore, I put g_t in the first position and $spread_t$ in the last position[4].

---

[4]Monetary policy is often implemented after the information about the government expenditure, price level, and output is known. Besides inflation, monetary policy cares much about the lending rate, which affects the production sector. Therefore, the bank spread could depend on all the previous information. In addition to this order, given the positions of the government expenditure and the bank spread I have checked the other ordering alternatives for output, inflation, and the policy rate. I see that the responses of the VAR model do not change much. I also checked the VAR model with the Generalized Impulse Responses by Pesaran and Shin (1998), I do not see any significant differences in terms of response directions.

Figure 2.3. Empirical impulse responses to a financial shock
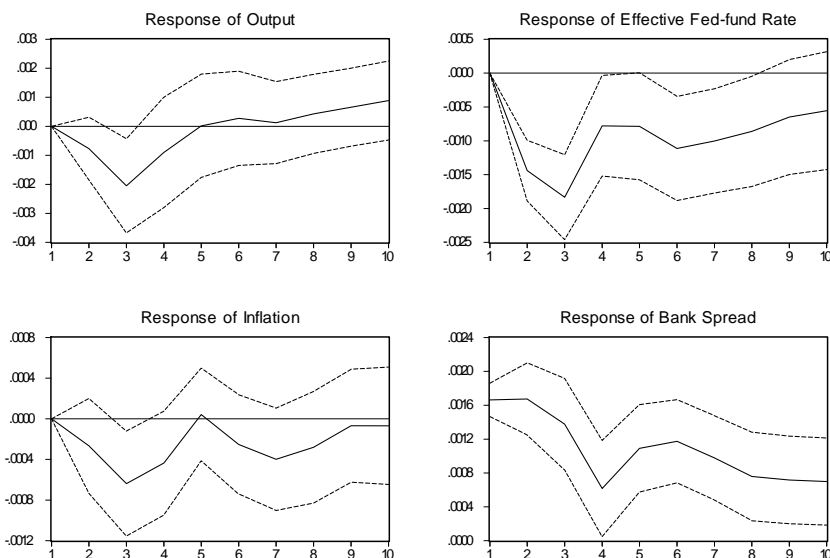
Bank spread, inflation (Pi), effective Fed-funds rate (R) and output (Y) are in log-form.

Bank spread is based on the difference of prime rate and deposit rate.

Figure 2.4. Empirical impulse responses of the bank spread to shocks
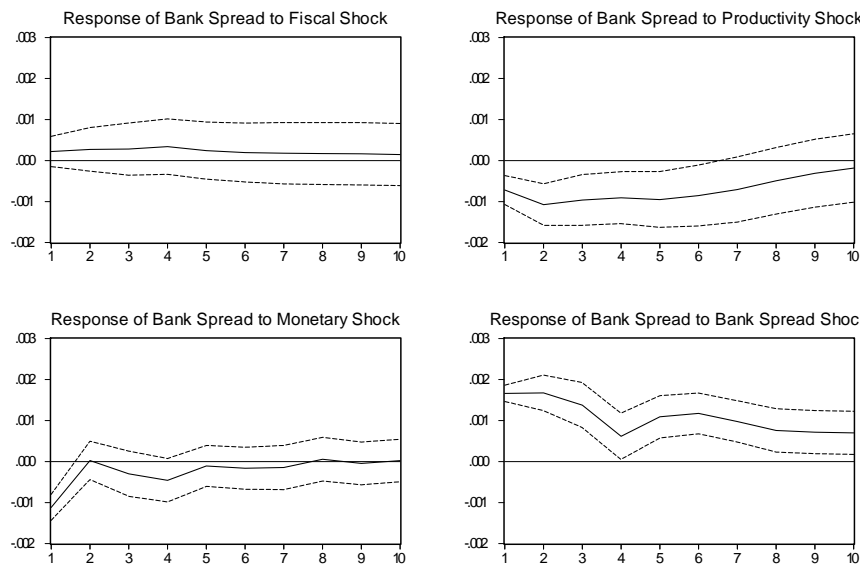
Bank spread, inflation (Pi), effective Fed-funds rate (R) and output (Y) are in log-form.

Bank spread is based on the difference of prime rate and deposit rate.

Figure 2.3 shows the impulse response functions of X_t to a disturbance to the bank spread. The effective Fed-funds rate, inflation, and output decrease in response to a bank spread disturbance. Figure 2.4 shows the responses of the bank spread to all four shocks. The dynamics of the bank spread measures how different the dynamics of the lending rate and the savings rate are. Figure 2.4 implies significant differences of the dynamics of the lending and savings rates under four types of shocks. For example, a positive monetary shock of one standard deviation would differentiate the increases of the savings rate and the lending rate by about 0.1 percent points.

2.3. Model economy

This section models an economy with costly financial intermediaries (or banks). I call this current model economy the benchmark model. The economy contains five participants: a representative consumer, banks, intermediate and final good firms, the government, and the monetary authority. Except the prices of goods, inflation rate, interest rates, and returns, the other variables in capital letters are in real values. Notation E_t is the conditional expectation in period t. I use timing as in a standard real business cycle model (e.g. Eichenbaum et al., 2005). In period 't':

- Intermediate firms finance a new investment by both retained earnings and bank loans. This new investment lags one period even though it is produced in the current period. It means that a period-t investment is for period 't+1' production. The new investment is not perishable. Intermediate firms use labor effort and aggregate capital to produce intermediate goods. Final firms buy intermediate differentiated goods to produce final goods.

- A representative consumer gets income from five sources: the wages from labor supply, the dividends of equity shares invested last period, the returns of bond

holding and deposits, and money holding. Her/his income is redistributed to consumption, new equity shares, new bond holding, new deposits, and new money holding. It notes that equity shares today are used to claim dividends next period.

- Banks take savings from the consumer and make loans to intermediate firms. To monitor loans, banks need labor effort. It assumes that labor is perfectly mobile. Therefore, wages are the same in both the production sector and the financial sector. The amount of banks' labor effort is dependent on firms' current period loan and current financial leverage.

- The government issues new bonds at a risk-free rate (which is the policy interest rate). The government uses a lump-sum tax and new bonds to pay for its previous borrowing and current consumption expenditure. This chapter estimates a fiscal rule from an empirical data set.

- The monetary authority uses a monetary rule to control the policy interest rate. This chapter estimates a standard Taylor monetary rule from an empirical data set.

2.3.1. Firms

There are two types of firms: intermediate good firms and final good firms. Final firms use a standard Dixit-Stiglitz specification to produce final goods from intermediate goods. Intermediate firms are subject to a Rotemberg (1983)-style menu cost.

2.3.1.1. Final good firms

Final good firms produce final goods by aggregating intermediate differentiated goods $Y_{i,t}$s. A standard Dixit–Stiglitz aggregation in final good production is $Y_t = \left(\int_0^1 Y_{i,t}^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}}$

where ε is the elasticity of substitution between intermediate differentiated goods. The cost minimization problem of final good firms at time t

$$\min\{\int_0^1 P_{i,t}Y_{i,t}di\} \text{ subject to } Y_t = \left(\int_0^1 Y_{i,t}^{\frac{\varepsilon-1}{\varepsilon}}di\right)^{\frac{\varepsilon}{\varepsilon-1}} \qquad (2.2)$$

gives the demand for each differentiated intermediate good i and aggregate price P_t as follows:

$$Y_{i,t} = \left(\frac{P_{i,t}}{P_t}\right)^{-\varepsilon}Y_t \qquad (2.3)$$

$$P_t = \left(\int_0^1 P_{i,t}^{1-\varepsilon}di\right)^{\frac{1}{1-\varepsilon}} \qquad (2.4)$$

2.3.2. Intermediate good firms

Intermediate good firm i uses capital $K_{i,t}$ and labor $N_{i,p,t}$ to produce differentiated good $Y_{i,t}$ under an economy-wide productivity shock ϵ_{zt}.

$$Y_{i,t} = \exp(z_t)K_{i,t}^{\alpha}N_{i,p,t}^{1-\alpha} \qquad (2.5)$$

Assume that z_t is auto-regressive of order 1:

$$z_t = \phi_z \ z_{t-1} + \epsilon_{zt} \text{ where } \epsilon_{zt}\tilde{~}i.i.d.N(0,\sigma_z^2) \qquad (2.6)$$

The next period capital stock is based on the current capital stock depreciated at rate δ and the current investment flow.

$$K_{i,t+1} = (1-\delta)K_{i,t} + I_{i,t} \qquad (2.7)$$

This timing means that investment $I_{i,t}$ lags one period. The period-t investment is financed by real loan $L_{i,t}$ at pre-determined lending rate R_t^l and real retained earning $E_{i,t}$:

$$I_{i,t} = L_{i,t}^{\omega} E_{i,t}^{1-\omega} \tag{2.8}$$

Intermediate firms incur a Rotemberg-style menu cost when they change price. Such a menu cost in terms of final good is $\frac{\psi}{2}(\frac{P_{i,t}}{P_{i,t-1}} - 1)^2 Y_t$. Intermediate firms pay dividends to share-holders at the end of each period. In period t, intermediate firm i would have dividend $D_{i,t}$ as follows:

$$D_{i,t} = \frac{P_{i,t} Y_{i,t}}{P_t} - W_t N_{i,p,t} - \frac{R_{t-1}^l L_{i,t-1}}{\Pi_t} - E_{i,t} - \frac{\psi}{2}(\frac{P_{i,t}}{P_{i,t-1}} - 1)^2 Y_t \tag{2.9}$$

where:

- $\frac{P_{i,t} Y_{i,t}}{P_t}$ is the real income from selling differentiated good $Y_{i,t}$;

- $W_t N_{i,p,t}$ is the real labor cost based on real wage W_t for each unit of banking labor effort $N_{i,p,t}$;

- $\frac{R_{t-1}^l L_{i,t-1}}{\Pi_t}$ is the real return on loan $L_{i,t-1}$ at pre-determined lending rate R_{t-1}^l;

- $E_{i,t}$ is the real equity saved from revenue for investment production;

- $\Pi_t = \frac{P_t}{P_{t-1}}$ is the gross backward inflation rate;

- $\frac{\psi}{2}(\frac{P_{i,t}}{P_{i,t-1}} - 1)^2 Y_t$ is the menu cost in terms of final good.

Intermediate firms would maximize expected discounted dividends:

$$\max \mathrm{E}_t \left\{ \sum_{s=0}^{\infty} \Lambda_{t+s,t} [D_{i,t+s}] \right\} \tag{2.10}$$

where $\Lambda_{t+s,t}$ is the stochastic discount factor based on the consumer's relative marginal utility between period 't+s' and period 't'. $\Lambda_{t+s,t}$ could be derived from the consumer's

utility specification:

$$\Lambda_{t+s,t} = \beta^s \frac{U_{C_{t+s}}}{U_{C_t}} \qquad (2.11)$$

where U_{C_t} is the consumer's marginal utility of consumption in period t. Given that the utility function is separable and in a logarithm form, I could have:

$$\Lambda_{t+s,t} = \beta^s \frac{C_t}{C_{t+s}} \qquad (2.12)$$

Define $\lambda_{i,t}^Y$ as the Lagrange multiplier associated with intermediate firm i's production function, $Y_{i,t} = z_t K_{i,t}^\alpha N_{i,p,t}^{1-\alpha} = \left(\frac{P_{i,t}}{P_t}\right)^{-\varepsilon} Y_t$ and $\lambda_{i,t}^K$ as the Lagrange multiplier associated with capital accumulation in period t, $K_{i,t+1} = (1-\delta)K_{i,t} + I_{i,t}$. In the Rotemberg setup, intermediate firm i sets intermediate price $P_{i,t+s}$, given aggregate price P_{t+s}, to maximize (2.10).

The first order conditions are:

$$W_t = \lambda_{i,t}^Y (1-\alpha) \frac{Y_{i,t}}{N_{i,p,t}} \qquad (2.13)$$

$$\mathrm{E}_t \left[\Lambda_{t+1,t} \frac{R_t^l}{\Pi_{t+1}} \right] = \omega \lambda_{i,t}^K \frac{I_{i,t}}{L_{i,t}} \qquad (2.14)$$

$$(1-\omega)\lambda_{i,t}^K \frac{I_{i,t}}{E_{i,t}} = 1 \qquad (2.15)$$

$$\Lambda_{t,t-1}[\alpha \, \lambda_{i,t}^Y \, \frac{Y_{i,t}}{K_{i,t}} + (1-\delta)\lambda_{i,t}^K] - \lambda_{i,t}^K = 0 \qquad (2.16)$$

$$(1 - \varepsilon)(\frac{P_{i,t}}{P_t})^{1-\varepsilon}Y_t + \varepsilon \ \lambda_{i,t}^Y(\frac{P_{i,t}}{P_t})^{-\varepsilon}Y_t + \psi(1 - \frac{P_{i,t}}{P_{i,t-1}})\frac{P_{i,t}}{P_{i,t-1}}Y_t \qquad (2.17)$$

$$= \ \mathrm{E}_t \left[\frac{\Lambda_{t+1}}{\Lambda_t}\psi(1 - \frac{P_{i,t+1}}{P_{i,t}})\frac{P_{i,t+1}}{P_{i,t}}Y_{t+1}\right]$$

In a symmetric equilibrium, all intermediate good firms are identical and they set the same price. The first order conditions above become:

$$W_t = \lambda_t^Y(1 - \alpha)\frac{Y_t}{N_{p,t}} \qquad (2.18)$$

$$\mathrm{E}_t\left[\Lambda_{t+1,t}\frac{R_t^l}{\Pi_{t+1}}\right] = \omega\lambda_t^K\frac{I_{i,t}}{L_{i,t}} \qquad (2.19)$$

$$(1 - \omega)\lambda_t^K\frac{I_t}{E_t} = 1 \qquad (2.20)$$

$$\Lambda_{t,t-1}[\alpha \ \lambda_t^Y \ \frac{Y_t}{K_t} \ + (1 - \delta)\lambda_t^K] - \lambda_t^K = 0 \qquad (2.21)$$

$$[\lambda_t^Y - \frac{(\varepsilon - 1)}{\varepsilon}] = \frac{\psi}{\varepsilon}\mathrm{E}_t\left[(\Pi_t - 1)\Pi_t - \beta\frac{C_t}{C_{t+1}}\frac{Y_{t+1}}{Y_t}(\Pi_{t+1} - 1)\Pi_{t+1}\right] \qquad (2.22)$$

There are two notes. *First*, λ_t^Y is actually the dynamic mark-up for the real wage. The greater ε leads λ_t^Y to be close to 1, shifting this model toward a standard non-differentiated good model. *Second*, given the same lending rate and the consumer's economic decisions, the ratio of loan L_t to equity E_t is the same for all the intermediate firms. It means that the financial leverage, defined by $f_t = \frac{L_t}{L_t+E_t}$, of these intermediate firms is identical.

2.3.3. Consumers

A representative consumer supplies labor for intermediate good producers and banks. She or he receives income from bond holding, savings (or deposits), equity return, and banks' profit. The consumer allocates after-tax income and previous money holding to consumption, new savings, new equity share investment, new bond holding, and new money holding. The consumer's real budget constraint in period t is:

$$
\begin{aligned}
W_t N_t &+ \frac{R_{t-1}^s S_{t-1} + R_{t-1} B_{t-1} + M_{t-1}}{\Pi_t} + (Q_t + D_t) J_{t-1} + \Gamma_t^b \qquad (2.23) \\
&= C_t + S_t + B_t + Q_t J_t + M_t + T_t
\end{aligned}
$$

where:

- W_t is the real wage;

- N_t is the aggregate labor supply;

- Γ_t^b is the real profit of banks;

- R_t^s and R_t are the returns on real savings (or deposits) S_t and real bond holdings B_t, respectively;

- D_t and Q_t are the dividend per share and the price of share, respectively;

- J_t is the firm share, a proportion of what the consumer buys at time t;

- M_t is the real money holding;

- Π_t is the gross backward inflation rate, which is equal to $\frac{P_t}{P_{t-1}}$;

- T_t is the lump-sum tax.

The consumer's utility function is:

$$U(C, M, D, B, N) = \mu_C \ln(C) + \mu_M \ln(M) + \mu_s \ln(S) + \mu_B \ln(B) - \frac{\vartheta}{2} N^2 \qquad (2.24)$$

Subject to the budget constraint, the consumer's optimization problem is:

$$\max \mathbf{E}_t \left\{ \sum_{s=0}^{+\infty} \beta^s U_{t+s} \right\} \qquad (2.25)$$

Define the equity return as $R_t^e = \frac{D_t + Q_t}{Q_{t-1}}$. Note that the period-t returns on savings and bonds are known from period (t-1) but the period-t return on equity share is only known at period 't'. Define λ_t^C as the Lagrange multiplier associated with the consumer's budget constraint in period t. The first order conditions are as follows.

$$\frac{1}{C_t} = \lambda_t^C \qquad (2.26)$$

$$\frac{1}{C_t} = \beta \mathbf{E}_t \left[\frac{Q_{t+1} + D_{t+1}}{Q_t} \frac{1}{C_{t+1}} \right] \qquad (2.27)$$

This standard Euler equation equates the marginal utility of the current consumption to the expected marginal utility of the future consumption if one unit of the current consumption is saved and invested for the consumption in the next period.

The equations for the trade-offs between assets M_t, D_t, B_t and consumption C_t in the current period are:

$$\frac{\mu_M}{M_t} = \frac{\mu_C}{C_t} - \beta \mathbf{E}_t \left[\frac{1}{\Pi_{t+1}} \frac{\mu_C}{C_{t+1}} \right] \qquad (2.28)$$

$$\frac{\mu_D}{D_t} = \frac{\mu_C}{C_t} - \beta \mathbf{E}_t \left[\frac{R_t^d}{\Pi_{t+1}} \frac{\mu_C}{C_{t+1}} \right] \qquad (2.29)$$

$$\frac{\mu_B}{B_t} = \frac{\mu_C}{C_t} - \beta \mathbf{E}_t \left[\frac{R_t}{\Pi_{t+1}} \frac{\mu_C}{C_{t+1}} \right] \tag{2.30}$$

The equation for the trade-off between working and consumption is:

$$\vartheta N_t = \frac{\mu_C}{C_t} W_t \tag{2.31}$$

The first order conditions for the representative consumer are standard. Note that the consumer has some utility from bond holding and savings[5].

