PRUDENTIAL BANKING REGULATION AND MONETARY POLICY

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the
Graduate School of The Ohio State University

By

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2004

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ABSTRACT

Central bankers know that financial intermediation is important for achieving macroeconomic stability. Without a functioning banking system, an economy will grind to a halt. But monetary policy and prudential supervisory policy can work at cross-purposes. While monetary policymakers want to ensure that there is always sufficient lending activity to maintain high and stable economic growth, bank supervisors work to limit banks' lending capacities in order to prevent excessive risk-taking. To avoid working at cross-purposes, central bankers need to adopt a policy strategy that accounts for the impact of capital adequacy requirements. For this purpose, I derive an optimal monetary policy (in chapter 2) that reinforces prudential capital requirements and stabilizes aggregate economic activities at the same time. In chapter 2, I also find empirical evidence that in the United States the Federal Reserve lowers interest rates by more when the bank capital constraint binds during downturns, which is consistent with the theory. In contrast, central bankers in Germany and Japan clearly do not adjust interest rate policy in a way that would neutralize the procyclical impact of bank capital requirements.

On the other hand, it is the job of bank regulators and supervisors to ensure that the financial system functions smoothly. Despite the consensus that moral hazard is a main cause for significant banking sector problems, policymakers can not reach an agreement on how to design optimal prudential banking policies. In particular, little is known about how existing banking policies, such as capital adequacy requirements and deposit insurance, complement one another. By constructing a dynamic model of moral hazard with endogenous franchise values in chapter 3, I not only argue that a coordinated combination of optimal bank capital requirements and optimal deposit insurance can control moral hazard efficiently but also derive analytically the forms of optimal banking policies. In this model, more competition stimulates risk-taking by banks but risk-taking decreases when capital regulation and deposit insurance are conducted. Based on the bank data from 43 countries during the 1990s, I find evidence that both deposit insurance and capital adequacy requirements enhance banking stability.

ACKNOWLEDGMENTS

First and foremost, I am deeply grateful to my advisers Professor Pok-sang Lam and Professor Stephen G. Cecchetti. Professor Lam's advice based on his broad knowledge in economic theories always help me avoid detours in research. His hard-working and rigorous attitude towards research has inspired me. I have also benefited greatly from Professor Cecchetti, whose insights always keep my research moving in the right direction. I am very indebted to his guidance over the years.

My thanks also go to Professor Masao Ogaki. His thoughtful and detailed comments are very helpful for improving my thesis. I also want to thank Professor Huston J. McCulloch for helpful discussions and suggestions. In addition, I wish to thank the participants of the Macroeconomics workshop in Economics Department, Ohio State University, especially Professor Paul Evans for his valuable comments.

I would like to extend my special thanks to Professor Belton M. Fleisher, whom I have known for more than ten years. His warm-hearted help and encouragement have firmly supported me during the past several years. I have also learned from Professor Hajime Miyazaki's rigorous attitude towards economics.

Last, but not least, I would like to thank my wife, Xiaodai Xin, whose support and understanding during the past few years have been most important to me. Her

devotion to me throughout my graduate studies has made this dissertation possible in the end.

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FIELDS OF STUDY

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CHAPTER 1

PREFACE

Central bankers and financial supervisors often have different goals. It is the job of central bankers to ensure the achievement of macroeconomic stability. But bank supervisors aim to achieve financial stability. Sometimes, prudential bank regulations may conflict with the objective of monetary policy. Capital adequacy regulation is a clear example.

As an important component of prudential banking policies, capital adequacy regulation requires banks to have enough buffer capital with respect to their risk exposures. When banks' balance sheets deteriorate as a result of economic downturns, bank supervisors respond naturally by strengthening the capital regulation which restricts banks' risk exposures. As a result, a more tightly-managed banking system is more likely to cut back bank lending and push the economy into a deep slump instead of providing sufficient credits support to the slumped economy. It looks as if capital adequacy regulation "has the potential to amplify the business cycle" (Basel Committee on Banking Supervision (2001)). This is known as the procyclical effect of capital adequacy requirements in the literature.

Realizing the problem created by capital requirements, central banks need to have an optimal strategy, which can explicitly account for the impact of capital requirements. This is the question I address in chapter two. In that chapter, I derive an optimal monetary policy with both static and dynamic models in which the procyclical effect of capital requirements is embedded. I find that when an economic slump is under way, optimal policy requires that central banks should lower short-term interest rates more aggressively if banks are capital constrained. In other words, a country's monetary policymakers should react to the state of their banking system's balance sheet. In doing this, they can neutralize the procyclical effect of capital regulation. Using simulations, I also find that the optimal policy which reacts to the state of the banking system generates substantial welfare gains.

The empirical part of chapter two examines whether policy-controlled interest rates respond to the financial stress due to bank capital constraints as the theory suggests. Using the data for the three most influential central banks in the world, the Federal Open Market Committee (FOMC) in the United States, the Bundesbank of Germany and the Bank of Japan, I find that FOMC's policy is the most consistent with the model's prediction, that is, to lower the interest rate in response to the stress in the banking system when the economy is in a downturn. In contrast, the monetary authorities in Germany and Japan raise their overnight interest rates relative to the baseline when bank capital constraint binds - the opposite of what the model suggests they should do.

While prudential banking policies have important macroeconomic implications and affect the behavior of central banks, their primary goal is to promote banking stability and control excessive risk-taking by banks.

In the past two decades, many countries have experienced significant banking sector problems[1]. While banks have been experienced intense competition during the period, moral hazard in banking is no doubt one of the important reasons. A simple way to explain moral hazard in banking is as follows: Since banks know that their losses are limited if things go wrong (due to limited liability), they act recklessly and disregard the downside risks by expanding credits excessively and competing unduly in deposit markets.

To better control moral hazard in the banking sector, bank supervisors and regulators have developed various prudential policies. According to Edwards (1996), such banking policies have five key components: deposit insurance, capital adequacy requirements, activity restrictions, supervisory monitoring and intervention and the central bank's lender-of-last-resort capability. The existing literature mainly investigates each of these policies separately but seldom studies these policies simultaneously. As a result, little is known about how these policies complement one another. To fill this gap, chapter three examines the joint impact of capital requirements and deposit insurance upon banks' behaviors in a unified framework.

In doing so, I develop a model in which moral hazard and competition lessen a bank's incentive to act prudently. Compared to the benchmark case without moral

[1] According to IMF report *Bank Soundness and Macroeconomic Policy* (1996), "A review of the experiences since 1980 of the 181 current Fund [IMF] member countries reveals that 133 have experienced significant banking sector problems at some stage during the past fifteen years [1980-Spring 1996]. Two general classes [of problem] are identified: 'crisis' (41 instances in 36 countries) and 'significant' problems (108 instances)."

hazard, in the moral hazard case the bank tends to take excessive risks and to compete aggressively in deposit markets. In this model, as required by capital adequacy regulation and deposit insurance, the bank needs to keep its capital above the statutory level set by bank regulators, and it needs to pay a deposit insurance premium. The model also assumes that the deposit insurance premium is sensitive to the risk-taking behavior of the bank.

The focus of chapter three is to characterize the optimal level of bank capital and the optimal level of the deposit insurance premium set by policymakers. The intuition is that if regulatory policies are overly lax, the bank will take risks excessively; on the other hand, if bank supervisors force the bank to hold too much capital or to pay a high deposit insurance premium, the policies are not efficient.