2.3.4. Banks

Banks reallocate funds from the representative consumer to intermediate firms. I assume that savings are the only inflow sources banks could have[6]. My setup is to introduce the presence of a financial shock in the banking sector like a shock in the production sector. One could also see that the default risk in this chapter is endogenous and incurs some costs to banks. The financial setup here is different from others (e.g. Stracca, 2007, Calza et al., 2007, Iacoviello, 2005, Campbell et al., 2003), where a fixed proportion of borrowers' lifetime wealth is used as a borrowing limit (which is binding at the steady state and is assumed to be binding during simulation exercises).

Banks absorb a screening and monitoring cost as they need labor effort to manage loans. This cost increases with the amount of loans and financial leverage. In this

---

[5]Savings and bond holding could provide consumers some transaction service even though they can not provide as much as money does. Empirically it is true since consumer would use saving and bond holding to collateralize for some purchases. And it may be that consumers and producers agree to use saving and bonds as a partial method of payment. See Canzoneri, Cumby, Diba, and López-Salido (2006) for further extensive arguments.

[6]Practically, funds for banks would be from time deposits, checking deposits, risk-free bonds, and retained earnings. In some recent models (e.g. Canzoneri et al., 2008), banks could issue bonds. Dellas et al. (2010) model retained equity for banks.

model, the financial leverage of all intermediate firms is identical as it is dependent on economy-wide interest rates and the consumer's economic decisions.

Suppose that L_t is the real aggregate debt and $f_t = \frac{L_t}{L_t + E_t}$ is the financial leverage of the whole market. The aggregate labor effort in the banking sector is assumed to be:

$$N_{b,t} = \exp(x_t) L_t \Phi(f_t) \tag{2.32}$$

where x_t is a financial factor and $\Phi(f_t)$ to be chosen later is a function of f_t. Assume that financial factor x_t is auto-regressive of order 1 and that financial shock ϵx_t follows a normal distribution.

$$x_t = \phi_x x_{t-1} + \epsilon x_t \text{ where } \epsilon x_t \text{ is i.i.d } N(0, \sigma_x^2) \tag{2.33}$$

Assume that function $\Phi(f_t)$ satisfies:

- $\Phi(0) = 0$ - if there are no loans, banks do not need any labor effort.
- $\Phi(1) = +\infty$ - if there are mainly loans (as financial leverage limits to 1), banks would need a lot of labor effort.
- $\Phi'(f_t) > 0$ and $\Phi''(f_t) < 0$ - increasing labor effort goes along with increasing financial leverage but labor effort has decreasing marginal productivity.

I choose $\Phi(f_t) = \frac{-\ln(1-f_t)}{a}$ where 'a' is a parameter to be chosen later.

The net income of banks in period t is:

$$\Gamma_t^b = -W_t N_{b,t} - L_t + S_t + \mathbf{E}_t \left[\Lambda_{t,t+1} \frac{R_t^l L_t - R_t^s S_t}{\Pi_{t+1}} \right] \tag{2.34}$$

where:

- $\mathbf{E}_t \left[\Lambda_{t,t+1} \frac{R_t^l L_t - R_t^s S_t}{\Pi_{t+1}} \right]$ is the expected net return on making loans and paying off deposits in the next period;

- $W_t N_{b,t}$ is the labor cost of banking business in period t.

- $-L_t + S_t$ is the net money of loans and savings in period t.

The optimization problem for banks in period t is:

$$\max \Gamma_t^b \tag{2.35}$$

subject to a balance sheet constraint:

$$S_t = L_t \tag{2.36}$$

The balance sheet constraint holds because it assumes that time deposits are the only sources of funds for banks and that banks have no retained earnings. Banks would make loans by using all savings. And $\Lambda_{t+j,t}$ is the stochastic discount factor, derived from the consumer's optimization problem and also used in the intermediate firms' optimization problem. The first order condition for banks' optimization problem is:

$$R_t^l = R_t^s + \exp(x_t) W_t \Phi(f_t) \mathbf{E}_t \left[R_{t+1}^e \right] \tag{2.37}$$

This equation of loan supply has one important interpretation. If there is no costly financial market friction, that is, $exp(x_t) \simeq 0$ or $\Phi(f_t) = 0$, lending rate R_t^l must be equal to deposit rate R_t^s. In this case, banks perfectly reallocate loans from consumers to intermediate firms without any cost.

The bank spread is defined as the difference between the lending interest rate and the time deposit (or savings) interest rate:

$$spread_t = \exp(x_t)W_t\Phi(f_t)\mathrm{E}_t\left[R_{t+1}^e\right] \tag{2.38}$$

This bank spread is equal to the marginal cost of loan monitoring multiplied by the opportunity cost of equity investment. Note that $spread_t$ contains broad information about the status of the whole economy via the dynamic changes of x_t in the financial market, W_t and R_{t+1}^e in the production sector, and the practices of risk rating via $\Phi(f_t)$.

2.3.5. Government expenditure and monetary policy

I employ standard structures of a Taylor-style monetary policy rule and a government expenditure rule. The monetary authority implements monetary policy by following a standard rule:

$$\ln(\frac{R_t}{R^*}) = \phi_r\ln(\frac{R_{t-1}}{R^*}) + \phi_\Pi\ln(\frac{\Pi_t}{\Pi^*}) + \phi_Y\ln(\frac{Y_t}{Y^*}) + \epsilon r_t \tag{2.39}$$

where R^*, Π^*, Y^* are the steady state values of the policy interest rate, inflation rate, and output and ϵr_t is a monetary shock which follows an i.i.d $N(0, \sigma_{\epsilon r}^2)$.

The government uses a fiscal rule:

$$\ln(\frac{G_t}{G^*}) = \phi_G\ln(\frac{G_{t-1}}{G^*}) + \phi_B\ln(\frac{B_{t-1}}{B^*}) + \epsilon b_t \tag{2.40}$$

where G^*, B^* are the steady state values of the government expenditure and the risk-free bond and ϵb_t is a fiscal shock which also follows an i.i.d $N(0, \sigma_{\epsilon b}^2)$. I use an empirical data set to estimate the monetary rule and the fiscal rule. Details of the estimation are in Appendix B.4.

The government budget constraint is:

$$\frac{R_{t-1}B_{t-1} + M_{t-1}}{\Pi_t} + G_t = B_t + M_t + T_t \tag{2.41}$$

2.3.6. Market equilibrium

An equilibrium is a state of the model economy where:

- Final good firms minimize their final good production cost given the prices of intermediate goods;
- Intermediate good firms maximize their profit given the labor wage, the aggregate price and the interest rates;
- Consumers maximize their expected discounted life-time utility given the real wage, the bond return, the equity return, the aggregate price, and the interest rates;
- Banks maximize their profit given the labor wage and the interest rates
- All the markets are clearing:
  - The final goods market is clearing:

$$C_t + G_t + L_t + E_t + \frac{\psi}{2}(\Pi_t - 1)^2 Y_t = Y_t \tag{2.42}$$

  - The labor market is clearing:

$$N_t = N_{b,t} + N_{p,t} \tag{2.43}$$

  - The equity market is clearing:

$$J_t = 1 \tag{2.44}$$

2.4. Results

In this section, I use two models: the current model economy as the benchmark model and a standard New Keynesian model. The detailed structure of the standard model is in Appendix B.1. There are two key differences between them. First, while the benchmark model contains a costly financial market, the standard model excludes it. Second, the consumer in the benchmark model has utility of savings while the consumer in the standard model does not. I focus on the benchmark model and compare its performance to the other. I also construct a sticky lending rate structure, which is used in the analyses of a financial shock. The details of this sticky lending rate structure are in Appendix B.2.

2.4.1. Remarks

Remark 2.1. *In every state of the benchmark model economy, banks have zero profit.*

Proof. See Appendix B.5 □

This remark is understandable since the banking sector in this chapter is perfectly competitive. Therefore, banks should have zero profit.

2.4.2. Parameters

<table>
<caption>Table 2.2. Parameters</caption>

Production	ε	α	δ	ω	ψ	ϕ_z	$\sigma^2_{\epsilon z}$
	8	0.3	0.025	0.55	20	0.945	$4.46*10^{-5}$
Consumer	μ_C	μ_M	μ_B	μ_S	ϑ	β	
Benchmark	1	0.25	0.0105	0.0025	1	0.9832	
Standard	1	0.25	0.0105		1	0.9832	
Banks	a	ϕ_x	$\sigma^2_{\epsilon x}$	$\rho_{\epsilon z,\epsilon x}$			
	170	0.95	$4.46*10^{-5}$	0.5			
Monetary Policy	ϕ_R	ϕ_Π	ϕ_Y	$\sigma^2_{\epsilon r}$			
	0.841	0.151	0.07	$1.1*10^{-5}$			
Fiscal Policy	ϕ_G	ϕ_B	$\sigma^2_{\epsilon b}$				
	0.758	-0.018	$6*10^{-5}$				

</table>

ε	Elasticity of substitution across differentiated goods
α	Proportion of capital income in production function
ω	Proportion of equity income in investment production
ψ, δ	Menu-cost coefficient, depreciation rate
$\phi_z, \sigma^2_{\epsilon z}$	Productivity shock coefficients
$\beta, \mu_C, \mu_M, \mu_{B,} \mu_S, \vartheta$	Discount factor and coefficients of utility from C, M, B, S, N,
a	Banking labor cost function coefficient
$\phi_x, \sigma^2_{\epsilon x}, \rho_{\epsilon z,\epsilon x}$	Financial shock coefficients
$\phi_R, \phi_\Pi, \phi_Y, \sigma^2_{\epsilon r}$	Monetary rule coefficients
$\phi_G, \phi_B, \sigma^2_{\epsilon b}$	Government spending rule coefficients

Criteria	Benchmark model	Benchmark model with OSR- bank spread rule	Empirical data
R (Standard Error)	1.0061 (0.0037)	1.0061 (0.0036)	1.0061 (0.0088)
R^l (Standard Error)	1.0115 (0.0005)	1.0115 (0.0006)	1.0115 (0.0080)
R^s (Standard Error)	1.0063 (0.0004)	1.0063 (0.0005)	1.0063 (0.0084)
R^e (Standard Error)	1.0171 (0.0091)	1.0171 (0.0069)	1.0171 (0.0874)
$ln\Pi$ (Standard Error)	0 (0.0484)	0 (0.0037)	0 (0.0062)
Corr(R^l,spread)	0.6281	0.6977	0.0405
Corr(R^s,spread)	0.5423	0.6319	-0.3062(*)
Corr(R,spread)	-0.1275	-0.2168	-0.2045 (*)
Corr(R,R^l)	0.3444	0.2353	0.9592(*)
Corr(R,R^s)	0.3892	0.2812	0.9857(*)
Corr(R,R^e)	0.0650	-0.1571	-0.2072(*)
Corr(lnC,lnY)	0.3110	0.4250	0.6769(*)
SE(lnY)	0.0082	0.0087	0.0152
SE(lnC)	0.0026	0.4172	0.0128

Table 2.3. Benchmark model versus empirical data

R - effective Fed-funds rate; R^l - three-month prime rate; R^s is three-month deposit rate; R^e - equity return; C - consumption; Y - GDP; G - government spending; spread= R^l-R^s

SE-standard error; (*) means significant at level of 5%.

All variables but interest rates and returns are in logarithm form.

To calibrate parameters, I use some sources of data and techniques of data processing. The details of data and data processing are in Appendix B.3. The details of the

parameterization process are in Appendix B.4. Using the empirical data, I estimate the parameters for the monetary policy rule and the fiscal rule. I also pick up some standard values in the literature of the New Neoclassical Synthesis framework. Table 2.2 summarizes the values of parameters used in calibration.

Table 2.3 checks some simulation statistics from the benchmark model versus the empirical data. At some degree, the benchmark model is quite consistent with the empirical data. The correlation of consumption and output are positively significant. Interest rates are strongly related as well. The correlation of the bank spread and the effective Fed-funds rate is close to its empirical value. However, the correlations related to market return do not fit and the correlations of the bank spread and the lending rate and the savings rate are too high in the benchmark model.

2.4.3. Comparison: benchmark model versus standard model

There are two methods to see the effects of one component in a model. One method is to keep the same parameters and examine how this component affects the outcomes of the model. The other is to use a different set of parameters, which maintain some fixed criteria for each case. While the latter method is often used to check how well a model mimics observed facts, the former is used to claim how important the component is. I follow the first method[7].

As said above, the first issue of this chapter is to examine how a costly financial market could change effects of normally-studied shocks on economic variables. I use

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[7]I actually calibrate two parameter sets, one for each model, in order to fit some macroeconomic criteria. Then I calibrate each model with its own parameter set. Two models generate close responses to a shock except consumption and market return. It means that even though I intend to mimic empirical facts in both models, their responses to a shock are still different. However, since I do not intend to set up a model in order to completely fit empirical data, such a comparison is just for further references. My intention is to set up a model to show how monetary policy responds to a financial disturbance.

three criteria: impulse response functions, variance decomposition and the cost of price rigidity. Costly financial intermediaries make the performances of the two models different.

2.4.3.1. Impulse responses

Figures 2.5, 2.6, and 2.7 show the impulse responses of output, inflation, consumption, investment, interest rates, and market return to three types of shocks: monetary shock, fiscal shock and productivity shock. The directions of these responses in both the benchmark and standard models are quite conventional.

Interestingly, while a positive monetary shock in the standard model has a stronger effect on the policy rate, the benchmark model observes higher volatility of all the other variables. In the benchmark model, due to lower investment, output, consumption and inflation are lower as well.

A fiscal shock shows that the benchmark model owns stronger volatility of the responses of macroeconomic variables. In this model, that the production sector is partially dependent on loans shows a stronger crowding-out effect as the response of investment is stronger. As a result, the increase of consumption in the benchmark model is less than in the standard model. However, in the benchmark model, output, market return and inflation are more consistently responsive to a fiscal shock.

A positive productivity shock in the benchmark model has a smaller effect on output. As a result, the benchmark model has smaller responses of consumption, inflation, and market return.

Figure 2.5. Model impulse responses to a monetary shock
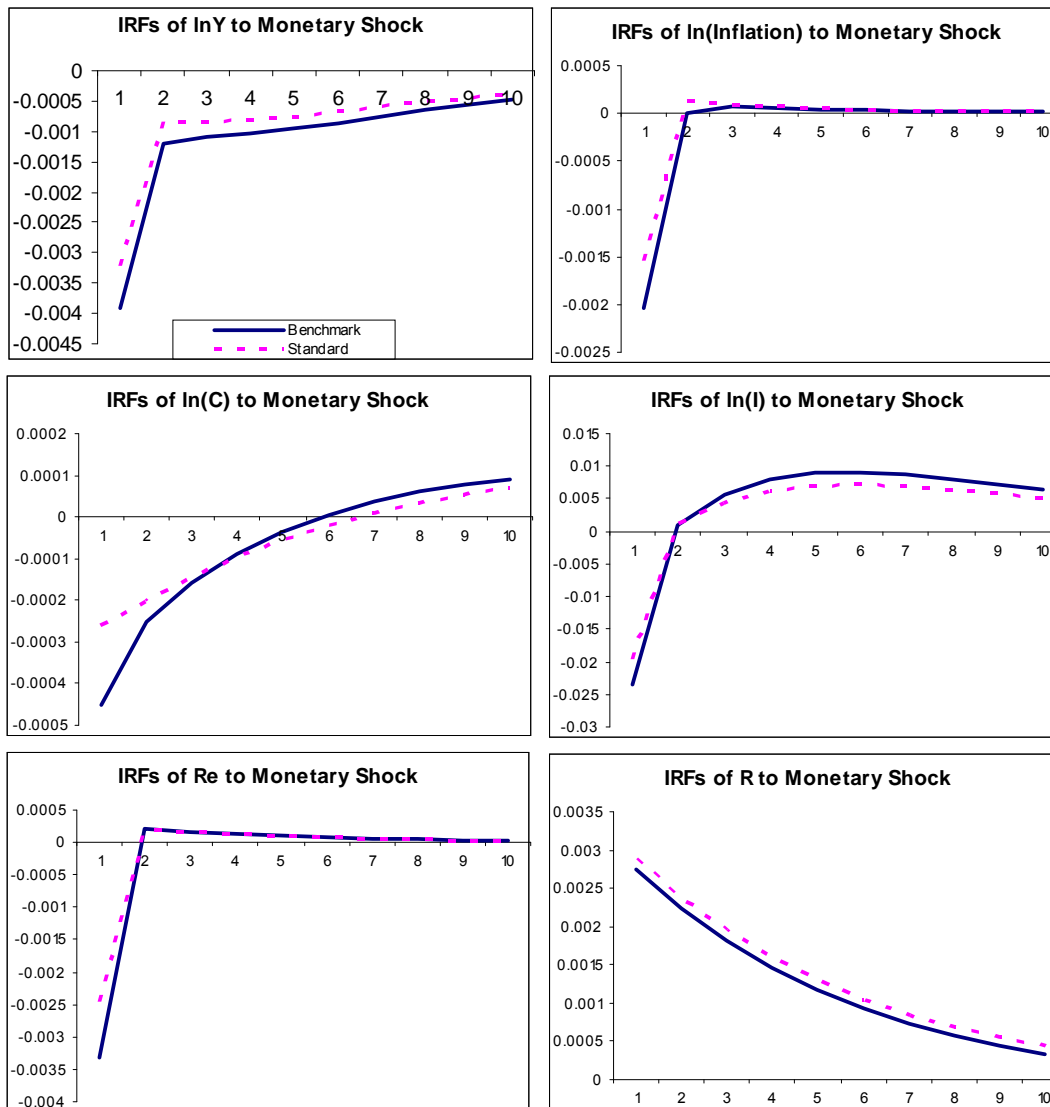
Y as output. C as consumption. I as investment.

Re as market return. R as policy interest rate.

Benchmark: Model with a costly financial market

Standard: Model without a financial market

Figure 2.6. Model impulse responses to a fiscal shock

Y as output. C as consumption. I as investment.

Re as market return. R as policy interest rate.

Benchmark: Model with a costly financial market

Standard: Model without a financial market

Figure 2.7. Model impulse responses to a productivity shock
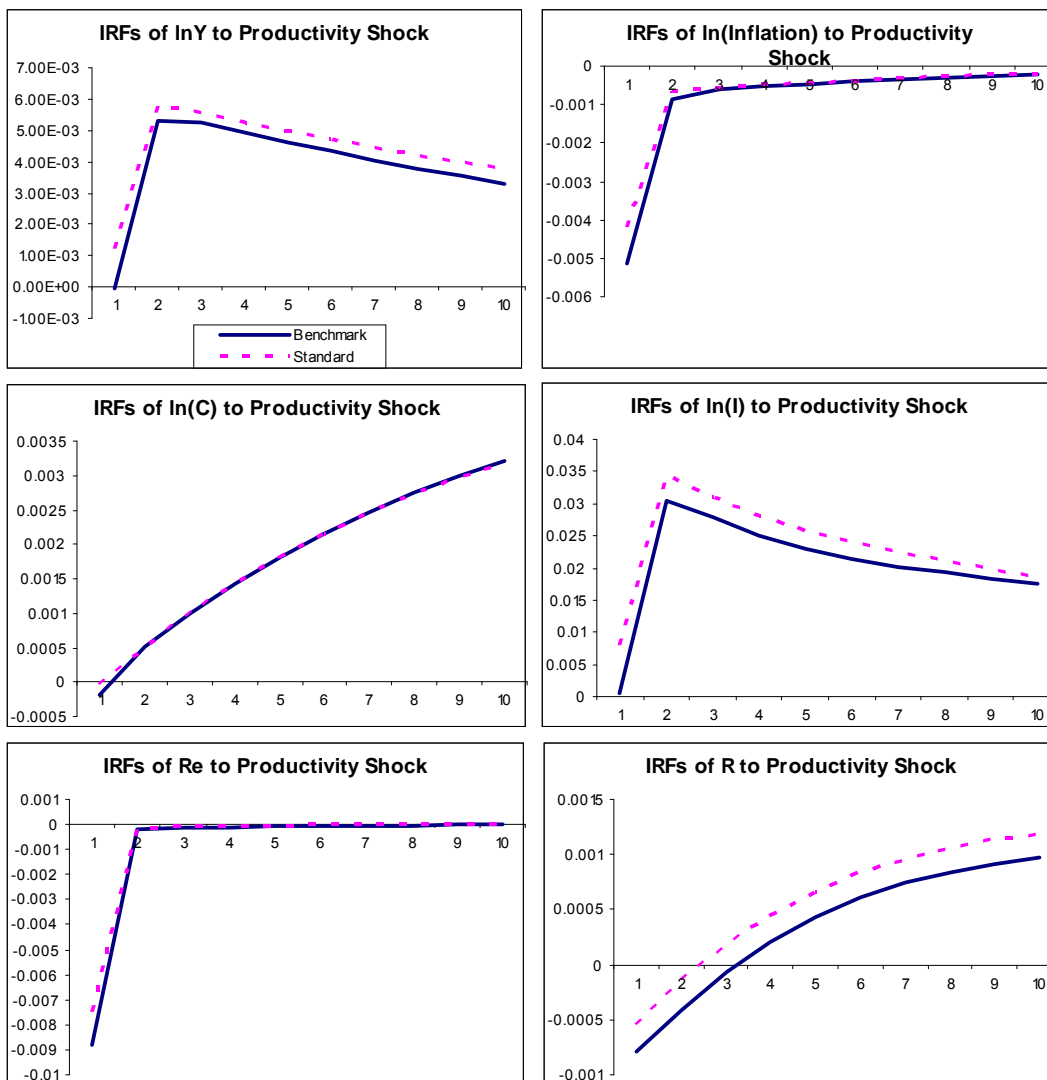
Y as output. C as consumption. I as investment.

Re as market return. R as policy interest rate.

Benchmark: Model with a costly financial market.

Standard: Model without a financial market

In summary, the addition of banks to a monetary model could change the effects of a normally studied shock on some economic variables.

2.4.3.2. Variance decomposition

Table 2.4. Variance decomposition							
	Benchmark Model				Standard Model		
Shock	ϵ_R	ϵ_G	ϵ_Z	ϵ_X	ϵ_R	ϵ_G	ϵ_Z
R	83.05	0.59	16.36	0	85.89	0.33	13.79
R^e	12.89	1.20	85.91	0	10.15	1.14	88.71
$\ln(\Pi)$	14.37	1.40	84.23	0	13.11	1.24	85.64
$\ln(Y)$	20.56	2.44	76.99	0	14.27	1.55	84.18
$\ln(I)$	35.67	4.70	59.63	0	24.00	3.13	72.87
$\ln(C)$	4.25	0.06	95.69	0	2.12	0.08	97.79

Benchmark Model				
Shock	ϵ_R	ϵ_G	ϵ_Z	ϵ_X
R^l	37.77	2.39	59.32	0.51
R^s	42.78	3.07	54.14	0.00
spread	12.36	1.48	50.59	35.57

No saving rate and lending rate in the simple standard model. Table 4, lower part, shows how important a financial shock is to financial sector (spread), consumers (R^s) and producers (R^l). Monetary rule: estimated monetary rule.

Table 2.4 reports the variance decomposition of some main macroeconomic variables. The two models agree with the conventional wisdom that a productivity shock is a main source of economic fluctuations and a fiscal shock does not contribute much to these fluctuations.

However, the benchmark model shows a larger role of a monetary shock in the variances of all variables except the policy interest rate. In addition, financial disturbances slightly account for the variance of the lending interest rate and significantly contribute to the variance of the bank spread. Both the lending interest rate and the bank spread are important variables and are not available in the standard model. It means that the role of a financial factor in economic fluctuations may be important.

2.4.3.3. Welfare loss

This criterion compares the welfare cost of price rigidity of the two models above. The welfare of the whole society is the expected life-time utility of the representative consumer. Define V_t as the value function for the aggregate welfare of the representative consumer in period t. From a periodic utility function $U_t(C_t,M_t,S_t,B_t,N_t)$, V_t is recursively given by:

$$V_t(\psi) = U_t + \beta \mathbf{E}_t V_{t+1}(\psi) \tag{2.45}$$

where ψ is the coefficient of the menu cost for the intermediate firms.

In this section, I use Dynare to approximate V_t at the second order under four values of ψ : $\{0;\ 10;\ 20;\ 40\}$. If ψ is equal to 0, the intermediate firms do not suffer any menu cost and the whole economy is under the flexible price framework. In the benchmark model, I set ψ to be 20. Assuming that the whole economy starts from the deterministic steady state. $V_0(\psi)$ is the aggregate utility of the consumer in period 0 given menu cost parameter ψ. The welfare cost is defined as:

$$WL_0(\psi) = V_0(0) - V_0(\psi) \tag{2.46}$$

$WL(\psi)$ is a cardinal number and it needs interpretation. Following Lucas (2003) and Canzoneri et al. (2007), $WL(\psi)$ could be interpreted in terms of the percentage of consumption that the representative consumer wants to add to his/her consumption every period in order to get the same utility under the flexible price framework, assuming that the other variables in the utility function are unchanged.

To see it, define ξ as a fraction of consumption the representative consumer wants to add to periodic consumption in the benchmark model to get the same aggregate utility under the flexible price framework:

$$V_0(0) = \mathbf{E}_0 \sum_{t=0}^{\infty} \beta^t U_t(C_t^0, M_t^0, S_t^0, B_t^0, N_t^0) = \mathbf{E}_0 \sum_{t=0}^{\infty} \beta^t U_t((1+\xi)C_t, M_t, S_t, B_t, N_t)$$

(2.47)

where $C_t^0, M_t^0, S_t^0, B_t^0, N_t^0$ are state variables in period t when there is no menu cost $(\psi = 0)$ and C_t, M_t, S_t, B_t, N_t are state variables in period t in the benchmark model.

Note that the utility function is separable with consumption in the logarithm. The equation above could be rewritten as:

$$V_0(0) = \mathbf{E}_0 \sum_{t=0}^{\infty} \beta^t U_t((1+\xi)C_t, M_t, S_t, B_t, N_t) = \frac{\mu_C \, \xi}{1-\beta} + \mathbf{E}_0 \sum_{t=0}^{\infty} \beta^t U_t(C_t, M_t, S_t, B_t, N_t)$$

$$V_0(0) = \frac{\mu_C \, \xi}{1-\beta} + V_0(\psi)$$

After transforming some factors in the equation above, the welfare loss is now given by:

$$WL_0(\psi) = V_0(0) - V_0(\psi) = \frac{\mu_C \, \xi}{1-\beta} \tag{2.48}$$

As I use $\beta = 0.9832$, the welfare loss above becomes:

$$\frac{1.168}{\mu_C} WL_0(\psi) = \frac{1.168}{\mu_C} [V_0(0) - V_0(\psi)] = 100\xi$$

$\frac{1.168}{\mu_C} WL_0(\psi)$ is interpreted as the percentage of consumption that the consumer wants to have more each period in order to get the same welfare as under the flexible price framework. I apply the method above to the benchmark model and the standard model.

Table 2.5. Cost of price rigidity: welfare loss		
Menu cost coefficient	Standard Model	Benchmark Model
10	0.0426	0.0597
20	0.0772	0.1065
40	0.1295	0.1742

Table 2.5 presents some estimates of the cost of price rigidity for three non-zero values of menu cost coefficient ψ under the estimated monetary rule (Appendix B.4). If the coefficient of menu cost increases, the welfare loss of price rigidity in both models increases. However, this table projects that financial intermediaries affect and increase the cost of price rigidity.

2.4.4. Financial shock

This section focuses on the effects of a financial shock on economic variables. I pay attention to two aspects: the impulse responses of economic variables to a financial shock and a set of economic indicators to identify this shock. I also examine how a

sticky lending rate structure changes the effects of this shock. The details of a sticky lending rate structure are in Appendix B.2.

2.4.4.1. Effects of a financial shock

Figure 2.8. Model impulse responses to financial shock

Y as output. C as consumption. S as saving. I as investment.

Rl as lending rate. Re as market return. Rs as saving rate. R as policy rate.

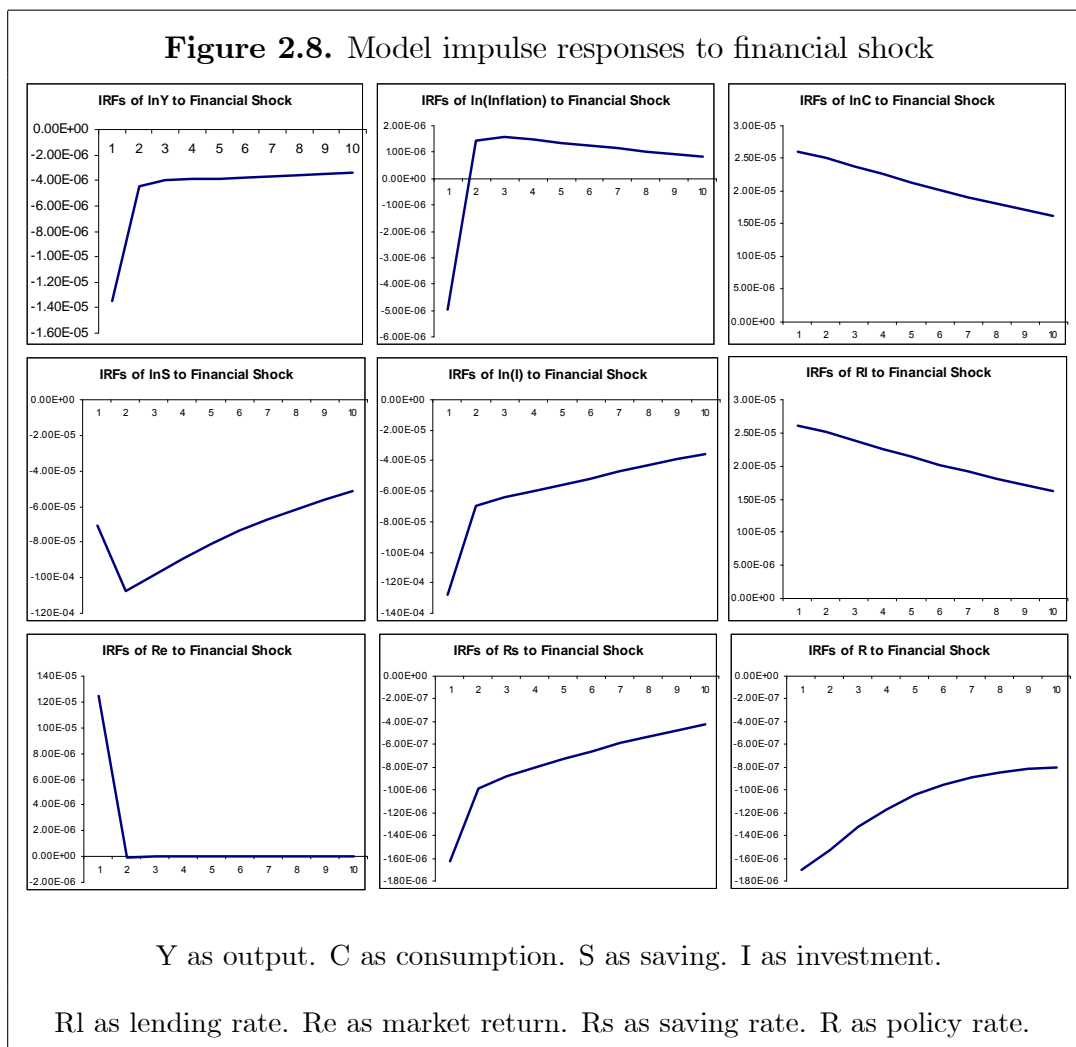Figure 2.8 reports the impulse responses of some main economic variables to a financial shock in the benchmark model. Generally, a direct channel of effects comes from the transmission between two sources of labor demand: the labor demand in the production sector and the labor demand in the financial sector. A financial shock increases labor in the banking sector and decreases labor in the production side. On

the other hand, as an indirect channel, this shock shifts the loan supply to the left, increasing the lending rate and decreasing the amount of loans supplied. A lower amount of loans would require a lower amount of banking labor effort. In aggregation, the labor effort in both the production and banking sectors decreases but the marginal cost in terms of labor effort per unit of loans increases. This means that the bank spread increases. That investment is lower implies the lower aggregate demand, which reduces both inflation and output.

A lower supply of loans would force firms to substitute retained earnings for bank loans to produce new investments. Furthermore, the marginal product of capital is higher. Therefore, the future market return goes up. The income effect from market return increases consumption while the income effect from lower savings reduces consumption. In general, the aggregate income effect may increase or decrease consumption.

I consider a sticky lending rate structure in the banking system. This structure adds stronger effects of a financial shock on the savings rate. As the lending rate is relatively more sluggish than the deposit rate, banks need to reduce the savings rate further to compensate the increasing cost from a positive financial shock. In general, these two structures (with or without a sticky lending rate) of the banking system do not make the responses of main economic variables much different but both confirm that a financial shock could affect main economic variables at large[8].

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[8]Since the addition of a sticky lending rate framework to the benchmark model does not change the qualitative analyses, I would like to skip further analyses of this framework. Quantitative changes are the volatility of the lending rate and the savings rate and a more negative correlation of bank spread and the policy interest rate. The detailed results are available upon request.

2.4.4.2. Bank spread as an economic indicator

Observation 2.1. *Suppose a shock is a monetary or financial shock. If the bank spread and the policy rate are in opposite directions, a shock is possibly a monetary shock. Otherwise, a shock is possibly a financial shock.*

Observation 2.2. *In consideration of all four types of shocks, if the savings rate and the lending rate are in opposite directions, there is a financial shock.*

Observation 2.3. *Based on interest rates and the bank spread, it is indeterminate to identify a fiscal shock or a productivity shock. Both inflation and output should be used to distinguish these two shocks.*

Table 2.6. Interest rates and the bank spread				
Benchmark Model				
A positive shock	R	R^s	R^l	$Spread = R^l - R^s$
Monetary shock ϵ_R	↑	↑	↑	↓
Productivity shock ϵ_Z	↓	↓	↓	↓
Fiscal shock ϵ_G	↑	↑	↑	↑
Financial ϵ_X	↑	↓	↑	↑

Table 2.6 reports the directions of shock effects on interest rates and the bank spread. Consistent with the results from the empirical VAR model[9], both empirical and theoretical findings confirm that the opposite directions of the effective Fed-funds rate and the bank spread serve as a signal for a monetary shock. Given that there is a

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[9]Note that in the VAR model, I use the logarithm form of the spread, the difference between the prime rate and the savings rate. Therefore, my empirical finding is consistent with the structure of the model where I propose that the spread in the benchmark model contains the information of a financial shock.

monetary shock or financial shock, the co-movement of the bank spread and the policy rate is a signal for a financial shock. Theoretically, like Observation 1.1 in Chapter 1, it is also possible to use the lending rate and the bank spread in order to distinguish a financial shock from a monetary one.

Simultaneously, taking all four shocks into account, a positive fiscal shock or a negative productivity shock could generate the same directions of interest rates and the bank spread as a financial shock. Therefore, one needs additional information of inflation and output to identify these two shocks. In addition, the opposite directions of the savings and lending rates clearly signal financial disturbances.

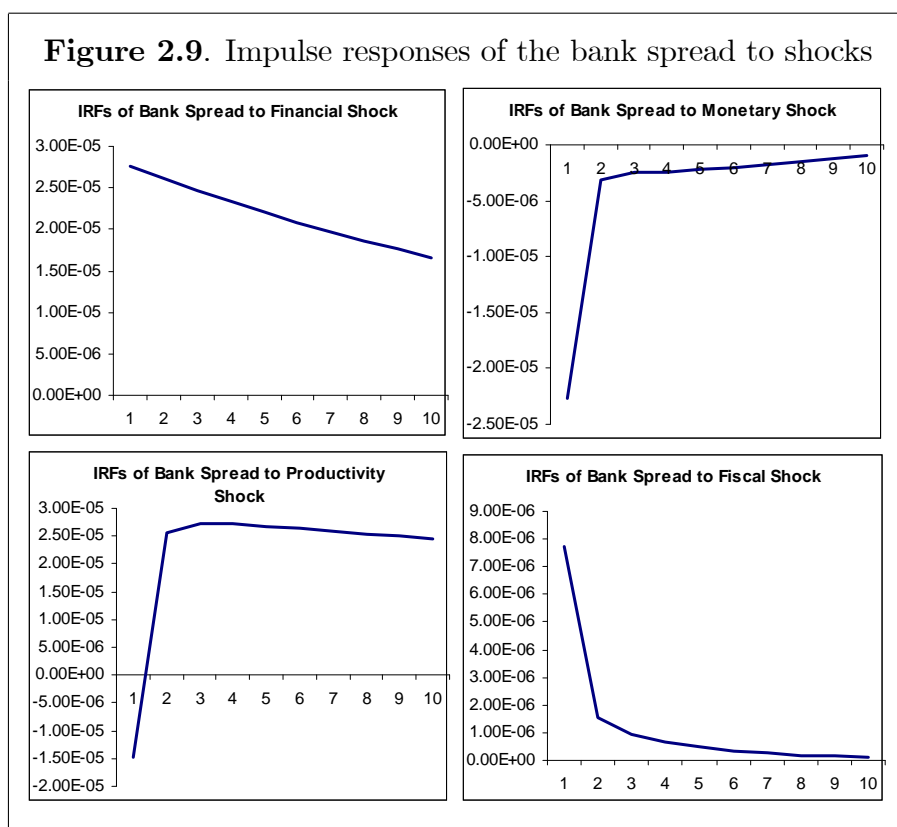**Figure 2.9**. Impulse responses of the bank spread to shocks

Figure 2.9 also reports the impulse responses of the spread to four types of shocks. All four shocks have large effects on the bank spread. The variance decomposition

(Table 2.4) also reveals that a financial shock accounts for a large part of the variation of the bank spread.