To examine how to conduct banking policies optimally, in chapter three I derive analytically both optimal bank capital and optimal deposit insurance premium that can control moral hazard completely. Such optimal policies are available even when policymakers can not observe the bank's risk-taking.

I go on to report empirical evidence that, other things equal, the presence of capital regulation and deposit insurance reduces the risks taken by banks, using the cross-country data for banks in 43 countries. The empirical study suggests that capital adequacy requirements and deposit insurance both enhance banking stability.

CHAPTER 2

MONETARY POLICY, CAPITAL ADEQUACY REQUIREMENTS AND BUSINESS CYCLES

2.1 Introduction

Central bankers know that financial intermediation is important for achieving macroeconomic stability. Without a functioning banking system, an economy will grind to a halt. It is the job of regulators and supervisors to ensure that the financial system functions smoothly. But monetary policy and prudential supervisory policy can work at cross-purposes. An economic slowdown can cause deterioration in the balance sheets of financial institutions. Seeing the decline in the value of assets, supervisors naturally react by insisting that banks contract their loan portfolios in order to ensure that they have sufficient capital given their risk exposures. The limit on bank lending set by capital adequacy requirements declines during recessions and increases during booms. And as intermediation falls, the level of economic activity goes down with it. It looks as if regulation deepens recessions. As the Basel Committee on Banking Supervision (2001) put, the capital regulation "has the potential to amplify business cycles."

Blum and Hellwig (1995) provided the first theoretical demonstration that capital requirements can exacerbate business-cycle fluctuations. In focusing entirely on the behavior of the banking system, the Blum and Hellwig model provides an important first step, but in the end their analysis is incomplete. They do not consider the response of the central bank to economic fluctuations. This assumption is critical for their result but certainly unrealistic. What if central banks conduct monetary policy to explicitly account for the impact of capital requirements? Will the procyclical effect of capital requirements remain? Is this the optimal thing to do for central banks? To answer these questions, I derive an optimal monetary policy rule with both static and dynamic models in which the potential procyclicality of capital requirements is embedded.

The conclusions are as follows: A country's monetary policymakers should react to the state of their banking system's balance sheet. And when they do, the procyclical effect of prudential capital regulation can be counteracted and completely neutralized. For a given level of economic activity and inflation, the optimal policy reaction dictates setting interest rates lower the more financial stress there is in the banking system. This chapter also presents simulation results to give a sense of the magnitude of the required reaction. But when taking this proposition to the data and estimating forward-looking monetary policy reaction functions for the United States, Germany (pre-unification) and Japan, I find that while monetary policymakers in the U.S. behave as the theory suggests, lowering interest rates by more in downturns in which the banking system is capital-constrained, in contrast, central bankers in Germany and Japan do not.

This chapter is organized as follows: Sections 2 and 3 derive optimal interest rate rules with the static model and the dynamic model, respectively. Section 4 reports the simulation results and Section 5 discusses the empirical estimation. Section 6 concludes.

2.2 A Static Model

2.2.1 The model

We begin with a static aggregate demand-aggregate supply model modified to include a banking sector. The purpose of this model is to highlight the impact of introducing bank capital requirements in the simplest form in order to show the extent to which the banking industry can affect business cycles.

The starting point is an aggregate demand curve that admits the possibility of banks having an impact on the level of economic activity. Following Bernanke and Blinder (1988) we distinguish between policy-controlled interest rates and lending rates and write aggregate demand as:

$$y^d = y^d(i - \pi^e, \rho - \pi^e, \pi) + \eta, \tag{2.1}$$

where i is the short-term nominal interest rate, ρ is the nominal loan rate, π^e is expected inflation and π is the inflation rate. The white noise random variable η is referred to as the aggregate demand shock since in equilibrium it will tend to move output and inflation in the same direction. As we will see in a moment, while the lending rate ρ is determined by the equilibrium in the lending market, the short-term rate i is set by the monetary authority and can be treated as a constant. For future reference I will make the standard assumption that aggregate demand falls when any of the three arguments in equation (2.1) rises. That is, both higher inflation and higher real interest rates result in lower level of aggregate demand.

Turning to the loan market, banks receive deposits and make loans. Making loans requires both deposits and capital. When bank capital falls, it will constrain the quantity of loans they can make. This means that we have two cases. In the absence of any constraints, bank lending capacity is determined by bank deposits and bank capital. Assuming a reserve requirement of θ, we write real loan supply when the bank has sufficient capital and is not constrained, L_u^s, as

$$L_u^s = B + (1-\theta)D, \tag{2.2}$$

where B is real bank capital, and D is the level of real deposits.

When the capital requirement is binding, banks' lending cannot reach the level indicated in equation (2.2). Instead, loan supply is constrained to be a multiple of bank capital. That is,

$$L_c^s = cB, \tag{2.3}$$

where c is banks' statutory maximum leverage ratio which can be thought of as a measure of financial stress. In equilibrium, loan supply will be the minimum of L_u^s and L_c^s.

Next we need to model the relationship between bank deposits and bank capital on the one hand, and macroeconomic variables like output, interest rates, and inflation on the other. The level of real bank deposits, D, is assumed to depend on both the level of real output and the real short-term interest rate. We write this as

$$D = D(y, i - \pi^e), \tag{2.4}$$

where the function is increasing in the first argument and decreasing in the second argument. As for bank capital, it is assumed to rise and fall with aggregate economic activity. That is, a rise in real output results in an increase in the value of bank assets. This could be because of an increase in the value of tradable securities or because borrowers are now more able to repay their debts. Using the established notation, this is

$$B = B(y), \tag{2.5}$$

where the function is upward sloping.

To complete the story of banks and the loan market, we turn to the demand side. We assume that real loan demand depends on the real loan rate and the level of real economic activity, so

$$L^d = L^d(\rho - \pi^e, y). \tag{2.6}$$

The higher the real loan rate ρ the lower the loan demand, and the higher aggregate output y the higher loan demand.

We use a standard supply curve in which output depends positively on unanticipated inflation plus an additive white-noise error. That is,

$$y^s = y^s(\pi - \pi^e) + \epsilon, \tag{2.7}$$

where the random variable ϵ is mean zero and uncorrelated with the aggregate demand shock η. The shock ϵ is a common aggregate supply shock, as it pushes output and inflation in opposite directions.

To determine the impact of capital requirements on aggregate fluctuations we need to compute the impact of a shock on output both when banks are constrained and when they are not. This means solving two versions of a linearized version of the model, which we write as

$$y^d = -y^d_\rho(\rho - \pi^e) - y^d_i(i - \pi^e) - y^d_\pi \pi + \eta, \quad y^d_\rho,\ y^d_\pi,\ y^d_i > 0, \tag{2.8}$$

$$D = D_y y - D_i(i - \pi^e), \quad D_y,\ D_i > 0, \tag{2.9}$$

$$B = B_y y, \quad B_y > 0, \tag{2.10}$$

$$L^s = \min[L^s_u, L^s_c];\ where\ L^s_u = B + (1-\theta)D\ and\ L^s_c = cB, \tag{2.11}$$

$$L^d = -L_\rho(\rho - \pi^e) + L_y y, \quad L_\rho\ , L_y > 0, \tag{2.12}$$

$$y^s = \beta(\pi - \pi^e) + \epsilon, \quad \beta > 0, \tag{2.13}$$

$$y^s = y^d = y, \tag{2.14}$$

$$L^s = L^d, \tag{2.15}$$

where X_h denotes the partial derivative of X with respect to h evaluated at the equilibrium values for the endogenous variables in the absence of shocks, which are normalized to be zero.

To solve this model, we first assume that agents have rational expectations, but are unaware of the shocks ϵ and η. This means that they expect inflation and output to be zero. That is, $\pi^e = 0$. Next, using the loan and goods market equilibrium conditions we solve for output and inflation as functions of the two shocks and the nominal interest rate i. We can write the resulting two solutions in compact form as

$$\pi = -a^j_\pi i - b^j_\pi \epsilon + c^j_\pi \eta, \quad a^j_\pi, b^j_\pi, c^j_\pi \geq 0, \tag{2.16}$$

$$y = -a^j_y i + b^j_y \epsilon + c^j_y \eta, \quad a^j_y, b^j_y, c^j_y \geq 0, \tag{2.17}$$

where the j superscript denotes whether the bank is constrained by the capital requirement, $j = c$, or not, $j = u$.

Our interest is in the reaction of output to a shock and how this changes as the bank goes from being unconstrained to being constrained. Specifically, the goal is to figure out whether $b_y^c > b_y^u$ ($b_y^c < b_y^u$) and whether $c_y^c > c_y^u$ ($c_y^c < c_y^u$).

Taking derivatives with respect to shocks, we can get two results: First, given a realization of shocks, real output responds to shocks more when the banking system is capital-constrained. Computation shows that the following is true:

$$b_y^c = \left[\frac{\partial y}{\partial \epsilon}\right]^c > b_y^u = \left[\frac{\partial y}{\partial \epsilon}\right]^u, \; if \; and \; only \; if \; B_y > \frac{1-\theta}{c-1} D_y. \tag{2.18}$$

$$c_y^c = \left[\frac{\partial y}{\partial \eta}\right]^c > c_y^u = \left[\frac{\partial y}{\partial \eta}\right]^u, \; if \; and \; only \; if \; B_y > \frac{1-\theta}{c-1} D_y. \tag{2.19}$$

That is, the capital requirement increases the amplitude of business cycles if and only if bank capital is sufficiently responsive to the level of real output. Or put in another way, given loan demand, the output sensitivity of the equilibrium loan rate (through loan supply side, so it is negative) is larger in absolute value when the bank is capital-constrained than when the bank is not.

Second, when the banking system is constrained, the response of output to a shock is bigger the higher the ratio of bank lending to bank capital. That is, b_y^c and c_y^c are both increasing in c, or,

$$\frac{\partial b_y^c}{\partial c} = \left[\frac{\partial^2 y}{\partial \epsilon \partial c}\right]^c > 0, \tag{2.20}$$

$$\frac{\partial c_y^c}{\partial c} = \left[\frac{\partial^2 y}{\partial \eta \partial c}\right]^c > 0. \tag{2.21}$$

What we have done thus far is to establish that Blum and Hellwig (1995)'s result follows through to our setup. In the next step I add optimal monetary policy to see what happens when interest rates are set with the knowledge that bank behavior is constrained.

2.2.2 Optimal monetary policy

We assume that the central bank is engaged in a stabilization policy. Monetary policymakers adjust the short-term interest rate i in an effort to reduce the variability of inflation and output. Formally, this means that the central bank solves a static optimization problem in which it seeks to minimize a weighted squared loss of inflation gap and output gap,

$$\lambda\pi^2 + (1-\lambda)y^2, \qquad 0 < \lambda \leq 1, \tag{2.22}$$

subject to the structure of the economy specified above. Central banks assign weights λ on inflation stabilization and $1-\lambda$ on output stabilization, where output and inflation are both expressed as deviations from their no-shock equilibrium levels (which are normalized to zero).

We assume that policymakers are able to set their instrument with full knowledge of the shocks that have hit the economy. This means that they can adjust the current interest rate i knowing the aggregate demand and aggregate supply shocks η and ϵ. Since they understand what is happening in the banking system, they will respond differently depending on whether the banking system is capital constrained or not. That is,

$$i_c^* = A_1^c\eta + A_2^c\epsilon, \tag{2.23}$$

$$i_u^* = A_1^u\eta + A_2^u\epsilon, \tag{2.24}$$

where again c refers to the case in which banks are capital constrained, and u refers to the case in which they are not.

The coefficients are given by

$$A_1^j = \frac{(1-\lambda)\beta c_y^j + \lambda c_\pi^j}{(1-\lambda)\beta a_y^j + \lambda a_\pi^j}, \quad j = c \; or \; u, \tag{2.25}$$

$$A_2^j = \frac{(1-\lambda)\beta b_y^j - \lambda b_\pi^j}{(1-\lambda)\beta a_y^j + \lambda a_\pi^j}, \quad j = c \; or \; u. \tag{2.26}$$

While the sign of A_1^j is always positive, the sign of A_2^j can be either positive or negative, depending on the "slope" of the first-order condition of (2.22) (that is the ratio of inflation and output, $-\frac{(1-\lambda)\beta}{\lambda}$) and the slope of the aggregate demand of (2.8) (while the loan rate is replaced with the solution from (2.15) and the interest rate is kept constant, that is, $-\frac{b_\pi^j}{b_y^j}$).

As is the normal case, monetary policy is capable of neutralizing aggregate demand shocks, but supply shocks will create a trade-off between output and inflation variability. The important thing here is that the interest rate rule depends on whether the banking system is capital constrained or not. And, as we would expect, when the banking system is constrained the interest rate reaction is larger. For an aggregate demand shock, the result is unambiguous:

$$\frac{\partial i_c^*}{\partial \eta} \geq \frac{\partial i_u^*}{\partial \eta}. \tag{2.27}$$

In response to a supply shock, whether the interest rate response is larger depends on whether bank capital amplifies the impact of the shock on output. That is,

$$\frac{\partial i_c^*}{\partial \epsilon} > \frac{\partial i_u^*}{\partial \epsilon}, \quad if \;\; and \; only \; if \;\; B_y > \frac{1-\theta}{c-1} D_y. \tag{2.28}$$

Next, we show that when the banking system is capital constrained, an increase in the ratio of bank lending and bank capital implies a bigger response of the interest rate to an aggregate supply shock. Using the established notation, we write this as

$$\frac{\partial^2 i_c^*}{\partial \epsilon \partial c} > 0. \tag{2.29}$$

Finally, we substitute the optimal monetary policy rule into the solution for output and inflation. That is, we substitute equations (2.23) and (2.24) into (2.16) and (2.17). After simplification, we write the result as

$$\begin{aligned} \pi &= -\tfrac{(1-\lambda)\beta}{\lambda+(1-\lambda)\beta^2}\epsilon, \\ y &= \tfrac{\lambda}{\lambda+(1-\lambda)\beta^2}\epsilon. \end{aligned}$$

When monetary policymakers behave optimally, the aggregate output and inflation depend only on the supply shock in a manner that is independent of the capital constraint. The equilibrium of this stabilized economy depends only on two parameters λ (the weight on inflation stabilization) and β (the slope of the short-term Phillips curve), regardless whether the banking system is capital constrained and the extent of the capital constraint. That is,

$$\begin{aligned} \left[\frac{\partial y}{\partial \eta}\right]^c &= \left[\frac{\partial y}{\partial \eta}\right]^u = 0, \\ \left[\frac{\partial y}{\partial \epsilon}\right]^c &= \left[\frac{\partial y}{\partial \epsilon}\right]^u = \frac{\lambda}{\lambda+(1-\lambda)\beta^2}. \end{aligned}$$

In addition, the second cross-derivatives of output with respect to shocks and the measure of financial stress (c) become zero.