Let's take a look at the bank spread:

$$spread_t = R_t^l - R_t^s = R_{t+1}^e x_t W_t \Phi(f_t) \tag{2.49}$$

There are three important points that the bank spread implies. *First*, the bank spread reflects a financial shock in x_t. This shock would increase the spread to compensate for an increasing labor cost. *Second*, the spread is connected with equity return. It measures the relative equivalence of one unit of funds used in the banking sector and in equity investment. *Third*, the spread contains information about financial structure in terms of risk rating. In this model, increasing the value of the risk-rating function $\Phi(f_t)$ at each level of financial leverage would increase the labor cost for the banking business.

Therefore, the bank spread can be a good economic indicator due to a crucial reason: the spread contains information about the status of the financial market. Kashyap et al. (1993) argue that the spread between the short-term commercial paper rate and the risk-free interest rate should be a good indicator for the status of an economy since firms issue short-term commercial papers more easily than borrow short-term loans from banks. Bernanke (1992) notes that some interest rate spreads in the money market could be good candidates for economic indicators. Cúrdia et al. (2009) claim that the credit spread contains information about shocks to patience rate and financial intermediaries.

This chapter has a different result from Kashyap's. I use the bank spread, an interest rate spread from the banking sector and show that the bank spread goes down

under a positive monetary shock. In Kashyap et al. (1993), the spread between the commercial paper rate and the policy rate should increase under a positive monetary shock. A possible explanation is that the commercial paper rate increases at a faster speed than the policy rate right after a positive monetary shock. This is true if firms suddenly face a change in funds and need funds to support production activities in a very short term. The prime rate used in this chapter goes up at a lower speed than the policy rate since this prime rate is quite consistent overtime for a firm even under an adverse monetary shock.

Bank spread in this chapter is also different from the spread implied by Taylor et al. (2010), Bernanke (1992) and Cúrdia et al. (2009) where the interest rate spread is the difference between the lending rate and the policy rate. In the benchmark model, the bank spread is banks' interest rate margin. Since banks respond to a financial shock from both inflow and outflow funds by changing their savings and lending interest rates in opposite directions, the bank spread is, therefore, a better representative for a financial shock than the credit spread by some other scholars.

In general, the bank spread is a good proxy for a financial shock as it contains much information concerning this shock. In addition, the interactions among the bank spread and interest rates help identify which type of shocks the whole economy is facing. It is particularly useful for a monetary shock and a financial shock. Output and inflation are additionally needed to identify a productivity shock and a fiscal shock.

2.4.5. Monetary policy

In this sub-section, I calibrate optimal simple rules with the bank spread or the asset price to minimize the welfare loss function in equation (2.48) under the standard value of the menu cost coefficient ψ in Table 2.2.

2.4.5.1. Monetary rules with bank spread

Recent papers (Faia et al., 2008, Calza et al., 2007 and Bernanke et al., 2001) recommend that a monetary rule should respond to financial shocks even though the response level is small. However, it is not easy to observe a financial shock. In the benchmark model, I show that the bank spread contains the information concerning a financial shock. Therefore, a response to the bank spread implies a response to a financial shock. A monetary rule indirectly responsive to the bank spread is more practical than a rule directly responsive to a financial shock.

I use Dynare to compute an optimal simple rule, which is supposed to be responsive to the previous policy rate, current inflation, current output and the bank spread. I modify the standard monetary rule (Eq. 2.39) by the following rule:

$$\ln(\frac{R_t}{R^*}) = \phi_r \ln(\frac{R_{t-1}}{R^*}) + \phi_\Pi \ln(\frac{\Pi_t}{\Pi^*}) + \phi_Y \ln(\frac{Y_t}{Y^*}) + \phi_{spread} \ln(\frac{spread_t}{spread^*}) + sr_t \quad (2.50)$$

An optimal simple monetary rule is one of the rule (Eq. 2.50) based on coefficients ϕ_r, ϕ_Π, ϕ_Y, ϕ_{spread} in order to minimize welfare loss function $WL_0(\psi)$ (Eq. 2.48). To compare monetary rules and see a clearer picture of an optimal simple rule within a costly financial market, I fix coefficients ϕ_r, ϕ_Π, and ϕ_Y as in the estimated monetary rule (Appendix B.4). Then I find the optimal response of the monetary rule (Eq. 2.50) to the bank spread.

Table 2.7 presents results of the optimal simple monetary rule and it reveals one crucial implication: the monetary authority should respond negatively to the bank spread. This direction of response is understandable since a financial shock increases

the lending interest rate. The monetary authority, therefore, needs to decrease the policy rate in order to reduce the lending rate and stimulate the economy.

Table 2.7. Optimal simple monetary rule				
Benchmark Model				
Menu cost coefficient	ϕ_r	ϕ_Π	ϕ_Y	ϕ_{spread}
$\psi = 20$	0.841	0.151	0.07	-0.016

This simple monetary rule with the bank spread is consistent with Cúrdia et al. (2009) that an optimal monetary rule partially responds to the credit spread. It is also consistent with Calza et al. (2007) and Stracca (2007) since a negative response to the bank spread implies a negative direct response to a financial shock. It is also consistent with Taylor and Williams (2010) in terms of the dynamics of spreads in the money market even though I use a different interest rate spread.

I also check how well the optimal simple monetary rule (Eq. 2.50) with the coefficients in Table 2.7 shifts the benchmark model to fit empirical findings and how it affects the cost of price rigidity. Column 3 of Table 2.3 reports that inflation and interest rates are less volatile and the correlation between the bank spread and the policy interest rate is more negative. Table 2.8 compares the variance decomposition of some variables in the benchmark model under two different monetary rules.

Interestingly, the rule with the bank spread attributes a larger role of a financial shock as well as a monetary shock. Since this rule reduces the variances of output and inflation, it also implicitly reduces the cost of price rigidity. Table 2.10 shows that the welfare loss of price rigidity is very small, about 0.03 percent if the current monetary rule negatively responds to the bank spread.

Table 2.8. Variance decomposition under monetary rule with the bank spread

$$\phi_r = 0.841, \ \phi_\Pi = 0.151, \ \phi_Y = 0.07, \ \phi_{spread} = -0.029$$

Shock type								

| | Benchmark Model | | | | | | | |
| | Estimated monetary rule | | | | Monetary rule with the bank spread | | | |
Shock type	ϵ_R	ϵ_G	ϵ_Z	ϵ_X	ϵ_R	ϵ_G	ϵ_Z	ϵ_X
R	83.05	0.59	16.37	0.00	94.36	0.40	3.40	1.84
R^e	12.89	1.20	85.91	0.00	25.66	2.42	64.25	7.66
R^s	42.78	3.07	54.14	0.00	35.18	2.34	51.55	10.93
R^l	37.77	2.39	59.32	0.51	31.10	1.82	52.96	14.12
spread	12.36	1.48	50.59	35.57	13.02	1.56	34.21	51.21
$\ln(\Pi)$	14.37	1.40	84.23	0.00	32.52	3.23	51.65	12.60
$\ln(Y)$	20.56	2.44	76.99	0.00	20.87	2.47	71.71	4.95
$\ln(I)$	35.67	4.70	59.63	0.00	31.92	3.54	59.33	5.22
$\ln(C)$	4.25	0.06	95.69	0.00	5.07	0.08	92.38	2.47

2.4.5.2. Monetary rules with asset price

In this subsection, I provide a framework which shows a close relationship between the bank spread and the asset price. Therefore, an investigation of the optimal monetary policy involved with the asset price would be somewhat equivalent to one involved with the bank spread. From equity return, R_t^e, and the bank spread, $spread_t$, I have:

$$spread_t = \frac{(D_{t+1} + Q_{t+1})}{(Q_t/\Pi_{t+1})} x_t W_t [\frac{-\ln(1 - f_t)}{a}] \tag{2.51}$$

Note that the financial leverage is related to the market return, the lending rate and the asset price. In this benchmark model, the relation between the spread and the asset price is not linear and their correlation is positive 0.3. However, the asset price and the bank spread have different directions of responses to fiscal and productivity shocks[10]. So that an optimal simple monetary rule responsive to the bank spread could mean some degree of response to the asset price.

First, I take all the coefficients, except the one of the bank spread, in the optimal simple rule (Eq. 2.50). I just replace the bank spread by the asset price. Second, I search the coefficient of the asset price in order to minimize welfare loss function $WL(\psi)$ in equation (2.48). A rule with the asset price is as follows:

$$\ln(\frac{R_t}{R^*}) = \phi_r \ln(\frac{R_{t-1}}{R^*}) + \phi_\Pi \ln(\frac{\Pi_t}{\Pi^*}) + \phi_Y \ln(\frac{Y_t}{Y^*}) + \phi_Q \ln(\frac{Q_t}{Q^*}) + sr_t \qquad (2.52)$$

Table 2.9. Estimated monetary rule with the asset price

Benchmark Model				
Menu cost coefficient	ϕ_r	ϕ_Π	ϕ_Y	$\phi_{asset\ price}$
$\psi = 20$	0.841	0.151	0.07	-0.087

Table 2.9 reports the coefficient of the asset price, ϕ_Q, to be about -0.087. To compare the monetary rule with the bank spread and the rule with the asset price, I use the impulse response functions and the cost of price rigidity.

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[10]Their impulse responses to shocks under a standard monetary rule in the benchmark model are available upon request.

Figure 2.10. Impulse responses of output and inflation

OSR-Bank Spread: Optimal simple rule responds to the bank spread,

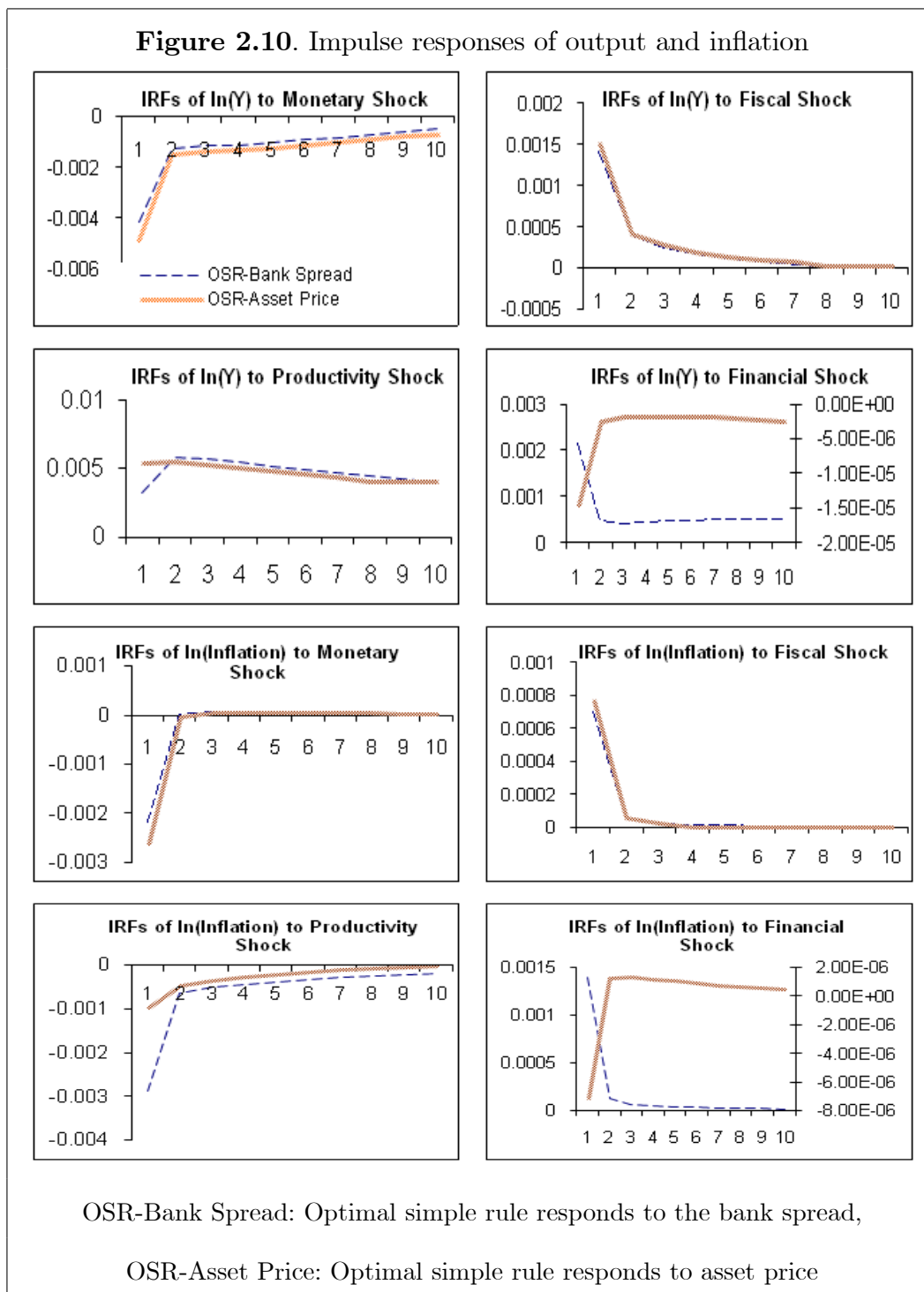OSR-Asset Price: Optimal simple rule responds to asset price

Figure 2.10 reports the responses of output and inflation to four types of shocks

under two monetary rules: the optimal simple rule with the bank spread (OSR- bank

spread) and the optimal simple rule with the asset price (OSR - asset price). These two rules do not give identical responses under normally studied shocks even though these responses are conventional.

Importantly, the responses of output and inflation to a financial shock are totally different. While the optimal simple rule with the bank spread responds to a financial shock by quickly reducing the policy rate. This would outweigh the effects of a financial shock and increase both inflation and output. The rule with the asset price are not strong enough to overturn both inflation and output into the positive zone.

Table 2.10. Cost of price rigidity: welfare loss	
Benchmark Model	
Estimated rule	0.1065
OSR - bank spread	0.0386
OSR - asset price	0.0609

In terms of the cost of price rigidity, Table 2.10 says that the monetary rule with the bank spread is better than the monetary rule with the asset price. A possible explanation is that the bank spread contains more information about a financial shock than the asset price since this shock arises from the banking sector.

Generally, there is no linear transmission from the bank spread to the asset price. To some degree, a monetary policy rule responsive to the asset price would be similar to one responsive to the bank spread. However, these two rules could generate different responses of output and inflation to a financial shock.

2.5. Conclusion

I construct a menu-cost model with financial intermediaries, so called the benchmark model. The benchmark model incorporates some characteristics in the financial market. I choose two properties. The first property is banks need labor effort to manage and monitor loans. The second property is the interaction between corporate finance and risk-rating. The criterion I use for risk-rating is based on the intermediate firms' financial leverage. Generally, the benchmark model keeps the connections from the policy interest rate to other interest rates consistent with their empirical findings.

A costly financial intermediary changes the responses of economic variables to an aggregate shock. It makes a model economy more volatile. Consequently, the cost of price rigidity is higher. Even though a financial shock would not explain much for the variances of some state variables, it contributes to the variances of the bank spread and the lending rate. The benchmark model also shows that a financial shock has significant effects on some economic variables. A financial shock also drives down production and inflation as it decreases the amounts of bank loans and investments.

The bank spread, which is the difference between the lending rate and the savings (or deposit) rate, could be a good economic indicator. From both the positive side and the normative side, the spread in interaction with interest rates could signal the origin of a shock. Importantly, this bank spread contains the information of a financial disturbance. An optimal simple monetary policy rule should negatively partially respond to this bank spread. Additionally, a negative response to this spread not only increases the role of a financial disturbance in explaining economic fluctuations but significantly reduces the cost of price rigidity as well.

This chapter also examines the equivalence between a monetary rule responsive to the bank spread and another rule responsive to the asset price. Two types of optimal simple rules seem to be similar in terms of the responses of output and inflation to a normally studied shock. However, the rule with a negative response to the bank spread seems to generate stronger responses of output and inflation by decreasing the policy interest rate by an amount, large enough to stimulate production and move production into the positive zone. A rule responsive to the asset price still witnesses output decrease under a financial shock.

In this chapter, practical computation for the Ramsey policy is not available. This job should be for future research. A monetary rule, which is responsive to the bank spread and which closely mimics the Ramsey policy, would be ideal to get a more complete argument about the importance of the bank spread in monetary policy. This would provide insights into the connection between rules and discretion of monetary policy when a financial market matters.

This chapter should address the issue of the optimal cooperation of monetary and fiscal policy. It is not only for a more stable economy, but also for policy implementation since the optimal cooperation could change the structure of monetary policy. I leave this analysis for future work.

Concerning the process of parameterization, a future study should address the law of motion of a financial shock. That it is not easy to observe a financial shock makes this task difficult. I also acknowledge that the coefficient of the menu cost function should be estimated even though the value used in the benchmark model generates a consistent level of the cost of price rigidity in the NNS literature.

CHAPTER 3

AN EMPIRICAL INVESTIGATION OF A SHOCK TO BANK SPREAD

3.1. Overview

Contrary to a common belief that a financial shock is trivial in comparison with other commonly examined shocks (e.g. Christiano et al., 2007), recent papers (e.g. Cúrdia et al., 2009 and Faia et al., 2007) document a financial shock in a monetary model and argue that a financial shock seems to play an important role in real business cycle and new neoclassical synthesis models. In addition, the current financial crisis seems to support the role of a financial factor in economic models and policy analyses.

Empirically, few studies investigate a financial shock due to a lack of a "common" ground of "belief" and "theory". There are some exceptions. Kashyap et al. (1993) examine the role of external finance in the monetary contraction periods. They also propose that credit spreads could be good indicators to identify a shock to the credit channel. This shock would be important to explain the changes of firms' financial structure since it would affect firms' external finance. Taylor et al. (2010) observe the fluctuations in interest rate spreads in the money market in the current financial crisis and conclude that the dawn of this crisis witnessed a significant increase of interest rate spreads in the money market while the effective Fed-funds rate went down.