$$\left[\frac{\partial^2 y}{\partial \epsilon \partial c}\right]^c = \left[\frac{\partial^2 y}{\partial \eta \partial c}\right]^c = 0. \tag{2.30}$$

2.3 A Dynamic Model

The results in the static context are important, as they establish the fragility of the earlier Blum and Hellwig result. That is, by simply adding an optimal monetary policy to their framework, we are able to show that capital constraints need not exacerbate business-cycle fluctuations. The next natural question is to see if these conclusions carry over to a dynamic framework; one in which output and inflation deviations are persistent, and policymakers cannot affect the economy immediately. To do this, I add a banking system to the model originally examined by Svensson (1997, 1999). The result is a dynamic form of the model written in equations (2.8) - (2.15) of the previous section:

$$y_{t+1} = \alpha_y y_t - \alpha_i(i_t - \pi_{t+1|t}) - \alpha_\rho(\rho_t - \pi_{t+1|t}) + \eta_{t+1}, \alpha_y < 1, \alpha_i, \alpha_\rho > 0, \quad (2.31)$$

$$D_t = D_y y_t - D_i(i_t - \pi_{t+1|t}), \quad D_y,\ D_i > 0, \quad (2.32)$$

$$B_t = B_y y_t, \quad B_y > 0, \quad (2.33)$$

$$L_t^s = \min[L_{t,u}^s, L_{t,c}^s];\ where\ L_{t,u}^s = B_t + (1-\theta)D_t\ and\ L_{t,c}^s = cB_t, \quad (2.34)$$

$$L_t^d = -L_\rho(\rho_t - \pi_{t+1|t}) + L_y y_t, \quad L_\rho,\ L_y > 0, \quad (2.35)$$

$$\pi_{t+1} = \pi_t + \beta_y y_t + \epsilon_{t+1}, \quad \beta_y > 0, \quad (2.36)$$

$$L_t^s = L_t^d, \quad (2.37)$$

where all variables are defined as before, except that now I write expected inflation as $\pi_{t+1|t}$, that is the expectation based on information available at time t. Note two additional important adjustments to the model (the equilibrium condition for the goods market is omitted). First, the output gap in aggregate demand (2.31), y_{t+1}, depends on the lagged output gap, as well as the real loan and policy-controlled interest rate. And second, we write aggregate supply (2.36) with inflation on the left-hand-side, and it is a function of previous inflation. As before, the loan rate ρ_t is determined in the loan market depending on whether the banking system is constrained, and the central bank controls the short-term interest rate i_t. Finally, when α_ρ equates zero and so lending is unimportant, the system collapses into the Svensson model.

To solve the model, we can compute the equilibrium loan rate from (2.32) to (2.35), holding the policy-controlled interest rate fixed. As before, there are two solutions that depend on whether the capital constraint binds. Substituting these results into the aggregate demand curve (2.31) and using the aggregate supply curve (2.36) to compute inflation expectations, we can obtain the following solution for the dynamics of the output gap

$$y_{t+1} = -\phi_i^j (i_t - \pi_t) + \phi_y^j y_t + \eta_{t+1}, \qquad \phi_i^j,\ \phi_y^j > 0, \tag{2.38}$$

where, as before, the superscript j equals either c when the capital constraint binds or u when it does not. The coefficients ϕ_i^j and ϕ_y^j are complex functions of the model parameters. When the short-term interest rate is constant, this economy can display the same behavior as the static model. As in Blum and Hellwig (1995), the impact of shocks upon output can be amplified by a capital-constrained banking system if bank capital is sufficiently responsive to the level of real output. I present the details in the Appendix.

The next step is to introduce a central bank engaged in a stabilization policy. Following the derivation in the static model, we introduce a policymaker's objective function and then derive an optimal monetary policy rule. In the dynamic context, this means that the central bank chooses a path for the interest rate $\{i_{t+k}\}_{k=1}^{\infty}$ in order to minimize a forward-looking version of the objective function (2.22). That is,

$$Min_{\{i_{t+k}\}_{k=1}^{\infty}} \frac{1}{2} E_{t+1} \sum_{k=1}^{\infty} \delta^k [\lambda \pi_{t+k}^2 + (1-\lambda) y_{t+k}^2], \quad 0 < \lambda,\ \delta < 1, \tag{2.39}$$

subject to the structure of the economy specified from (2.31) to (2.37); where δ is a discount factor and, following our previous convention, output and inflation are written as deviations from their no-shock equilibrium values.

Solving the resulting stochastic dynamic optimization problem, we can derive optimal interest rate rule at $t+1$ in terms of the state variables, π and y:

$$i^*_{c,t+1} = A^c_\pi \pi_{t+1} + A^c_y y_{t+1}, \tag{2.40}$$

$$i^*_{u,t+1} = A^u_\pi \pi_{t+1} + A^u_y y_{t+1}, \tag{2.41}$$

where the A's are complex functions of the parameters of the model (see the Appendix for details).

The complete form of the optimal policy rule based on the solution is

$$\begin{aligned} i^*_{c,t+k|t+1} &= A^c_\pi \pi_{t+k|t+1} + A^c_y y_{t+k|t+1},\;\; k > 1, \\ & \quad if\ the\ capital\ constraint\ is\ expected\ to\ be\ binding\ in\ t+k \\ & \quad based\ on\ the\ information\ in\ t+1, \end{aligned} \tag{2.42}$$

$$\begin{aligned} i^*_{u,t+k|t+1} &= A^u_\pi \pi_{t+k|t+1} + A^u_y y_{t+k|t+1},\;\; k > 1, \\ & \quad if\ the\ capital\ constraint\ is\ expected\ to\ be\ non-binding\ in\ t+k \\ & \quad based\ on\ the\ information\ in\ t+1. \end{aligned} \tag{2.43}$$

If we assume that there is a single shock at $t+1$, and no shocks after this (ϵ_{t+i} (or η_{t+i}) $= 1$ for $i = 1$, 0 otherwise) and policymakers observe the shocks as they occur, we can rewrite optimal interest rate rule i_{t+1} in terms of η_{t+1} and ϵ_{t+1}:

$$i^*_{c,t+1} = A^c_\pi \epsilon_{t+1} + A^c_y \eta_{t+1}, \tag{2.44}$$

$$i^*_{u,t+1} = A^u_\pi \epsilon_{t+1} + A^u_y \eta_{t+1}, \tag{2.45}$$

where the A's have the same definition as (2.40) and (2.41). We note that the stability condition that $A_\pi > 1$ always holds whenever the structural parameters of the model meet the conditions we have imposed.

We can derive the impact multipliers for the dynamic model. The results are analogous to those in the static model. Following a shock, the interest rate reaction depends on whether the banking system is constrained. If it is, monetary policy becomes more aggressive:

$$\begin{aligned}
\frac{\partial i^*_{c,t+1}}{\partial \epsilon_{t+1}} &> \frac{\partial i^*_{u,t+1}}{\partial \epsilon_{t+1}}, \\
\frac{\partial i^*_{c,t+1}}{\partial \pi_{t+1}} &> \frac{\partial i^*_{u,t+1}}{\partial \pi_{t+1}}, \\
\frac{\partial i^*_{c,t+1}}{\partial \eta_{t+1}} &> \frac{\partial i^*_{u,t+1}}{\partial \eta_{t+1}} \qquad if\ B_y > \frac{1-\theta}{c-1} D_y, \\
\frac{\partial i^*_{c,t+1}}{\partial y_{t+1}} &> \frac{\partial i^*_{u,t+1}}{\partial y_{t+1}} \qquad if\ B_y > \frac{1-\theta}{c-1} D_y.
\end{aligned}$$

Furthermore, the higher the ratio of bank lending to bank capital, the bigger the interest-rate response:

$$\begin{aligned}
\frac{\partial^2 i^*_{c,t+1}}{\partial \eta_{t+1} \partial c} &> 0, \\
\frac{\partial^2 i^*_{c,t+1}}{\partial y_{t+1} \partial c} &> 0.
\end{aligned}$$

Finally, by substituting the optimal interest rate into (2.38) and using (2.36), we can write the output gap as a function of previous shocks,

$$y_{t+k} = \eta_{t+k} - \frac{1-\varphi(\beta_y,\delta,\lambda)}{\beta_y}[\frac{\beta_y \eta_{t+k-1} + \epsilon_{t+k-1}}{1-\varphi(\beta_y,\delta,\lambda)L}], \qquad k \geq 1, \tag{2.46}$$

where L is a lag operator, and

$$\varphi(\beta_y,\delta,\lambda) = \frac{1-\lambda}{1-\lambda+\beta_y^2 \delta l} < 1. \tag{2.47}$$

The current output gap is the sum of all previous shocks weighted by a constant factor less than unity. The output process becomes stable and mean-reverting. More importantly, when monetary policymakers behave optimally, the output gap depends on shocks in a manner that is independent of the capital requirements.

2.4 Simulation

The theoretical exercise yields an important analytical result: Optimal monetary policy will move interest rates by more when the banking system is capital-constrained making the output gap invariant to the level at which the capital requirement is set. To help understand if this analytical result is quantitatively important, we now turn to a simple simulation exercise. Specifically, we compare two policy regimes. The first, labeled regime **I**, assumes the policymaker behaves optimally following the rule $i^*_{c,t+k}$ in (2.40) when banks are capital-constrained at period $t+k$ and policy rule $i^*_{u,t+k}$ in (2.41) when banks are not. We compare this to a policy regime, labeled regime **II**, in which the policymaker ignores the fact that the banking system occasionally becomes constrained. This naive policymaker simply uses the rule $i^*_{u,t+k}$ all the time.

2.4.1 Parameter Values

In order to simulate the model, we need to make a number of decisions, which are summarized in Table 2.1. First, the model is interpreted as applying roughly to economic activity at an annual frequency. With this in mind, I choose our parameter values (except those parameter values related to the loan market) based on Jensen (2002). That is, the output persistence α_y is 0.5; the real interest rate sensitivity of demand α_i is 0.75; the sensitivity of inflation to the output gap β_y is 0.1; the weight on inflation stabilization λ is 0.8. The discount factor δ is set to be 0.96 rather than 0.99 in Jensen (2002)[2].

The difference between the benchmark (policy regime **I**) and alternative policy regime **II** mainly is a result of the fact that bank capital and deposits are both output-sensitive. That is, the difference between the behaviors of output, inflation, and the optimal interest rate in the two cases depends largely on B_y and D_y. In an attempt to get the rough scaling correct, I set B_y and D_y to be 0.15 and 0.2, respectively. The rest of the parameters are set primarily for illustration.

They are as follows: the leverage ratio c is set to 10 (recent leverage ratio of the U.S. banking system); the reserve requirement ratio for bank deposits θ is set equal to 0.1; the output sensitivity of loan demand L_y is set to zero (for simplification); the real loan rate sensitivity of aggregate demand α_ρ equals 0.75 (the conventional value for α_i); the real loan rate sensitivity of loan demand L_ρ is normalized to be unity and the real policy-controlled rate sensitivity of bank deposit D_i is set to zero. Finally, the standard deviation of two random shocks (σ_η and σ_ϵ) are each normalized to one. Note that the parameters are set so that the condition for the Blum and Hellwig result holds.

2.4.2 Simulation Results

We start with a baseline experiment in which the central bank does not react to shocks at all, instead keeping the policy-controlled rate constant. To give some sense of what these parameter settings mean, we compute that a one-standard-deviation purely transitory negative shock to either aggregate demand or aggregate supply

[2] Jensen wants to use a value closed to unity so that the deviation from natural-rate hypothesis is negligible, while in our model this concern does not exist. So, we use a more conventional value.

drives output down by five times as much after four periods in the economy that is capital unconstrained.

Transitory supply shock

Turning to the experiment, we first examine the impact of a one-standard-deviation purely transitory aggregate supply shock. That is, we set $\epsilon_t = 1$ for $t = 1$, and 0 otherwise. Furthermore, we set the initial conditions so that the economy is capital-constrained at the outset. Under regime **II** the central bank sets interest rates ignoring the capital constraint, using equation (2.41). Under regime **I**, the central bank takes account of the capital constraint and uses the interest rate rule given by equation (2.40), switching to equation (2.41) whenever the capital constraint no longer binds. The resulting paths for output, inflation, and the interest rate are shown in Figure 2.1. As we would expect, the output and inflation fluctuations are much larger under regime **II** when the policymakers ignore the banking system. But under regime **I**, since interest rates are moved aggressively in response to the negative output gap at the outset, they are less variable over the entire horizon of the simulation. The standard deviation of interest rates under regime **I** and **II** are 0.36 and 0.82 over 100 periods, respectively.

More specifically, to offset a transitory inflationary supply shock, the policy-controlled interest rate has to rise in the initial period. Over the following period, the fully-optimal policy (regime **I**) moves the interest rate low (aggressive) enough to counteract the procyclical effect of the binding capital constraint so that the inflation gap and the output gap are set on the optimal path (see (B.6) in the Appendix) as soon as possible.

The suboptimal policy (regime **II**) is conducted with the same intention as the policy regime **I** but fails to account for the procyclical effect of the capital constraint. Therefore, it does not dampen the recession enough by setting the interest rate too high at period 2. In Figure 2.1, from period 1 to period 9, the banking system is constrained by capital and policymakers keep conducting the suboptimal policy (regime **II**). However, starting from period 10, bank capital constraints are not binding under policy regime **II**[3]. From period 10, the inflation gap and the output gap are set on the optimal path. The suboptimal policy (regime **II**) generates significantly larger losses over the entire horizon. In other words, the optimal policy generates substantial welfare gains. Computing the welfare over a horizon of 100 periods – that is, I truncate the infinite-horizon objective function (2.39) – I find that the optimal policy entails a loss that is less than half the size (the simulated losses in regime **I** and regime **II** are 4.7 and 11.4, respectively).

Transitory demand shock

I examine the impact of a one-standard-deviation transitory aggregate demand shock with the same parameter configuration and present the paths of the output gap, inflation and the interest rate under different policy regimes in Figure 2.2. That is, I set $\eta_t = 1$ for $t = 1$, and 0 otherwise. Again, the banking system is capital-constrained at the outset.

In the period that the demand shock arrives, the bank capital constraint binds. Different policy regimes cause the output gap to differ in the following period. Namely, the optimal policy moves the interest rate low enough so that the output gap and

[3] In the simulation of supply shocks, the bank capital constraint always binds under policy regime **I**.

inflation return to their optimal paths, while the suboptimal policy fails to set the output gap and inflation on their optimal paths until period 5.

In this model, the demand shock is largely (but not completely) offset by the fully-optimal policy. Computing the welfare over 100 periods, I find that the simulated losses in regime **I** and regime **II** are 0.24 and 0.52, respectively. The difference between two policy regimes is substantial.