For policy makers, a response to a financial shock seems to be important. However, they need to use some proxy variables for such a shock. Filardo (2002) and Bernanke et al. (2001) empirically evaluate the performance of monetary policy rules responsive to asset prices. Their crucial argument is that asset prices contain information about

the health of the financial market and that it is always better for monetary policy to respond to asset prices. This implies that a shock in the financial market may exist and that this shock needs to receive the attention of policy makers.

In this chapter, I continue to use the approach by Kashyap et al. (1993) and Taylor et al. (2010) as well as employ a vector autoregressive framework by Christiano et al. (1999, 2005), extensively discussed by Sims (1980). First, I use a new variable, the bank spread, which is the difference between the lending interest rate and the savings interest rate. Extending Taylor et al. (2010), I consider some other exogenous variables in an uni-variate time series regression to estimate a disturbance to the bank spread as well as examine how the bank spread is related to other dependent variables.

Second, I use a vector autoregressive regression (VAR) model to investigate how a disturbance to the bank spread affects other economic variables. I add the bank spread to a model by Christiano et al. (1999) and employ the argument by Hamilton (1994) to order variables for the Cholesky decomposition. However, I also use the generalized impulse responses proposed by Pesaran and Shin (1998) to check the role of ordering in variance decompositions.

My choice of the bank spread as a proxy variable for a financial shock is supported by recent theoretical models. For example, Chapter 1 shows that the bank spread could be derived by

$$R_t^l - R_t = R_t q_t \frac{W_t}{P_t} \frac{1}{D_{2,t}^\alpha} \tag{3.1}$$

where R_t^l is the lending rate; R_t is the policy rate; $\frac{W_t}{P_t}$ is the real wage; $D_{2,t}^\alpha$ is a risk-rating factor; and q_t is the process of a shock to a financial intermediary. Obviously, a monetary shock which directly affects the policy interest rate, a productivity shock

which directly affects the real wage, and a financial shock which directly affects q_t all contribute to the variation of the bank spread.

In a similar sense, Cúrdia and Woodford (2009) assume that a credit spread is controlled by

$$R_t^l - R_t = \Phi(b_t) \tag{3.2}$$

where R_t^l is the lending rate; R_t is the policy rate; and $\Phi(b_t)$ is a function of aggregate private credit b_t. This function is also subject to a financial disturbance. In this structure, a monetary shock and a financial disturbance directly affect function $\Phi(b_t)$ or the credit spread in equilibrium.

In general, equation (3.1) and equation (3.2) above show that a shock to a financial intermediary turns out to be a direct shock to the bank spread. Even though one could see that other shocks would directly affect the bank spread, a shock to financial intermediaries may account for a large proportion of the variation of the bank spread. Therefore, an estimate of a financial shock could be tracked by the process of a disturbance to the bank spread.

Chapter 3 has one main finding. A disturbance to the bank spread is relatively significant in comparison with standard shocks in the literature. It contributes an important part to economic fluctuations, so this shock should receive attention in economic analyses.

In addition to this overview section, Chapter 3 contains three others. Section 3.2 provides econometric setups. Section 3.3 shows results. Section 3.4 concludes the chapter.

3.2. Econometric models

3.2.1. ARIMAX model

In this sub-section, to examine a financial disturbance to the bank spread I use a linear autoregressive cointegrated moving average exogenous variable (ARIMAX) model, in which the dependent variable is the bank spread and the independent variables are lagged bank spreads and other exogenous variables. A version of such a model is:

$$spread_t = b_0 + \sum_{i=1}^{p} b_i \ spread_{t-i} + \sum_{i=0}^{q} D_i Z_{t-i} + e_t + \sum_{i=1}^{k} \theta_i e_{t-i} \qquad (3.3)$$

where $D_i s$ are 1x4 matrices; Z_t is vector $[g_t, \pi_t, y_t, r_t]'$; g_t is government expenditure gap; y_t is output gap; π_t is inflation rate, and r_t is policy rate; $spread_t$ is the bank spread, the spread between outflow return and inflow cost of funds; and e_t is the disturbance term.

A direct connection from a financial shock to a change in the bank spread is theoretically studied in Cúrdia et al. (2009) and Vu (2010). In their models, as shown in equations (3.1) and (3.2), a shock to financial intermediaries, a monetary shock, and a productivity shock directly cause a change in the bank spread. To capture this feature, I consider other exogenous variables Z_t.

This uni-variate ARIMAX model assumes that a financial disturbance would not affect all the exogenous variables in the current period. This assumption is similar to the one by Christiano et al. (2005) in which they assume that a monetary shock would affect interest rate but the other variables in the current period. Because a financial shock would increase the lending rate for borrowers' current loans that do not go into investment and production in the current period, this assumption is reasonable for my ARIMAX model.

This model approach is also similar to Taylor et al. (2010) in which they argue that a single equation would be useful to investigate disturbance sources associated with the bank spread. The difference is that I consider other exogenous variables in order to account for the effects of other shocks such as productivity, fiscal, and monetary ones.

3.2.2. VAR model

I use a vector autoregressive (VAR) model by Christiano et al. (1999, 2005) to investigate how significantly a disturbance to the bank spread affects other economic variables. This helps one grasp some understanding about how the bank spread owns different dynamics of responses to the other shocks as well.

Due to the lack of a common theoretical model which documents the role of a financial shock, I follow Sims (1980) to assume a free structure of a model economy in which all economic variables would interact with each other. An econometric model is as follows:

$$X_t = \sum_{i=1}^{p} A_i X_{t-i} + \Omega \epsilon_t \tag{3.4}$$

where a period-t vector X_t is $[g_t, \pi_t, y_t, r_t, spread_t]'$; g_t is government expenditure gap; y_t is output gap; π_t is inflation rate, and r_t is policy interest rate; $spread_t$ is the bank spread; ϵ_t is a 5-dimension vector of zero-mean, non-correlated shocks; and Ω is a 5 x 5 lower triangular matrix with unit diagonal terms.

To simulate a shock, I use the Cholesky decomposition of residuals. For proper ordering to reflect the style of this decomposition, the most endogenous variable should be in the last position and the most exogenous variable should be in the first position. I assume that new information about shocks at period 't' is sequentially ordered in X_t from the government expenditure to the bank spread (Hamilton, 1994). Therefore, I

put g_t in the first position and $spread_t$ in the last position[1]. I also use the generalized impulse response method by Pesaran and Shin (1998) to check the effects of an economic shock. These two methods of variance decomposition give similar responses of economic variables. Therefore, I just report the Cholesky decomposition in this chapter.

3.3. Results

3.3.1. Data exploration

Table 3.1. Correlations and some statistics					
	r	$spread$	π	y	g
r	1				
$spread$	-0.3457(***)	1			
π	0.3292(***)	-0.0780	1		
y	0.2740(***)	-0.2235(***)	0.1397(*)	1	
g	-0.2167(***)	0.1275	-0.1147	-0.0161	1
ADF Z-statistics	-13.986	-5.672	-19.872	-8.757	-12.623
p-value	0.000	0.000	0.000	0.000	0.000
Standard error	0.00363	0.00284	0.00738	0.008	0.0075
ADF Z-statistics is the statistics of the Augmented Dickey Fuller (ADF) test.					
(*), (**) and (***) mean significance at 10%, 5% and 1%, respectively.					

Table 3.1 reports some statistics for the five data series. Output y and government spending g are quarterly growth rates based on real GDP and the real government spending. Interest rate change r is the first difference of the effective Fed-funds rate and inflation change π is the first difference of the inflation rate. Bank spread $spread$

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[1]Monetary policy is often implemented after the information about government expenditure, price, and output is revealed.

is the difference between the three-month prime rate and the three-month deposit rate. Appendix C describes the data set.

The augmented Dickey-Fuller stationary test confirms that fine data series in X_t are stationary. In addition, the bank spread is much more relatively stable than the other variables as it has the smallest standard error. Consistent with business cycle theories, government expenditure is not significantly correlated with output, inflation, or the bank spread in the long run. A simple t-distribution test shows that the bank spread is not correlated with government spending and inflation but interest rate and output. While the changes of the effective Fed-funds rate are negatively correlated with government spending and the bank spread, these changes are positively related with inflation and output.

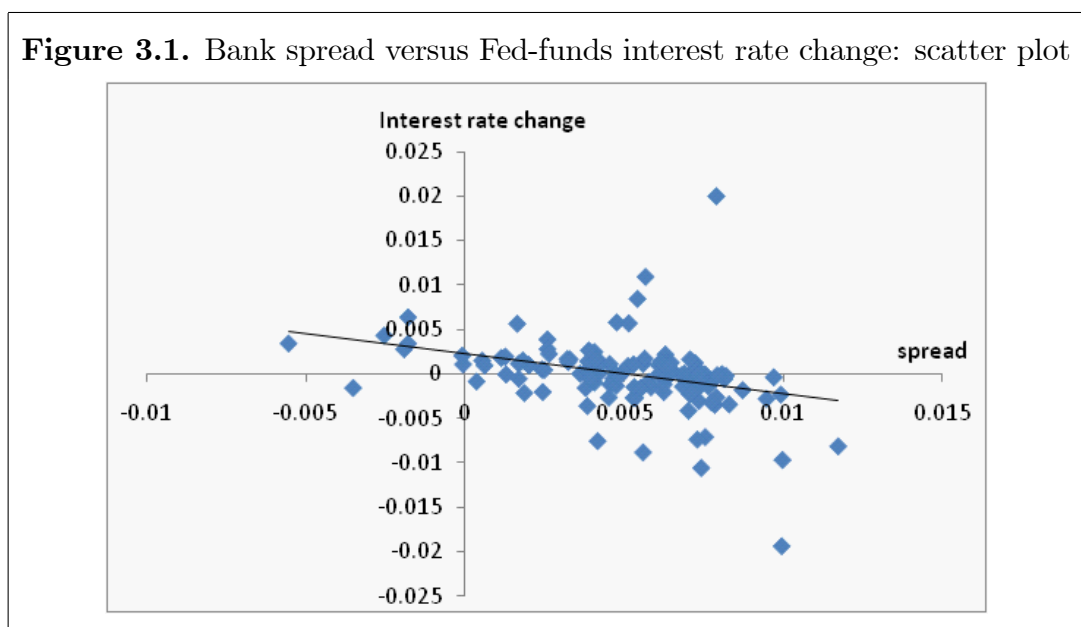**Figure 3.1.** Bank spread versus Fed-funds interest rate change: scatter plot

Figure 3.1 shows a scatter plot of the bank spread and the effective Fed-funds rate change. Figure 3.1, along with the correlations in Table 3.1, further reveals that the bank spread and the change in the policy interest rate seem to have a reverse relation.

Figure 3.2. Bank spread and Fed-funds interest rate change: time series
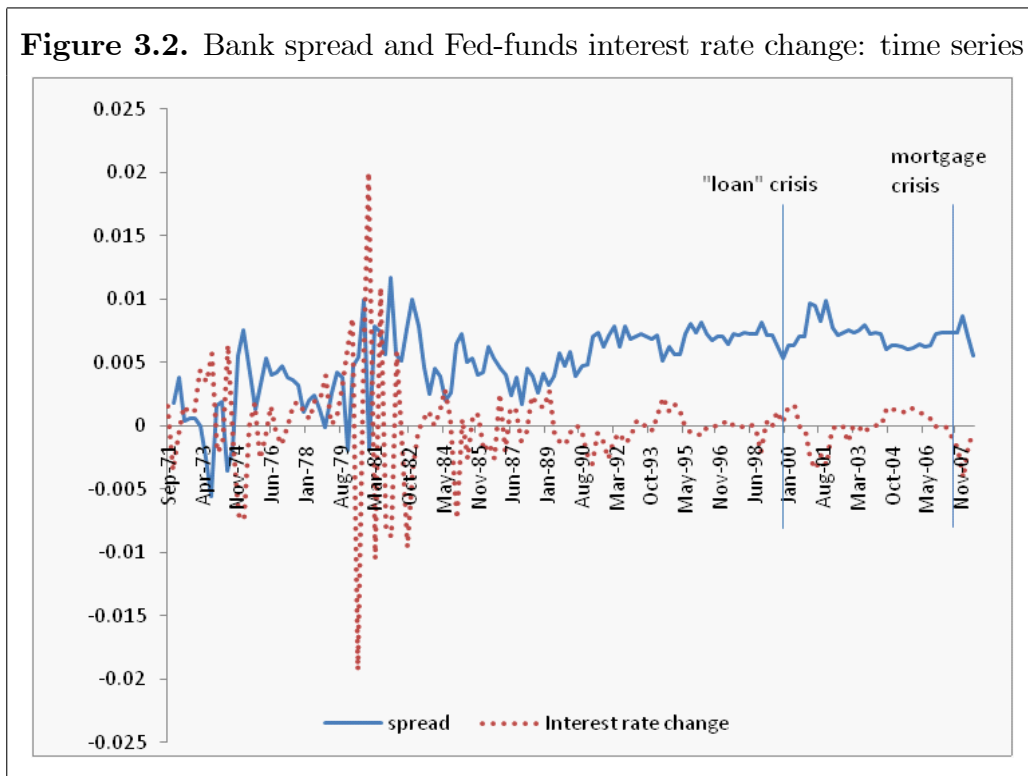
Figure 3.2 plots the change of the effective Fed-funds rate and the bank spread over time. It shows that in the beginning of some financial crises like the current one, the bank spread quickly increases. The same was true at the savings and loan crisis.

3.3.2. ARIMAX model estimation

$$spread_t = b_0 + \sum_{i=1}^{p} b_i \ spread_{t-i} + \sum_{i=0}^{q} D_i Z_{t-i} + e_t \qquad (3.5)$$

In this section, I examine the variables that affect the bank spread. Following Kashyap et al. (1993) I use a single equation estimation. Differences from Kashyap et al. (1993) and Taylor et al. (2010) are some exogenous variables. The equation above is a short version of the ARIMAX model without moving average factors.

Table 3.2. Residual tests		
Durbin's alternative test: Ho = no autocorrelation		
lag	χ^2	p-value
1	0.900	0.3427
2	4.093	0.1292
ARCH test: Ho = no ARCH effect		
lag	χ^2	p-value
1	1.111	0.2918
2	1.233	0.5397
Breusch-Pagan test for heteroskedasticity: Ho = constant variance		
	χ^2	p-value
	20.74	0.0000

Table 3.2 reports tests for auto-correlation and heteroskedasticity. First, I implement a standard Durbin's tests for autocorrelation of residual e_t. The result shows that there is no autocorrelation. Second, I check if heteroskedasticity presents itself. The result shows that residuals face heteroskedasticity. However, I check a null hypothesis to see if there is a problem of autoregressive conditional heteroskedasticity (ARCH) I reject that null hypothesis.

With the tests implemented, I assign autoregressive level p as 4 and exogenous variables's lag q as 4. I run two ARIMAX models, equation (3.3) and equation (3.5). Equation (3.3) is an ARIMAX model with moving average factors. Equation (3.5) is an ARIMAX model without moving average terms. My estimation process uses the Robust procedure to correct heteroskedasticity. Table 3.3 reports the result.

| **Table 3.3.** Univariate estimate results with robust procedure | | | | |
| spread | ARIMAX(4,0,0) | | ARIMAX(4,0,2) | |
	Coef.	z-value	Coef.	z-value
spread(-1)	0.2403981	1.79(*)	-0.1364437	-1.09
spread(-2)	0.1676546	1.79(*)	-0.1422418	-1.20
spread(-3)	0.135875	0.70	0.4746421	4.55(***)
spread(-4)	0.3957588	2.67(***)	0.617497	5.66(***)
y	-0.0580427	-3.28(***)	-0.0611347	-3.70(***)
y(-1)	-0.0343742	-1.60	-0.0369751	-1.80(*)
y(-2)	-0.0135229	-0.54	-0.0270003	-1.08
y(-3)	-0.0285434	-1.51	-0.0414013	-2.41(**)
y(-4)	-0.0503461	-2.81(***)	-0.0617457	-3.89(***)
g	0.0112428	0.60	-0.0060478	-0.33
g(-1)	-0.0109631	-0.61	-0.0102358	-0.59
g(-2)	-0.0092008	-0.61	0.0073843	0.45
g(-3)	-0.0105663	-0.48	-0.0026642	-0.14
g(-4)	-0.0118517	-0.74	-0.0182232	-1.08

Table 3.3. Univariate estimate results with robust procedure

(continued)

spread	ARIMAX(4,0,0)		ARIMAX(4,0,2)	
	Coef.	z-value	Coef.	z-value
π	0.021137	0.63	0.0279012	1.02
$\pi(-1)$	-0.0350821	-1.11	-0.0168619	-0.58
$\pi(-2)$	-0.1012413	-2.52(**)	-0.0688364	-1.73
$\pi(-3)$	-0.0911417	-2.41(**)	-0.0534614	-1.44
$\pi(-4)$	-0.0214595	-0.83	-0.0032522	-0.14
R	-0.1448308	-1.59	-0.1202474	-1.72(*)
R(-1)	0.2222093	4.95(***)	0.2844176	6.34(***)
R(-2)	0.0466273	0.78	0.1123272	2.08(**)
R(-3)	0.1445398	2.71(***)	0.1988264	3.75(***)
R(-4)	-0.044935	-0.73	-0.0434412	-0.83
MA(-1)			0.4895854	2.87(***)
MA(-2)			0.6706662	3.72(***)
sigma	0.0014153		0.0013443	
(*), (**), (***) mean significance of 10%, 5%, and 1% respectively.				

Table 3.3 shows that the estimated standard errors of residuals are quite large, within a range from 0.0013 to 0.0015. Additionally, except the coefficients of lagged bank spreads, the other coefficients are quite similar between two ARIMAX models. To validate the role of exogenous variables, I implement a joint Wald test, in which the null hypothesis does not support the effect of an exogenous factor. Table 3.4 reports the testing result.

Table 3.4. Hypothesis testing		
Joint tests. Level of significance: 0.05		
Null hypothesis	$\chi^2(4)$ - ARIMAX(4,0,0)	$\chi^2(4)$ - ARIMAX(4,0,2)
g=0; g(-i)=0, i=1 - 4	2.80	2.33
π=0; π(-i)=0, i=1 - 4	11.39(**)	7.06
spread(-i)=0, i=1 - 4	247.15(***)	70.16(***)
r=0; r(-i)=0, i=1 - 4	52.26(***)	152.08(***)
y=0; y(-i)=0, i=1 - 4	21.93(***)	28.02(***)
(***), (**): significance of 1% and 5%, respectively.		