As for the volatility of interest rates, the optimal interest rate is slightly more variable than the suboptimal rate, with standard deviations being 0.25 and 0.21 over 100 periods, respectively. But the relatively high volatility of the interest rate under regime **I** purely comes from the strong reaction in period 1. After period 1, the interest rate is less variable under regime **I**.

2.5 What were Central Banks Doing?

The simulation gives us some sense of how monetary policymakers should account for capital constraints. The next natural question is whether central banks in fact follow a strategy like the one the model suggests. In other words, do banks' balance sheets and capital requirements play a material role in central banks' decisions? In this section, I examine data to see what central banks were actually doing. To characterize the actions of central banks, I adopt the now standard framework of estimating policy reaction functions, or the Taylor rule, for the central banks of three major countries in the world: US, Germany (pre-unification) and Japan. In his original work, John Taylor (1993) characterized his now famous policy rule as a description of the Federal Reserve behavior from the mid-1980s through the early 1990s. That is, he suggested that what the FOMC actually did was to set the nominal federal funds rates so that

$$i_t = r^* + \pi_t + 0.5(\pi_t - \pi^*) + 0.5y_t, \tag{2.48}$$

where i_t is the nominal federal funds rate at period t, r^* is the natural real interest rate (Taylor set this to 2 percent), π_t is current inflation, π^* is the inflation target (Taylor set this to 2 percent), and y_t is the percentage deviation of actual output from a measure of potential or trend output. Clarida, Gali and Gertler (1998, 2000) have proposed estimating a forward-looking version of this interest-rate rule based on the view that policymakers are forward-looking. That is, they derive a reaction function of the form

$$i_t^* = r^* + \pi^* + \gamma_\pi [E_t \pi_{t,k} - \pi^*] + \gamma_y E_t y_{t,q}, \tag{2.49}$$

where i_t^* is the target rate for the nominal short-term interest rate in period t, $\pi_{t,k}$ is the inflation from period t to period $t+k$, $y_{t,q}$ is the output gap from period t to period $t+q$, and $E_t(\cdot)$ is the expectation conditional on information at t. As a sufficient (but not necessary) condition for the model to be well behaved, the coefficient on inflation has to be larger than one (recall Taylor's original rule-of-thumb was to set γ_π equal to 1.5).

To see whether the central bank's response to the output gap depends on the state of the banking system (as suggested by the theoretical models), we augment equation (2.49) with certain measure of the stress in the banking system. Equations (2.40) and (2.41) suggest that the optimal interest rate should be lower in an economic downturn and higher in an upturn when bank capital constraint binds. We denote the bank stress in downturns and upturns with s_t^d and s_t^u, respectively. Our augmented version of (2.49) is

$$i_t^* = r^* + \pi^* + \gamma_\pi[E_t\pi_{t,k} - \pi^*] + \gamma_y E_t y_{t,q} + \gamma_s^d s_{t-1}^d + \gamma_s^u s_{t-1}^u. \qquad (2.50)$$

I let s_{t-1}^d be the *lagged* deviation of the leverage ratio from its HP trend when the output gap is negative, otherwise zero; s_{t-1}^u be the *lagged* deviation of the leverage ratio from its HP trend when the output gap is positive, otherwise zero[4]. To address the possible endogeneity of the leverage ratio – and its response to the interest rate – I estimate the relationship with a one-quarter lag.

Based on the theoretical models, all other things equal, the policy-controlled interest rate should be lower when the leverage ratio is above-the-trend in an downturn and higher when the leverage ratio is above-the-trend in an upturn. So, if policymakers react to the stress in the banking system optimally, we expect the coefficient on s_{t-1}^d, γ_s^d, to be negative and the coefficient on s_{t-1}^u, γ_s^u, to be positive.

The observed interest rate adjusts smoothly to this desired level according to the partial adjustment equation

$$i_t = \Psi(L)i_{t-1} + [1 - \Psi(1)]i_t^* + \upsilon_t, \qquad (2.51)$$

where $\Psi(L)$ is a polynomial in the lag operator L, and υ_t is an i.i.d. random variable that we can think of as a monetary policy control error resulting from things like unanticipated shifts in the demand for bank reserves. Equation (2.51) summarizes the view that policymakers are responding smoothly to a combination of inflation and the output gap. The standard procedure is to substitute (2.50) into (2.51) and estimate the resulting equation.

[4]Ideally, we would like to include a measure that tracks only the banks that are under stress – what might be thought of as the marginal stress in the banking system. Our average leverage ratio is a proxy for this marginal measure since high average measure implies that there have been a relatively large number of banks with relatively high leverage ratios.

I estimate this model using the Generalized Method of Moments[5] on quarterly data with two lags in the interest rate adjustment equation – $\Psi(L)$ is a second-order polynomial, assuming that expectation horizon for inflation is 4 quarters. In the table below, we reported the results for two expectation horizons of output gap (0 and 4 quarters). The instrument set for the estimation includes a constant, 3 lags of short-term interest rates, inflation, output gaps, producer price inflation, M2 growth (for Germany is M3), the term spreads between the long-term bond rate and short-term interest rate, and leverage ratios.

For the U.S. the sample runs from 1989 to 2000, coinciding roughly with the Greenspan Fed era, but starting two years late to avoid the changes in the banking regulation that occurred in the 1980s. For Germany, data begin in 1979 and end in 1989 to avoid the impact of the unification. And for Japan, I examine the data from 1979 to 1989 to avoid the financial turmoil during the 1990s in Japan.

Turning to the data, for each country I use the overnight rate that is controlled by the central bank to measure the policy interest rate; inflation is measured by the consumer price index; the output gap is defined as the deviation of GDP from its potential. The leverage ratio is measured as total loans of the banking system divided by the sum of bank equity and subordinated debts for the U.S., and total assets divided by bank capital plus reserves for Germany and Japan. Details of the sources and construction are described in the Appendix.

Estimation also requires that we make assumptions about both the target inflation (π^*) and the target natural real interest rate (r^*). For the U.S. we assume these both

[5] Our estimation method relies on the assumption that all of the variables are stationary. We use the ADF test to reject the null hypothesis that there is a unit root in the interest rate or inflation for the US, Germany and Japan.

to be 2 percent. For Germany, the inflation target is set at 2 percent, and the natural real interest rate is determined in the estimation. And for Japan, the inflation target is set as an HP filtered trend, and the natural real interest rate is estimated.

Before examining the estimation results, it is useful to take a brief look at the data on the leverage ratio. The three panels of Figure 2.3 display data for each of the countries I study over the examined sample period. Note that a general downward trend in both the German and Japanese data is likely related to changes in regulatory standards. For the U.S., leverage rose dramatically beginning in 1999.

2.5.1 Estimates

Estimates of the various policymakers' reaction functions are summarized in the three panels of Table 2.2. For each country I report estimates both with and without the leverage ratios (lagged and multiplied by the dummy variable that is one when output is above or below potential), and for two settings of the assumed expectation horizons for the output gap ($q = 0$ and 4). The p - values of the tests of overidentifying restrictions for all specifications validate the moment conditions I use. And the R^2s suggest that the models fit relatively well.

The overall results are reported as follows. For the US, the estimated coefficients on the inflation gap are larger than unity, implying stability, and close to the original Taylor benchmark of 1.5. The coefficients on the output gap are close or larger than the benchmark value of 0.5. Looking at the results for where the policymaker is assumed react to both current and future output gap ($q = 0$ and 4), we first see that, while the signs of γ_s^d are negative in both cases, the data do *not* support adding s_{t-1}^d to the policy rule. That is, the FOMC did *not* react strongly to the state of banking system during economic downturns. Although the standard error for γ_s^d is large, it is still helpful to get some idea of the economic magnitude of the response. In this case, a one-standard-deviation increase in the leverage ratio equals 1.82 and this is estimated to result in a 0.36 - percent cut in the federal funds rate, all other things equal.

Next, we see that the signs of γ_s^u are positive and significant in both cases, the data do support adding s_{t-1}^u to the reaction rule. That is, the FOMC did raise federal funds rate when the leverage ratio is higher-than-trend[6] during an upturn, all other things equal. The point estimate of the coefficient is large, implying that a one-standard-deviation rise in the leverage ratio causes a 2.8-percent rise in the federal funds rate, all other things equal.

Turning to the German case, we start by noting that the coefficients before inflation and output gap are close to the original Taylor values. Turning to the banking system stress variable, to the extent that the Bundesbank *did* react, it did so in a way that appears to have made matters worse. The estimate of γ_s^d is significantly positive and the sign of γ_s^u is both negative and significant. These coefficients imply that a one-standard-deviation increase in leverage ratio will raise the call money rate by 5 percent in a downturn and lower it by 0.9 percent in an upturn.

Our estimates for the Bank of Japan are reported in the bottom panel of the table. For most specifications, the coefficients on inflation and the output gap look a bit large. Regardless of other settings, we find that the data *do* support adding s_{t-1}^d to the policy rule but, as in the German case, the resulting coefficient estimates are of the *wrong* sign. To get some idea of the economic magnitude of the response, we can

[6] The high leverage ratio during an upturn could be the result of credit expansion due to loan demand rather than bank capital deterioration, so we must interpret this result carefully.

compute that a one-standard-deviation *rise* in the leverage ratio during a downturn equals 1.56 and that this causes a 2-percent *rise* in the call money rate, all other things equal. As for the coefficient before s^u_{t-1}, it is negative and insignificant. Bank of Japan *did not* react to the stress in the banking system in an upturn.

Taken together, the estimates of these policy reaction functions suggest that FOMC's policy is the most consistent with the model prediction, that is, to *lower* (*raise*) the interest rate in response to the capital constraint in the banking system when the economy is in a downturn (an upturn). By contrast, the estimates suggest that the policymakers in Germany and Japan raised their overnight interest rates, relative to the baseline, during period when output was below trend and their banks were under stress – the opposite of what the model suggests is optimal.[7]

2.6 Conclusion Remarks

Changes in bank lending are an important determinant of economic fluctuations. Central banks, in working to meet their stabilization goals, strive to ensure a sufficient supply of loans. In their effort to maintain a stable financial system, regulators can work against this objective. Capital requirements are a clear example. By dictating that all banks must maintain sufficient capital with respect to their risk exposures, capital requirements can limit the lending capacity of the banking system. Although the need for avoiding working at cross-purposes is recognized, it is not clear whether central banks have formulated an optimal strategy, namely, taken into account the impact of the capital requirements.

[7] To check the robustness, we also use alternative measures of inflation, different lags of interest rate adjustment, the last-week policy-controlled interest rate of the quarter, the original backward-looking Taylor rule specification and different interpolation method. The robustness analysis delivers the similar overall result.

This paper does three things. First, I confirm the results first derived by Blum and Hellwig (1995) that in the presence of completely passive monetary policy capital requirements are procyclical. That is, when banks become capital constrained, shocks to the economy generate larger movements in output. The second result is to establish that optimal monetary policy will neutralize the procyclical impact of capital requirements. That is, the prudential regulators need not encumber monetary policymakers in their pursuit of stable growth. Finally, I present evidence suggesting that while the Federal Reserve has been reacting as the model suggests, lowering interest rates by more during downturns in which banks are under stress and raising them by more during upturns when banks are constrained, the German and Japanese central banks clearly have not.

Eq.	Left-hand-side Variables/Parameters	Values
21a	Aggregate Demand (y_{t+1})	
	Output persistence (α_y)	0.50
	Elasticity w.r.t. real policy-controlled rate (α_i)	0.75
	Elasticity w.r.t. real loan rate (α_ρ)	0.75
	Standard deviation of demand shock (σ_η)	1.00
21b	Real Bank Deposit (D_t)	
	Elasticity w.r.t. output gap (D_y)	0.20
	Elasticity w.r.t. real policy-controlled rate (D_i)	0.00
21c	Bank Capital (B_t)	
	Elasticity w.r.t. output gap (B_y)	0.15
21d	Unconstrained Loan Supply ($L^s_{t,u}$)	
	Reserve deposit ratio (θ)	0.10
21d	Constrained Loan Supply ($L^s_{t,c}$)	
	Leverage ratio (c)	10.00
21e	Loan Demand (L^d_t)	
	Elasticity w.r.t. real loan rate (L_ρ)	1.00
	Elasticity w.r.t. output (L_y)	0.00
21f	Aggregate Supply (π_{t+1})	
	Elasticity of inflation w.r.t. real output (β_y)	0.10
	Standard deviation of supply shock (σ_ϵ)	1.00

Table 2.1: Calibration of the Parameters Values

Countries	q	Inflation Gap γ_π	Output Gap γ_y	Bank Stress Downturn γ_s^d	Bank Stress Upturn γ_s^u	Adjustment coefficient Ψ	J test	R^2
United States	0	1.28	0.61***			0.92***	0.87	0.95
		(0.21)	(0.09)			(0.01)		
		1.88***	1.10***	-0.20	1.41**	0.90***	0.87	0.95
1989q2		(0.23)	(0.29)	(0.33)	(0.53)	(0.02)		
-	4	1.13	0.51***			0.94***	0.91	0.95
2000q4		(0.30)	(0.15)			(0.01)		
		1.82**	1.31***	-0.16	1.87**	0.92***	0.88	0.95
		(0.35)	(0.39)	(0.48)	(0.76)	(0.02)		
Germany	0	1.05	-0.02			0.84***	0.94	0.93
		(0.13)	(0.29)			(0.03)		
1979q1		1.23**	0.33	6.26***	-0.67***	0.74***	0.98	0.94
-		(0.11)	(0.21)	(1.41)	(0.12)	(0.04)		
1989q4	4	0.93	0.47			0.87***	0.94	0.94
		(0.14)	(0.49)			(0.03)		
		1.18*	0.40	6.65***	-0.66***	0.73***	0.98	0.94
		(0.10)	(0.26)	(1.62)	(0.12)	(0.04)		
Japan	0	1.75	1.82***			0.83***	0.95	0.86
		(0.67)	(0.64)			(0.04)		
1979q1		1.40	1.31*	1.30***	-0.04	0.70***	0.92	0.86
-		(0.47)	(0.72)	(0.37)	(0.10)	(0.14)		
1989q4	4	1.75	1.19***			0.86***	0.94	0.86
		(0.90)	(0.42)			(0.05)		
		1.33	0.61	1.13**	0.09	0.75***	0.87	0.85
		(0.65)	(0.55)	(0.44)	(0.09)	(0.14)		