Table 3.4 shows that the government expenditure is insignificant. Inflation is significant in the model without moving average terms and it is insignificant in the other model. Output and the policy interest rate have explanatory power for the bank spread.

To examine a marginal effect of an exogenous variable, I use a simple z-test for its aggregate marginal effect in all periods. Table 3.5 reveals three points.

Table 3.5. Hypothesis testing		
Aggregate marginal effects		
Null hypothesis	ARIMAX(4,0,0)	ARIMAX(4,0,2)
$\sum_{i=1}^{4}$spread(-i) = 0.9	No reject	No reject
$\sum_{i=0}^{4}$r(-i) = 0.35	No reject	No reject
$\sum_{i=0}^{4}$y(-i) = -0.15	No reject	No reject
$\sum_{i=0}^{4} \pi$(-i) = 0	No reject	No reject
$\sum_{i=0}^{4}$g(-i) = 0	No reject	No reject

First, inflation and the government expenditure do not affect the bank spread. This means that inflationary shocks and fiscal shocks do not seem to affect this spread. Second, while the policy interest rate has a positive marginal effect on the bank spread, output has a negative marginal effect. Third, the bank spread is quite persistent over time with a marginal effect of 0.9.

In general, the ARIMAX models show that a disturbance to the bank spread has a quite large standard error. In addition, inflation and the government expenditure have insignificant explanatory power for the bank spread while output and the policy interest rate own significant effects on this spread.

3.3.3. VAR model estimation

In this section, I estimate the VAR model (Eq. 3.4), developed in the previous section. I mainly pay attention to a disturbance to the bank spread. Table 3.6 shows four information criteria used to select the number of lags.

| Table 3.6. Lag-order selection criteria			
lag	FPE	AIC	HQIC	SBIC
1	$3.8*10^{-24}$	-39.7485	-39.4959	**-39.1269**
2	$2.4*10^{-24}$	-40.1988	**-39.7357**	-39.0592
3	$2.2*10^{-24}$	-40.2817	-39.6082	-38.6242
4	$1.9*10^{-24}$	-40.4607	-39.5766	-38.2851
5	**$1.8*10^{-24}$**	**-40.5056**	-39.411	-37.8121
6	$1.9*10^{-24}$	-40.4737	-39.1687	-37.2622

The Schwarz's Bayesian Information criterion (SBIC) and the Hannan and Quinn's information criterion (HQIC) recommend two lags and one lag, respectively. The other two criteria need five lags to reach minimum. However, one could see that there are just little differences in each criterion in all six lags. According to Christiano et al. (1999, 2005) and Kashyap et al. (1993), a standard empirical model should use four lags. Given the estimated information criteria and previous empirical practices, I assign the number of lags p to be four.

Table 3.7 checks the stability of the VAR model with four lags. That all the eigenvalues have moduluses lower than unit confirms the VAR model is stable.

Table 3.7. Eigenvalue stability condition number of lag = 4. i = imaginary unit

Eigenvalues	Modulus
0.94202	0.94202
-0.54089 + 0.6169554i	0.820485
-0.54089 - 0.6169554i	0.820485
-0.118792 + 0.746477i	0.75587
-0.118792 - 0.746477i	0.75587
0.706493 + 0.2497335i	0.749332
0.706493 - 0.2497335i	0.749332
0.1864064 + 0.723263i	0.746898
0.1864064 - 0.723263i	0.746898
-0.4767293 + 0.5217933i	0.706781
-0.4767293 - 0.5217933i	0.706781
-0.01298687 + 0.6947388i	0.69486
-0.01298687 - 0.6947388i	0.69486
-0.6101547 + 0.205712i	0.643899
-0.6101547 - 0.205712i	0.643899
-0.6208492	0.620849
0.5930648 + 0.01467845i	0.593246
0.5930648 - 0.01467845i	0.593246
-0.5608113	0.560811
-0.04422379	0.044224

How does an increase in the bank spread affect other economic variables? To answer this question, I use the impulse response functions under the Cholesky decomposition. As said above, the ordering of dependent variables is important in VAR models since the Cholesky decomposition varies with different ordering combinations. I use the ordering of $X_t = [g_t, \pi_t, y_t, r_t, spread_t]'$ and show the impulse response functions in Figure 3.3.

Figure 3.3. Impulse responses to shocks

(Cholesky decomposition. Columns are for shocks and rows for variables)
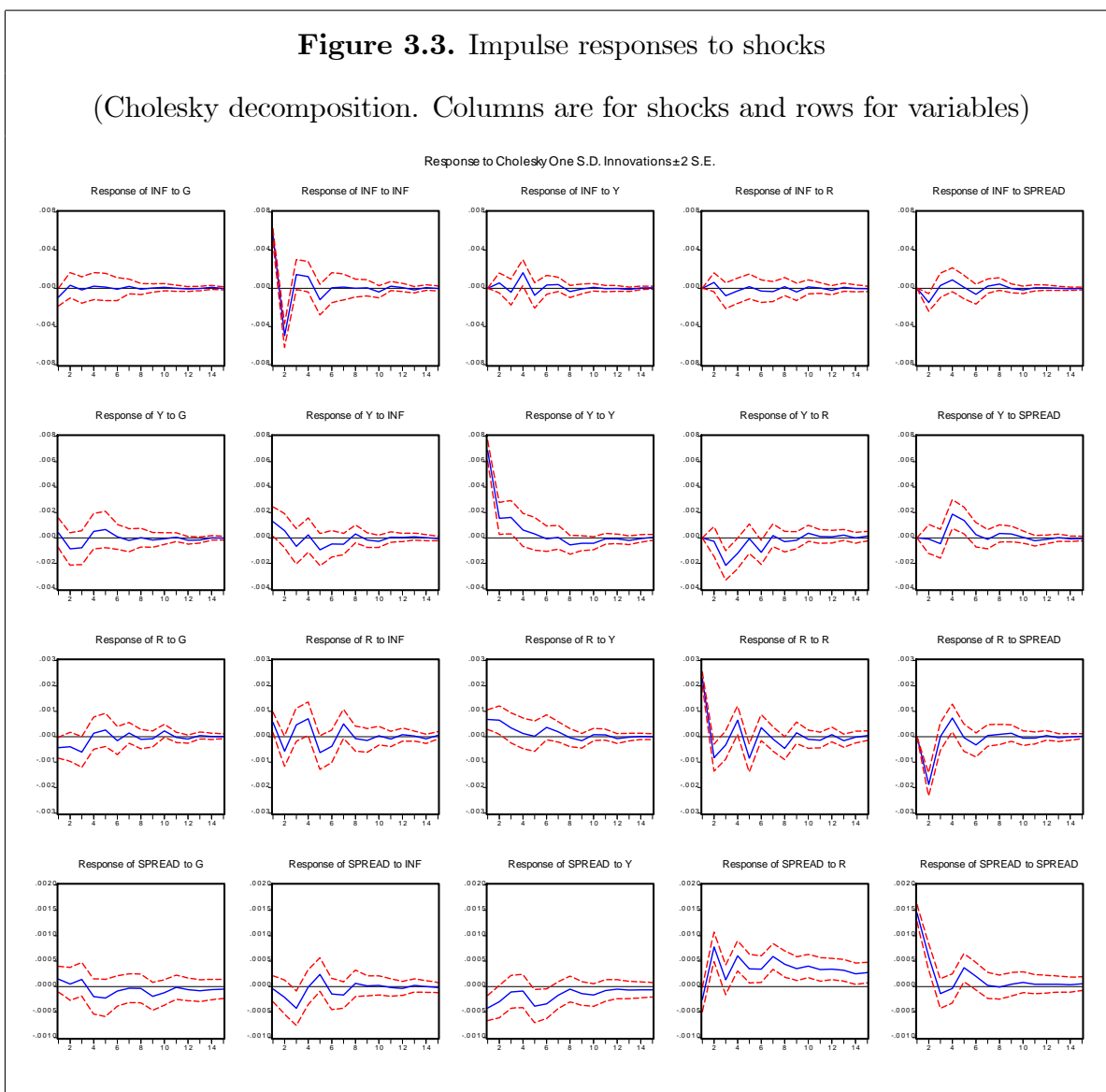
An increase in the bank spread drives down inflation, output, and the interest rate. As explained in Chapter 1 and Chapter 2, this financial disturbance would drain the available amount of credit for new investments and reduce the liquidity of funds. It means that aggregate demand is lower. Given that the price is sticky, such a shift in aggregate demand would reduce output, inflation, and the policy interest rate. This argument is supported by the current financial crisis. During the second and third quarters of 2007 (Figure 3.2), the beginning of the current financial crisis, the interest rate is lower and the bank spread is higher.

How does the bank spread respond to economic shocks? A shock to inflation and a fiscal shock to the government spending have insignificant effects on the bank spread as the responses of the bank spread to these shocks stay within one standard error. However, a productivity shock and a monetary shock both decrease the bank spread in some initial periods. Obviously, even though a shock to the bank spread and a monetary shock have similar effects on output and inflation, they may have different effects on the bank spread and interest rates.

How important is a shock to the bank spread? To answer this question, I check the standard error of a shock to the bank spread in comparison with other standard errors as well as investigate how much this shock contributes to the fluctuations in economic variables.

Table 3.8. VAR model: standard errors

Variable	g	π	y	r	spread
Standard error	0.0076	0.0056	0.0070	0.0025	0.0015

Table 3.8 reports the standard errors for the five variables in the VAR model. The standard errors of the government spending, inflation, output, and the effective Fed-funds rate are quite consistent with their values in the literature. In addition, the standard error of a shock to the bank spread is close to its estimates from the ARIMAX models (Table 3.3). This standard error is still quite significant, about a half of the standard error of a monetary shock.

Figure 3.4 reports the variance decomposition of output, inflation, the policy interest rate, and the bank spread from five shocks in the VAR model.

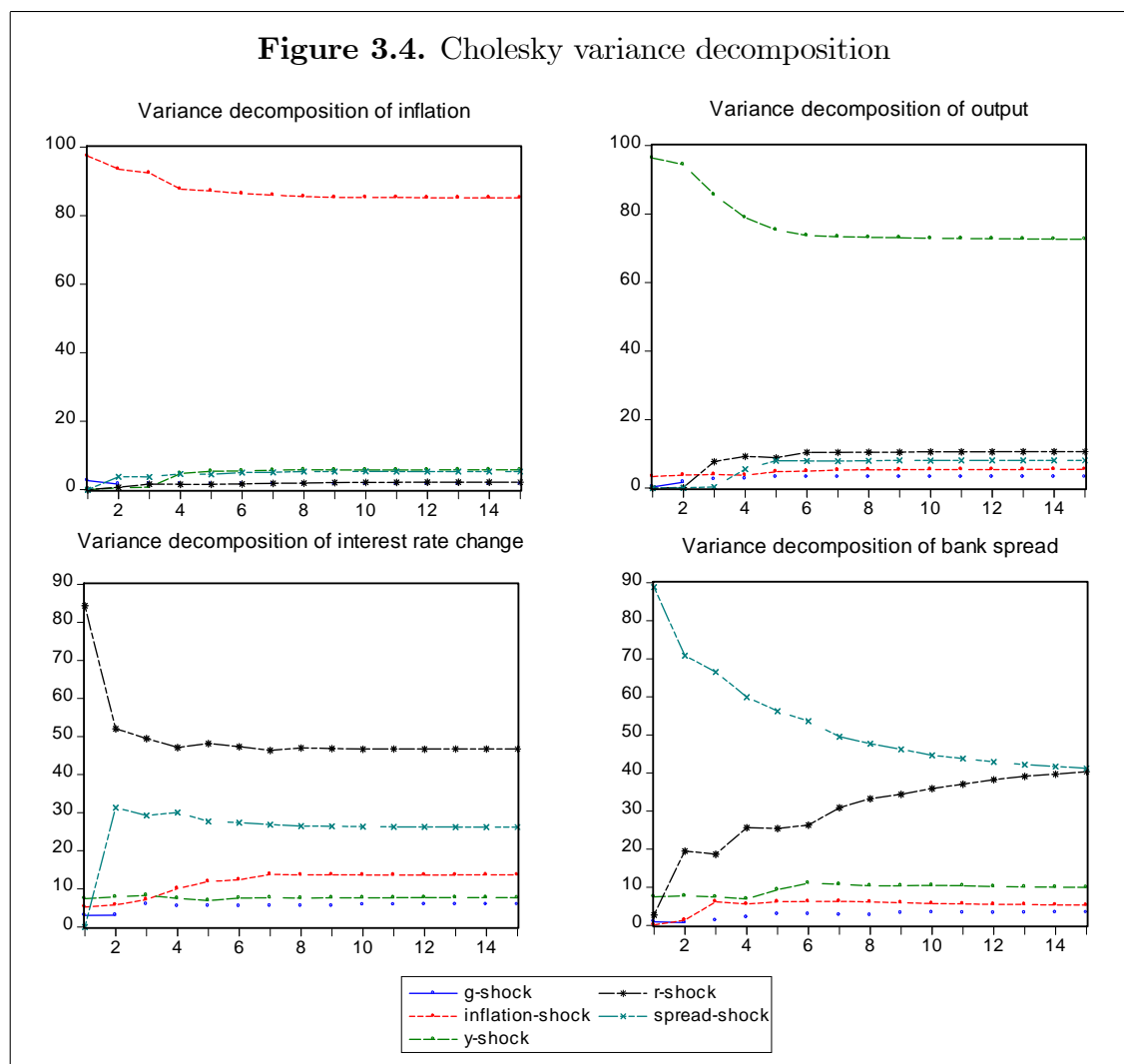**Figure 3.4.** Cholesky variance decomposition

Figure 3.4 clearly shows that while a bank spread disturbance does not have a big role in the fluctuations in output and inflation, it significantly contributes to the fluctuation in the policy interest rate and the bank spread. In addition, a monetary shock and a bank spread disturbance equally contribute to the fluctuations in output and inflation. This implies that the effects of a shock to the bank spread are significant. Therefore, future studies should consider a financial shock in a monetary model.

3.4. Conclusion

In this chapter, I show a consistent estimate of a shock to the bank spread in both ARIMAX and VAR models. This shock is quite significant and is half as much as a monetary one. Moreover, this shock has large effects on the bank spread and the effective Fed-funds rate and it equally contributes to the fluctuations in economic variables as a monetary shock does.

An increase in the bank spread drives inflation, the effective Fed-funds rate, and output down. Even though a positive shock to monetary supply would have similar effects on output and inflation, the movements of the bank spread and interest rates would be used to separate a financial shock from a monetary one.

The future expansions on this chapter include a structural approach, which needs a common financial framework augmented in standard economic models, and an alternative estimation from the VAR model where aggregate credit (e.g. Cúrdia et al., 2009 and Gertler et al., 2009), asset prices and market returns (Bernanke 2001, 2003, Filardo, 2002, Faia and Monacelli, 2008) could replace the bank spread as proxies for a financial shock.

APPENDIX FOR CHAPTER 1

A.1. Equations for calibration

A.1.1. High patience consumers' first order conditions

$$\frac{\mu_s}{s_{1,t}} = \frac{\mu_c}{c_{1,t}} - \beta_1 E_t\{\frac{\mu_c}{c_{1,t+1}}\frac{R_t^s}{\Pi_{t+1}}\} \tag{A.1}$$

$$\frac{\mu_m}{m_{1,t}} = \frac{\mu_c}{c_{1,t}} - \beta_1 E_t\{\frac{\mu_c}{c_{1,t+1}}\frac{1}{\Pi_{t+1}}\} \tag{A.2}$$

$$\frac{\mu_n}{\mu_c}N_{1,t}C_{1,t} = \frac{W_t}{P_t} \tag{A.3}$$

$$\frac{\mu_c}{c_{1,t}} = \beta_1 E_t\{\frac{\mu_c}{c_{1,t+1}}\frac{R_t}{\Pi_{t+1}}\} \tag{A.4}$$

$$\frac{\mu_x}{X_{1,t}}[1-\frac{\vartheta}{2}(1-\frac{D_{1,t-1}^2}{D_{1,t}^2})]-\beta_1\vartheta E_t\{\frac{\mu_x}{X_{1,t+1}}(1-\frac{D_{1,t+1}}{D_{1,t}})\} = \frac{\mu_c}{c_{1,t}} - \beta_1(1-\delta)E_t\{\frac{\mu_c}{c_{1,t+1}}\} \tag{A.5}$$

A.1.2. Low patience consumers' first order conditions

$$\frac{\mu_s}{s_{2,t}} = \frac{\mu_c}{c_{2,t}} - \beta_2 E_t\{\frac{\mu_c}{c_{2,t+1}}\frac{R_t^s}{\Pi_{t+1}}\} \tag{A.6}$$

$$\frac{\mu_m}{m_{2,t}} = \frac{\mu_c}{c_{2,t}} - \beta_2 E_t\{\frac{\mu_c}{c_{2,t+1}}\frac{1}{\Pi_{t+1}}\} \tag{A.7}$$

$$\frac{\mu_n}{\mu_c}N_{2,t}C_{2,t} = \frac{W_t}{P_t} \tag{A.8}$$

$$\frac{\mu_c}{c_{2,t}} = \beta_2 E_t\{\frac{\mu_c}{c_{2,t}}\frac{R_t^l}{\Pi_{t+1}}\} \tag{A.9}$$

$$\frac{\mu_x}{X_{2,t}}[1-\frac{\vartheta}{2}(1-\frac{D_{2,t-1}^2}{D_{2,t}^2})]-\beta_2\vartheta E_t\{\frac{\mu_x}{X_{2,t+1}}(1-\frac{D_{2,t+1}}{D_{2,t}})\} = \frac{\mu_c}{c_{2,t}}-\beta_2(1-\delta)E_t\{\frac{\mu_c}{c_{2,t+1}}\} \tag{A.10}$$

A.1.3. Banks' first order conditions

$$N_{s,t} = q_t(1-\omega)\frac{l_{2,t}}{D_{2,t}^\alpha}) \tag{}$$

$$(1-\omega)l_{2,t} = (1-r_t)(\omega s_{1,t} + (1-\omega)s_{2,t}) + b_{b,t} \tag{A.11}$$

$$R_t^s - 1 = (1-r_t)(R_t - 1) \tag{A.12}$$

$$(q_t\frac{W_t}{P_t}\frac{1}{D_{2,t}^\alpha} + 1)R_t = R_t^l \tag{A.13}$$

A.1.4. Intermediate firms' first order conditions

$$Y_t = z_t N_p \tag{A.14}$$

$$1 = (1-\theta_p)\frac{1}{\Pi_t^{1-\varepsilon}} + \theta_p\frac{\overline{P}_t^{1-\varepsilon}}{P_t^{1-\varepsilon}} \tag{A.15}$$

$$\frac{\overline{P}_t}{P_t} = \frac{\varepsilon}{\varepsilon-1}\frac{E_t\left\{\sum_{s=0}^\infty \Lambda_{t+s}(1-\theta_p)^s \prod_{j=0}^s \Pi_{t+j}^\varepsilon Y_{t+s}mc_{t+s}\right\}}{E_t\left\{\sum_{s=0}^\infty \Lambda_{t+s}(1-\theta_p)^s \prod_{j=0}^s \Pi_{t+j}^{\varepsilon-1}Y_{t+s}\right\}} \tag{A.16}$$

A.1.5. Market clearing conditions

$$Y_t = \omega[C_{1,t} + (D_{1,t} - (1-\delta)D_{1,t-1})] + (1-\omega)[C_{2,t} + (D_{2,t} - (1-\delta)D_{2,t-1})] + G_t \quad \text{(A.17)}$$

$$\omega b_{1,t} = b_{b,t} + b_{g,t} \quad \text{(A.18)}$$

$$\omega N_{1,t} + (1-\omega)N_{2,t} = N_{p,t} + N_{s,t} \quad \text{(A.19)}$$

A.1.6. Monetary policy, government budget constraint and fiscal policy

$$(\ln R_t - \ln R^*) = \phi_r(\ln R_{t-1} - \ln R^*) + \phi_\pi(\ln \Pi_t - \ln \Pi^*) + \phi_y(\ln Y_t - \ln Y^*) + u_{rt} \quad \text{(A.20)}$$

$$\frac{R_{t-1}b_{g,t-1} + \omega m_{1,t-1} + (1-\omega)m_{2,t-1} + r_{t-1}(\omega s_{t-1} + (1-\omega)s_{2,t-1})}{\Pi_t} + G_t$$
$$= b_{g,t} + \omega m_{1,t} + (1-\omega)m_{2,t} + r_t(\omega s_{1,t} + (1-\omega)s_{2,t}) + T_t \quad \text{(A.21)}$$

$$\ln G_t - \ln G^* = \phi + \phi_G(\ln G_{t-1} - \ln G^*) + \phi_b(\ln b_g^* - \ln b_{g,t-1}) + u_{g,t} \quad \text{(A.22)}$$

A.2. Steady state values

From two Euler equations and the first order conditions for banks, I find the steady state values of interest rates

$$R = \frac{1}{\beta_1}, \quad R^l = \frac{1}{\beta_2}, \quad R^s = (1-r)(R-1) + 1 \quad \text{(A.23)}$$

Based on Remark 1.1 and Remark 1.2 on the status of consumers with respect to borrowers or lenders, I get two conditions of lenders' loans and borrowers' bond holding

$$l_1 = 0, \qquad b_2 = 0 \tag{A.24}$$

I use the steady state values of interest rates to find the steady state value of borrowers' durable goods

$$D_2 = X_2 = \left[q(\frac{W}{P}) \frac{R}{R^l - R} \right]^{1/\alpha} \tag{A.25}$$

Then I use the first order conditions of the borrower to find the steady state values of consumption, deposits, money holding, and labor supply of the borrower. I also use the budget constraint to find the aggregate amount of loan, eventually.

$$C_2 = (1 - \beta_2(1 - \delta)) \frac{\mu_c}{\mu_x} D_2 \tag{A.26}$$

$$s_2 = \frac{\mu_s}{\mu_c(1 - \beta_2 \frac{R^s}{\Pi})} C_2 \tag{A.27}$$

$$m_2 = \frac{\mu_m}{\mu_c(1 - \beta_2 \frac{1}{\Pi})} C_2 \tag{A.28}$$

$$N_2 = \left[\frac{\mu_c}{\mu_n} (\frac{W}{P}) \frac{1}{C_2} \right]^{1/\phi} \tag{A.29}$$

$$l_2 = \frac{1}{\frac{R^l}{\Pi} - 1} [C_2 + \delta D_2 + s_2(1 - \frac{R^s}{\Pi}) + m_2(1 - \frac{1}{\Pi}) - \frac{W}{P} N_2 + T] \tag{A.30}$$

$$N_s = q(1 - \omega)\frac{-l_2}{D_2^{\alpha}} \tag{A.31}$$

Define

$A_1 = \left[1 + \frac{\mu_x}{\mu_c}\frac{\delta}{(1 - \beta_1(1 - \delta))}\right],$

$A_2 = \left[\frac{\mu_c}{\mu_n}(\frac{W}{P})\right]^{1/\phi},$

$A_3 = \frac{(1-\omega)}{\omega}[C_2 + \delta D_2 - N_2] + \frac{G + N_s}{\omega}.$

Then C_1 is a solution of

$$C_1 A_1 - [C_1]^{-1/\phi} A_2 + A_3 = 0 \tag{A.32}$$

If $\phi = 1$, I get

$$C_1 = \frac{-A_3 + \sqrt{A_3^2 + 4A_1 A_2}}{2A_1} \tag{A.33}$$

$$s_1 = \frac{\mu_s}{\mu_c}\frac{1}{(1 - \beta_1\frac{R^s}{\Pi})}C_1 \tag{A.34}$$

$$m_1 = \frac{\mu_m}{\mu_c}\frac{1}{(1 - \beta_1\frac{1}{\Pi})}C_1 \tag{A.35}$$

$$D_1 = X_1 = \frac{\mu_x}{\mu_c(1 - \beta_1(1 - \delta))}C_1 \tag{A.36}$$

$$N_1 = \left[\frac{\mu_c}{\mu_n}(\frac{W}{P})\frac{1}{C_1}\right]^{1/\phi} \tag{A.37}$$

$$Y = [\omega N_1 + (1 - \omega)N_2] - N_s \tag{A.38}$$

$$b_b = -(1-r)(\omega s_1 + (1-\omega)s_2) - (1-\omega)l_2 \qquad \text{(A.39)}$$

$$b_1 = \frac{C_1 + \delta D_1 + s_1(1 - \frac{R^s}{\Pi}) + m_1(1 - \frac{1}{\Pi}) - \frac{W}{P}N_1 + T - \Gamma_1}{\frac{R}{\Pi} - 1} \qquad \text{(A.40)}$$

$$b_g = \frac{[\omega m_1 + (1-\omega)m_2 + r(\omega s_1 + (1-\omega)s_2)]\left(1 - \frac{1}{\Pi}\right) + T - G}{\left(\frac{R}{\Pi} - 1\right)} \qquad \text{(A.41)}$$

A.3. Parameterization

Discount factors β_1 and β_2: I use the average quarterly effective Fed-funds rate (adjusted for unit long term price index), $R = 1.011$, to get $\beta_1 = 0.99$ and I use the prime rate as the lending interest rate (also adjusted for unit long term inflation), $R^l = 1.015$, to get $\beta_2 = 0.985$.

Reserve ratio r: There are two ways to determine reserve ratio r. One is based on the reserve requirement and the other is based on the relation of the deposit rate and the bond rate. The former is hard to determine since there are some differences between time deposit reserve ratio and checking deposit reserve ratio and between minimum reserves and actual reserves. Data from the Federal Reserves implies the average reserve ratio is slightly more than 5%. The latter is implied from equation $R^s = (1-r)(R-1)+1$ or $r = 1 - \frac{R^s - 1}{R - 1}$. I choose the steady state value of the savings interest rate $R^s = 1.0094$. So r is 7 percent.

Depreciation rate δ: The standard value of depreciation rate is 10 percent annually or 2.5 percent quarterly, $\delta = 0.025$.

Proportion of high patience consumers ω: Iacoviello (2005) uses 0.64 (as income share of high patience consumer is about 64 percent). Samwick (1998)

also estimates it about 0.7. Campell et al. (2003) also empirically find that about more than 55 percent of consumers have positive net wealth holding. Cúrdia et al.(2008) assign $\omega = 0.5$. I use $\omega = 0.55$.

Risk-rating parameter α**:** I choose this smoothing exponent of collateral about 0.5.

Utility parameters $\mu_c, \mu_s, \mu_x, \mu_m, \mu_n$, **bank term** q, **fiscal parameters** T^*, G^***:** I solve back these parameters by setting the following ratios C/Y, l/Y, m/Y, s/Y, N_s/N, G/Y, b_g/Y, and b/Y of the model to equate the empirical average quarterly values. Table A3.1 summarizes the ratios I use to solve back these parameters. In Table A3.1, I do not have data series for aggregate bond, so I calibrate for the value of 260 percent of GDP. (In 2003, the total value of the U.S. bond market is \$23 trillion and the total value of U.S. GDP is about \$11 trillion.) The savings rate is 3 percent, close to the long run average value of about 2.5 percent. Canzoneri et al. (2006) use bank labor effort of 1.5 percent of the total labor effort. I use 1 percent. Government bond is about 75 percent of GDP. There is no investment in my model, I use the government expenditure is about 17 percent of GDP. Consumption is about 70 percent of GDP.

Table A3.1. Empirical ratios and parameters

l/Y	$=$	1.90	μ_c	$=$	1
C/Y	$=$	0.70	μ_s	$=$	0.00006
m/Y	$=$	0.50	μ_x	$=$	0.29
G/Y	$=$	0.17	μ_m	$=$	0.01
S/Y	$=$	0.03	μ_n	$=$	3
N_s/N	$=$	0.01	q	$=$	0.01
b/Y	$=$	2.60	T^*	$=$	0.115
b_g/Y	$=$	0.75	G^*	$=$	0.11

Sticky price parameter θ_p: I use a standard value $\theta_p = 1/3$

Elasticity parameter ε: I use $\varepsilon = 7.5$ so as to get the wage mark-up of about 15%.

Monetary rule $\phi_r, \phi_\pi, \phi_y, \sigma_r^2$: I use a close rule to the one in Canzoneri et. al. (2007): $\phi_r = 0.8$, $\phi_\pi = 2$, $\phi_y = 0.2$, $\sigma_r^2 = 0.000006$

Fiscal rule $\phi_g, \phi_{bg}, \sigma_g^2$: I use a close rule to the one in Canzoneri et. al. (2007): $\phi_g = 0.9$, $\sigma_g^2 = 0.0001$. Canzoneri et. al. (2007) use a process for a tax plan. I use a response of the government spending to the previous government bond by $\phi_{bg} = 0.025$

Productivity process ϕ_z, σ_z^2: I use a persistent level $\phi_z = 0.9$ and $\sigma_z^2 = 0.000064$. The variance of a productivity shock is higher than the one in Rios-Rull et. al. (2007) (about 0.000046).

Financial shock process ϕ_q, σ_q^2: There is little knowledge of the process of a financial shock and the persistence of such a shock may be short. I assign ϕ_q

equal to 0.5. (So a financial shock little affects an economy after 4 periods). Cúrdia et al. (2009) check their analyses with different values of ϕ_q. There is no common belief about the magnitude of a financial shock either. I choose $\sigma_q^2 = 0.00002$, larger than the variance of a monetary shock but lower than those of productivity and fiscal shocks.

Adjustment cost parameter ϑ: I use $\vartheta = 500$ to maintain the relative sluggish level of durable goods.

A.4. Proof of Remark 1.2

Remark 1.2: *The expected profit of banks in the beginning of periods is zero.*

Proof:

Note that the maximization problem for banks is:

$$\max E_0 \left\{ \sum_{t=0}^{\infty} \Lambda_t \left[\begin{array}{c} (b_{b,t} + \frac{\omega(-l_{1,t-1})+(1-\omega)(-l_{2,t-1})}{\Pi_t} R_{t-1}^l + \\ (1-r_t)(\omega s_{1,t} + (1-\omega)s_{2,t}) + r_{t-1}\frac{\omega s_{1,t-1}+(1-\omega)s_{2,t-1}}{\Pi_t}) - \\ (\frac{b_{b,t-1}R_{t-1}}{\Pi_t} + [\omega(-l_{1,t}) + (1-\omega)(-l_{2,t})] + \\ \frac{\omega s_{1,t-1}+(1-\omega)s_{2t-1}}{\Pi_t} R_{t-1}^s + N_{s,t}\frac{W_t}{P_t}) \end{array} \right] \right\} \tag{A.42}$$

The first order condition in terms of bank bonds is:

$$\Lambda_t - E_t \left[\Lambda_{t+1} \frac{R_t}{\Pi_{t+1}} \right] = 0 \tag{A.43}$$

This condition is actually the Euler equation of the high patience consumers.

The first order condition in terms of bank loans is:

$$\Lambda_t(1 - r_t) + E_t\left[\Lambda_{t+1}\frac{r_t}{\Pi_{t+1}}\right] - E_t\left[\Lambda_{t+1}\frac{R_t^s}{\Pi_{t+1}}\right] = 0 \tag{A.44}$$

This condition is equivalent to:

$$R_t^s = (R_t - 1)(1 - r_t) + 1 \tag{A.45}$$

The first order condition with respect to savings is:

$$\Lambda_t\left[q_t\frac{W_t}{P_t}\frac{1}{D_{2,t}^\alpha} + 1\right] - E_t\left[\Lambda_{t+1}\frac{R_t^l}{\Pi_{t+1}}\right] = 0 \tag{A.46}$$

This condition is equivalent to:

$$R_t^l = R_t\left[q_t\frac{W_t}{P_t}\frac{1}{D_{2,t}^\alpha} + 1\right] \tag{A.47}$$

Provided that the low patience consumers are always borrowers and the high patience consumers are always lenders, a competitive bank as a new entrant will get zero profit. As assumed, the cash flow at the end of each period would be transferred to the high patience consumers, so banks would get no retained equity. Suppose a new entrant without any assets and liabilities receives deposits, issues bonds, makes loans and employs labor effort to monitor loans. It will pay/receive pre-determined interest rates on deposits, bond and loans. The profit for a new banker is:

$$\left[(1 - r_t)(\omega s_{1,t} + (1 - \omega)s_{2,t}) + b_{b,t} - (1 - \omega)(-l_{2,t}) - q_t(1 - \omega)\frac{(-l_{2,t})}{D_{2,t}^\alpha}\frac{W_t}{P_t}\right]$$
$$+ \frac{1}{R_t}\left[(\omega s_{1,t} + (1 - \omega)s_{2,t})(r_t - R_t^s) - b_{b,t}R_t + (1 - \omega)(-l_{2,t})R_t^l\right]$$

and I know the balance sheet constraint is:

$$(1 - r_t)(\omega s_{1,t} + (1 - \omega)s_{2,t}) + b_{b,t} = (1 - \omega)(-l_{2,t})$$

Using the first order conditions of the banking sector, the expected profit of a new

entrant bank is:

$$\left[-q_t(1 - \omega)\frac{(-l_{2,t})}{D_{2,t}^\alpha}\frac{W_t}{P_t} \right] + \frac{1}{R_t}\left[\frac{(1 - \omega)(-l_{2,t}) - b_{b,t}}{1 - r_t}(r_t - R_t^s) - b_{b,t}R_t + (1 - \omega)(-l_{2,t})R_t^l \right]$$

$$= \frac{1}{R_t}\left[(1 - \omega)(-l_{2,t})(R_t^l + \frac{r_t - R_t^s}{1 - r_t} - q_t\frac{1}{D_{2,t}^\alpha}\frac{W_t}{P_t}R_t) + (-b_{b,t})(\frac{r_t - R_t^s}{1 - r_t} + R_t) \right]$$

$$= \frac{1}{R_t}\left[(1 - \omega)(-l_{2,t})(R_t^l - (q_t\frac{1}{D_{2,t}^\alpha}\frac{W_t}{P_t} + 1)R_t + \frac{r_t - R_t^s}{1 - r_t} + R_t) + (-b_{b,t})(\frac{r_t - R_t^s}{1 - r_t} + R_t) \right]$$

$$= 0$$

APPENDIX FOR CHAPTER 2

B.1. Structure of simple standard model

- Timing is the same as the benchmark model.

- Fiscal rule and monetary rule are the same as the benchmark model.

- There is no financial market. In other words, the financial market is perfectly competitive and costless to bridge funds from a representative consumer to firms.

- A representative consumer has no savings. Bonds provide utility. Consumer optimization problem is:

$$\max \mathrm{E}_t \left\{ \sum_{s=0}^{+\infty} \beta^s U_{t+s} \right\} \tag{B.1}$$

subject to the budget constraint:

$$W_t N_t + \frac{R_t B_t + M_t}{\Pi_t} + (D_t + Q_t) J_{t-1} = C_t + B_t + Q_t J_t + M_t + T_t \tag{B.2}$$

where:

- W_t is the real wage;

- N_t is the labor supply;

- R_t is the return on real bond B_t;

- Q_t and J_t are the price and amount of share in period t, respectively;

- M_t is the real money holding;

- Π_t is the gross backward inflation rate, which is equal to $\frac{P_t}{P_{t-1}}$;

- T_t is the lump-sum tax;

- $U(C, M, B, N) = \mu_C \ln(C) + \mu_M \ln(M) + \mu_B \ln(B) - \frac{\vartheta}{2}N^2$

- **Producers:**

Final good producers are the same as in the benchmark model economy. Intermediate good producers are simplified. Intermediate good firm i would use capital $K_{i,t}$ and production labor $N_{i,t}$ to produce differentiated good $Y_{i,t}$ under an economy-wide productivity shock ϵ_{zt}.

$$Y_{i,t} = \exp(z_t)K_{i,t}^{\alpha}N_{i,p,t}^{1-\alpha} \tag{B.3}$$

Assume that production residual z_t follows an AR(1):

$$z_t = \phi_z\ z_{t-1} + \epsilon_{zt} \text{ where } \epsilon_{zt}\tilde{}i.i.d.N(0, \sigma_z^2) \tag{B.4}$$

Capital is based on depreciation rate δ, previous capital stock, and current investment.

$$K_{i,t+1} = (1 - \delta)K_{i,t} + I_{i,t} \tag{B.5}$$

Investment is financed by real equity $E_{i,t}$:

$$I_{i,t} = E_{i,t} \tag{B.6}$$

Intermediate firms incur a menu cost in form of the Rotemberg-style setup when they change price. Such a menu cost in terms of final good is $\frac{\psi}{2}(\frac{P_{i,t}}{P_{i,t-1}} - 1)^2 Y_t$. I assume that firms use the discount rate as consumers' relative marginal utility $\Lambda_{t+s,t}$, which

could be derived later [to be equal to $\beta^s \frac{C_t}{C_{t+s}}$]. Intermediate firm i in period t would have dividend as follows:

$$D_t = \frac{P_{i,t} Y_{i,t}}{P_t} - W_t N_{i,t} - E_t - \frac{\psi}{2} (\frac{P_{i,t}}{P_{i,t-1}} - 1)^2 Y_t \tag{B.7}$$

where:

- $\frac{P_{i,t} Y_{i,t}}{P_t}$ is the real income from selling differentiated goods $Y_{i,t}$;

- $W_t N_{i,t}$ is the real labor cost;

- $E_{i,t}$ is the real retained earnings for period 't' investment;

- $\Pi_t = \frac{P_t}{P_{t-1}}$ is the gross backward inflation rate;

- $\frac{\psi}{2} (\frac{P_{i,t}}{P_{i,t-1}} - 1)^2 Y_t$ is the menu cost in terms of final goods.

Intermediate firms would maximize their lifetime discounted expected dividend as follows:

$$\max \mathrm{E}_t \left\{ \sum_{s=0}^{\infty} \Lambda_{t+s,t} [D_t] \right\} \tag{B.8}$$

B.2. Structure of sticky lending rate

In reality, the lending rate is sticky. Firms need some types of funds including long-term, short-term, and credit-funds. Some funds have a history of sticky rates. For example, firms may borrow a long-term loan at a fixed interest rate or banks could give firms some credit limits on a fixed interest rate during a period. Some authors have paid attention to this fact (Calza et al., 2007).

In this economy, structures of the government, the monetary authority, and consumers are the same as in the benchmark model economy. However there are some changes in the financial market. First, a financial aggregator would produce final loans

from all intermediate banks' differentiated loans. The aggregator then re-distributes final loans to all intermediate firms.

I assume that the financial aggregator is owned by the consumer. Intermediate banks need some labor effort to manage and monitor the whole market risk that firms face. I use a similar market risk rating mechanism based on intermediate firms' financial leverage in the benchmark model. The optimization problem for the financial aggregator is:

$$\min[\int_0^1 R_{i,t}^l L_{i,t} di] \tag{B.9}$$

$$\text{subject to } L_t = \left(\int_0^1 L_{i,t}^{\frac{\kappa-1}{\kappa}} di\right)^{\frac{\kappa}{\kappa-1}} \tag{B.10}$$

where κ is the elasticity of substitution between two differentiated loans. This problem generates demand for each differentiated loan and aggregate lending interest rate as follows:

$$L_{i,t} = \left(\frac{R_{i,t}^l}{R_t^l}\right)^{-\kappa} L_t \tag{B.11}$$

$$R_t^l = \left(\int_0^1 \left(R_{i,t}^l\right)^{1-\kappa} di\right)^{\frac{1}{1-\kappa}} \tag{B.12}$$

For each intermediate bank, it has a fixed probability θ_R to change its lending rate in each period. If not, it would keep the same lending rate from the last period. The details of interest rate changes are below:

If intermediate bank i does not meet a change to its lending rate, its lending rate is unchanged:

$$R_{i,t}^l = R_{i,t-1}^l \tag{B.13}$$

If intermediate bank i has a chance to change its lending rate, it has to choose $R_{i,t}^l$ to maximize the following optimal problem:

$$\max \mathrm{E}_t \left\{ \sum_{s=0}^{\infty} \Lambda_{t,t+s}(\theta_R)^s \left[\begin{array}{c} \frac{R_{i,t}^l L_{i,t+s} - R_{t+s}^s S_{i,t+s}}{\Pi_{t+s+1}} - x_{t+s} W_{t+s} L_{i,t+s} \Phi^{-1}(f_{t+s}) \\ -L_{t+s+1} + S_{t+s+1} \end{array} \right] \right\} \tag{B.14}$$

subject to a balance sheet constraint $S_{t+s} = L_{t+s}$ and intermediate loan demand $L_{i,t} = \left(\frac{R_{i,t}^l}{R_t^l} \right)^{-\kappa} L_t$.

The optimization problem for intermediate banks is:

$$\max \mathrm{E}_t \left\{ \sum_{s=0}^{\infty} \Lambda_{t,t+s}(\theta_R)^s L_{t+s} \left[\begin{array}{c} \frac{1}{\Pi_{t+s+1}} \left(\frac{(R_{i,t}^l)^{1-\kappa}}{(R_{t+s}^l)^{-\kappa}} - R_{t+s}^s \left(\frac{R_{i,t}^l}{R_{t+s}^l} \right)^{-\kappa} \right) \\ -x_{t+s} W_{t+s} \frac{(R_{i,t}^l)^{-\kappa}}{(R_{t+s}^l)^{-\kappa}} \Phi^{-1}(f_{t+s}) \end{array} \right] \right\} \tag{B.15}$$

I assume that all intermediate banks who could change their lending interest rates would eventually come up with the same lending rate. The first order condition for the optimal value of the lending interest rate of bank i at $\overline{R_t^l}$ is:

$$R_t^l \left(\frac{\overline{R_t^l}}{R_t^l} \right)^{\kappa+1} = \frac{(\kappa-1) \sum_{s=0}^{\infty} \Lambda_{t,t+s}(\theta_R)^s L_{t+s} \left[\frac{1}{\Pi_{t+s+1}} \frac{(R_t^l)^{-\kappa}}{(R_{t+s}^l)^{-\kappa}} \right]}{\kappa \sum_{s=0}^{\infty} \Lambda_{t,t+s}(\theta_R)^s L_{t+s} \left[\frac{1}{\Pi_{t+s+1}} R_{t+s}^s \left(\frac{R_t^l}{R_{t+s}^l} \right)^{-\kappa} + x_{t+s} W_{t+s} \frac{(R_t^l)^{-\kappa}}{(R_{t+s}^l)^{-\kappa}} \Phi^{-1}(f_{t+s}) \right]}$$
$$\tag{B.16}$$

From the aggregation of the lending rates and given the assumption of the symmetric equilibrium, the dynamics of the final lending rate would be:

$$1 = (1 - \theta_R) \left(\frac{R_{t+s-1}^l}{R_{t+s}^l} \right)^{1-\kappa} + \theta_R \left(\frac{\overline{R_{t+s}^l}}{R_{t+s}^l} \right)^{1-\kappa} \tag{B.17}$$

Two equations, (B.16) and (B.17), determine the dynamics of the optimal lending rate for intermediate banks. These equations are similar to the standard Calvo-style sticky price framework. Two different points are the inflation rate documented in the bank return from lending and the labor effort cost used to monitor loan. In calibration, I use $\kappa = 8$ and $\theta_R = 1/3$.

B.3. Data description

B.3.1. Data for equity return

I use the data set by Kenneth R. French[1]. In his library data, the U.S. returns are available in daily, weekly, and quarterly basis and used in Fama-French Three Factor Model.

- First, I take the monthly data of the 3-month treasury bill rate in the secondary market to calculate the quarterly data of the 3-month treasury bill rate. I note that the data set from the Federal Reserve gives the rate on the first day of each month. So, to get a quarterly data point, I have to move forward one month ahead, say, the rate on April 1 is the rate for the first quarter.

- Second, I take quarterly risk-premium added to the 3-month treasury bill rate in the secondary market. I then have the quarterly data for the market return. Similarly, one could get a higher frequency data set.

- Third, to match all available data points, I just take data from the second quarter, 1971 to the second quarter, 2009. Data from Kenneth R. French and the Federal Reserves can actually date back to 1930.

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[1] The address is http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

B.3.2. Data for inflation, interest rates, output, and consumption

Series of data are from the Federal Reserves and the Bureau of Economic Analysis.

- There are some types of the inflation rate. Instead of using the consumer price index, I use the GDP deflator. The long term inflation rate is the average of the GDP deflator over time. I adjust all observations of the gross inflation rate for the long-term inflation rate since this current chapter assumes that the steady state value of the inflation rate is 1.

- There are many types of interest rates. I use the effective Fed-funds rate (which is actually the inter-bank rate in the US) as the policy interest rate since it is effective among financial institutions. I use the three-month time deposit rate for the savings rate. The equity return is mentioned above. I use two types of lending interest rates: adjusted conventional mortgage rate and three-month prime rate. Again, note that the data set from the Federal Reserves gives the rate on the first day of each month. Interest rates are also adjusted for the long-term inflation rate.

- I filter the logarithm of real GDP and take data of detrended ln(GDP). This series is considered the deviation of real GDP from the steady state real GDP in terms of the growth rate. A similar method is used for consumption.

B.3.3. Government debt and government expenditure

These two series are from the Bureau of Economic Analysis. The first series is the total government consumption expenditure and investment, a proxy for government expenditure. The second series is the total public debt, a proxy for the total government debt. Both series are HP-filtered after being transformed into the logarithm form.

B.4. Parameterization

B.4.1. Parameters $\beta, \varepsilon, \alpha, \delta, \psi, \omega, a$

From the steady state conditions of consumers, I have $R^e = \frac{1}{\beta}$. From the market return adjusted for the long term inflation average, I have:

- $R^e = 1.0171$ and;

- $\beta = 0.9832$

From the effective Fed-funds rate, I have the long-term average value of the bond interest rate:

- $R = 1.0060$

From the three-month deposit rate, I have the long-term average value of the deposit (or savings) interest rate:

- $R^s = 1.0063$

From the prime rate, I have the average value of the lending interest rate:

- $R^l = 1.0115$

I set up a standard value for cross-elasticity of differentiated goods:

- $\varepsilon = 8$

I set up a value for α of 0.3 since the proportion of capital income is about 30 percent of production.

- $\alpha = 0.3$

As usual, the depreciation rate is about 10 percent annually or 2.5 percent quarterly. I then have:

- $\delta = 0.025$

As a standard parameter in the model with the Rotermberg-style menu cost and with capital accumulation, I choose $\psi = 20$, which gives the benchmark model the cost of price rigidity around 0.1%. A conventional value ψ in the NNS framework is around 30^2.

- $\psi = 20$

I do not know from previous research which estimates value for ω in a model with banks. So, I choose an arbitrary value for ω but I still keep this value within a common range.

- $\omega = 0.55$

To set up a value for a, I have one interest rate spread $R_t^l - R_t^s = R^e W[\frac{-\ln(1-f_t)}{a}]$ where $f = L/(E+L) = \frac{(L/E)}{1+(L/E)}$ and f depends on R^e, R^l. I use steady state values of R^e, R^l, R_t^s and W to find a.

- $a = 170$

B.4.2. Parameters $G^*, T^*, \mu_C, \ \mu_M, \ \mu_s, \ \mu_B, \ \vartheta$

B.4.2.1. G^*, T^*

I use empirical data from the first quarter, 1983 to the fourth quarter, 2008. It reveals that the average ratio of government expenditure to gross domestic product (GDP) is about 0.29. Then I set G^* and T^* in the benchmark model such that at the steady state position $G^* = 0.29Y^*$ and $T^* = 0.295Y^*$.

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[2]Practically, as the benchmark model contains a costly banking sector and its production is involved with capital, I should estimate this parameter by estimating the Phillips curve. I leave it for future work.

B.4.2.2. μ_C, μ_M, μ_s, μ_B, ϑ

I first fix $\mu_C = 1$ and $\mu_M = 0.25$. Then I use some ratios to back out parameters μ_S, μ_B, ϑ, G^* and T^*. These ratios are:

$$\frac{C}{Y} = 0.55; \ \frac{B}{Y} = 0.53; \ \frac{G}{Y} = 0.29; \ R = 1.0060; \ R^s = 1.0063$$

B.4.3. Parameters $\phi_r, \phi_\Pi, \phi_Y, \phi_G, \phi_B, \phi_z, \phi_x, \sigma^2_{\epsilon r}, \sigma^2_{\epsilon b}, \sigma^2_x$

B.4.3.1. Fiscal rule and fiscal shock

The government spending follows a fiscal rule $\ln(G_t/G^*) = \phi_G \ln(G_{t-1}/G^*) + \phi_B \ln(B_{t-1}/B^*) + \epsilon b_t$ where $\epsilon b_t \tilde{\ } i.i.d.N(0, \sigma^2_{\epsilon b})$. I note that there is no constant term. I also run under a robust standard in order to correct any heteroskedasticity. Additionally, the White-test rejects heteroskedasticity. An estimated fiscal rule is:

$$\begin{aligned}
\ln(G_t/G^*) &= \underset{(0.053)}{0.758} \ln(G_{t-1}/G^*) - \underset{(0.023)}{0.018} \ln(B_{t-1}/B^*) + \epsilon b_t \\
\underset{(s.e)}{} & \\
R^2 &= 0.5776 \\
\widehat{\sigma_{\epsilon b}} &= 0.00773 \\
Observations &= 151
\end{aligned}$$

B.4.3.2. Monetary rule and monetary shock

The monetary authority follows a rule $\ln(R_t/R^*) = \phi_r \ln(R_{t-1}/R^*) + \phi_\Pi \ln(\Pi_t/\Pi^*) + \phi_Y \ln(Y_t/Y^*) + \epsilon r_t$ where $sr_t \tilde{\ } i.i.d.N(0, \sigma^2_{\epsilon r})$. Again, note that there is no constant term. The White-test rejects heteroskedasticity. An estimated monetary rule is:

$$\ln(R_t/R^*) \underset{(s.e)}{=} \underset{(0.0387)}{0.841} \ln(R_{t-1}/R^*) + \underset{(0.053)}{0.151} \ln(\Pi_t/\Pi^*) + \underset{(0.018)}{0.07} \ln(Y_t/Y^*) + \epsilon r_t$$

$$R^2 = 0.8613$$

$$\widehat{\sigma}_{er} = 0.00332$$

$$Observations = 149$$

Since I do not have current data for the inflation rate, I drop two observations (the first two quarters) of 2009.

B.4.3.3. Financial shock and productivity shock

I follow a standard productivity shock process. The process for a financial shock is identical to a productivity shock. The process of both shocks are used in standard literature as follows:

$$\ln x_t = 0.954 \ln x_{t-1} + \epsilon x_t$$

$$\ln z_t = 0.954 \ln z_{t-1} + \epsilon z_t$$

where both ϵx_t and ϵz_t follow a normal distribution with mean 0 and variation $4.46*10^{-5}$. This process is extracted from Rios-Rull and Santaeulalia-Llopis (2007). Note that Rios-Rull et al. (2007) consider two shocks to productivity: distributive shocks and productivity shocks. One could aggregate these two shocks to get a variance about $8*10^{-5}$, a common number in the real business cycle literature. I use $4.46*10^{-5}$ as a standard value of the variance of a productivity shock. In a calibration

exercise, I also set the correlation coefficient of productivity shocks and financial shocks to be 0.5.

B.5. Proof of Remark 2.1

Remark 2.1: *In every state of the benchmark model economy, banks have zero profit.*

Proof:

Banks' discounted expected profit in period t+j is:

$$\Gamma^b_{t+j} = [-\exp(x_{t+j})W_{t+j}L_{t+j}\Phi^{-1}(f_{t+j}) - L_{t+j} + S_{t+j}] + \mathbf{E}_{t+j}\left[\frac{\Lambda_{t,t+j+1}}{\Lambda_{t,t+j}}\frac{R^l_{t+j}L_{t+j} - R^s_{t+j}S_{t+j}}{\Pi_{t+j+1}}\right]$$

I note that the balance sheet constraint requires $L_{t+j} = S_{t+j}$ at all equilibrium states of the economy and that the first order condition requires $R^l_{t+j} - R^s_{t+j} = x_{t+j}W_{t+j}\Phi^{-1}(f_{t+j})R^e_{t+j}$. Plugging the balance sheet constraint and the first order condition into the profit of banks, I have:

$$\Gamma^b_{t+j} = [-\exp(x_{t+j})W_{t+j}L_{t+j}\Phi^{-1}(f_{t+j})] + L_{t+j}\mathbf{E}_{t+j}\left[\frac{\Lambda_{t,t+j+1}}{\Lambda_{t,t+j}}\frac{R^l_{t+j} - R^s_{t+j}}{\Pi_{t+j+1}}\right]$$

$$\Gamma^b_{t+j} = [-\exp(x_{t+j})W_{t+j}L_{t+j}\Phi^{-1}(f_{t+j})] + L_{t+j}\mathbf{E}_{t+j}\left[\frac{\Lambda_{t,t+j+1}}{\Lambda_{t,t+j}}\frac{x_{t+j}W_{t+j}\Phi^{-1}(f_{t+j})R^e_{t+j+1}}{\Pi_{t+j+1}}\right]$$

$$\Gamma^b_{t+j} = \exp(x_{t+j})W_{t+j}L_{t+j}\Phi^{-1}(f_{t+j})\left(\mathbf{E}_{t+j}\left[\frac{\Lambda_{t,t+j+1}}{\Lambda_{t,t+j}}\frac{R^e_{t+j+1}}{\Pi_{t+j+1}}\right] - 1\right)$$

$$\Gamma^b_{t+j} = \exp(x_{t+j})W_{t+j}L_{t+j}\Phi^{-1}(f_{t+j})(1 - 1)$$

$$\Gamma^b_{t+j} = 0$$

APPENDIX FOR CHAPTER 3

C.1. Sources of data

There are two sources of data from the second quarter of 1971 to the third quarter of 2008:

- A data set from the Federal Reserves contains information about the bond rate, the effective Fed-funds rate, the three-month prime rate and the three-month deposit rate.

- A data set from the Bureau of Economic Analysis provides observations for the seasonal adjusted gross domestic product (GDP), the consumer price index (CPI), the government seasonal adjusted spending and expenditure (G).

C.2. Data processing

- Data series of gross domestic product, y, and government expenditure, g: I use quarterly growth rates in a similar way as Choi and Yen (2010).

- Gross inflation rate: I calculate quarterly inflation rate from quarterly consumer price index (CPI). Inflation rate is then taken with the first difference in order to satisfy the stability condition of non-unit root. I keep inflation rate in level, not percentage.

- Interest rate r: I use the effective Fed-funds rate as the policy interest rate. I keep the interest rate in level, not percentage. Then I take its first difference in order to satisfy the stability condition.

- Bank spread: the bank spread is the difference between the lending rate and the deposit rate. The three-month prime rate is a proxy for the lending rate. The three-month deposit rate is a proxy for the deposit (or savings) rate. I keep the bank spread in level, not percentage.

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