Table 2.2: The Reaction Functions of the United States, Germany and Japan

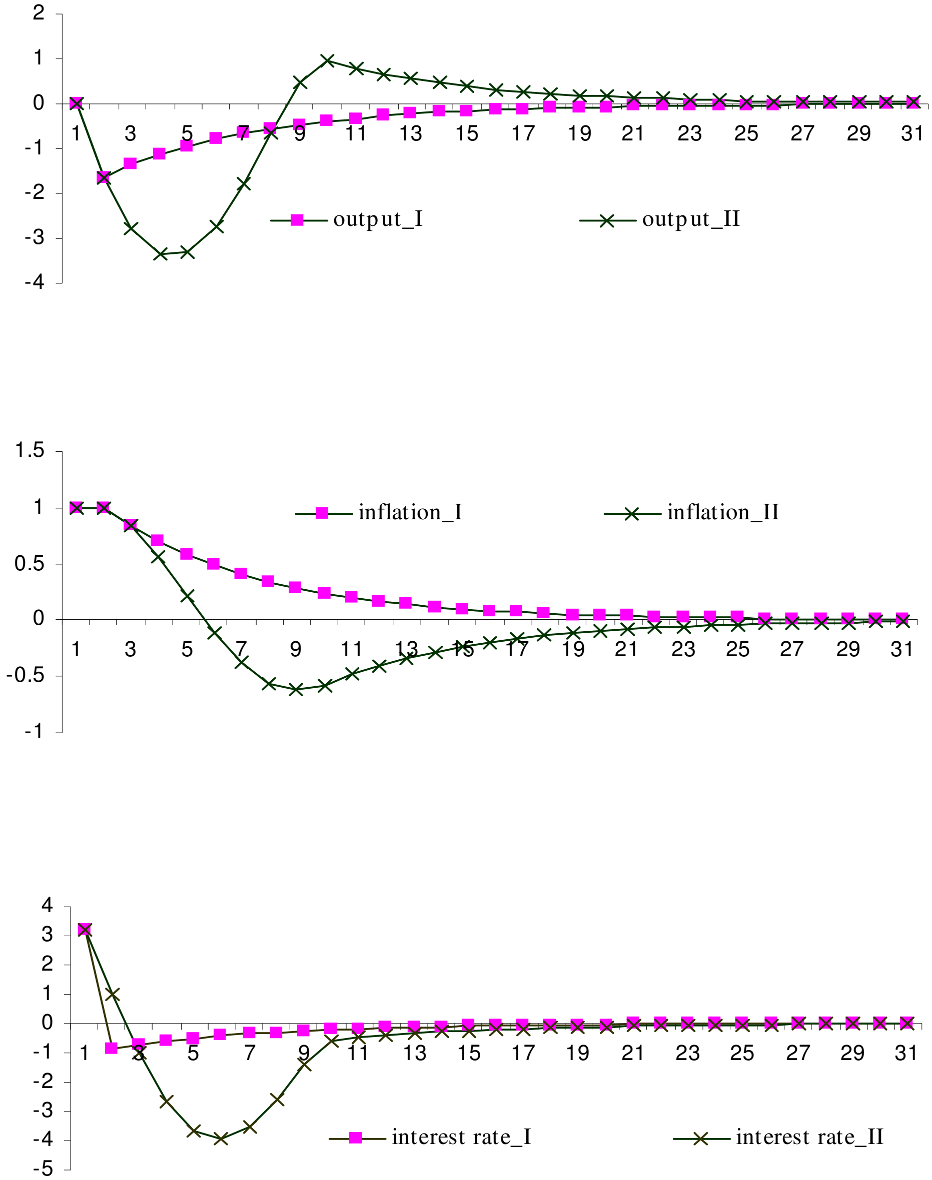

Figure 2.1: Output Gap, Inflation and Interest Rate with Different Monetary Policies: after a transitory supply shock

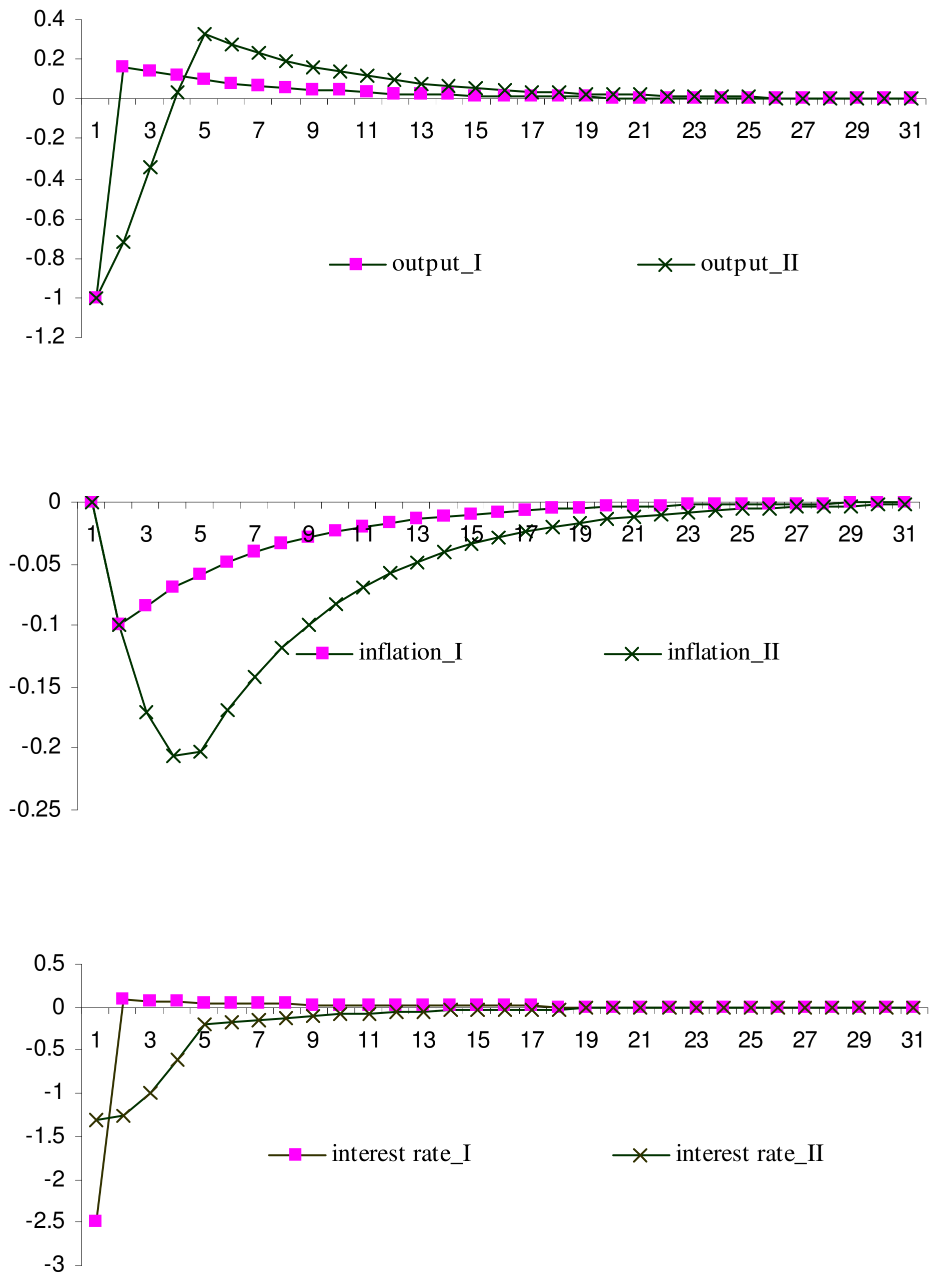

Figure 2.2: Output Gap, Inflation and Interest Rate with Different Monetary Policies: after a transitory demand shock

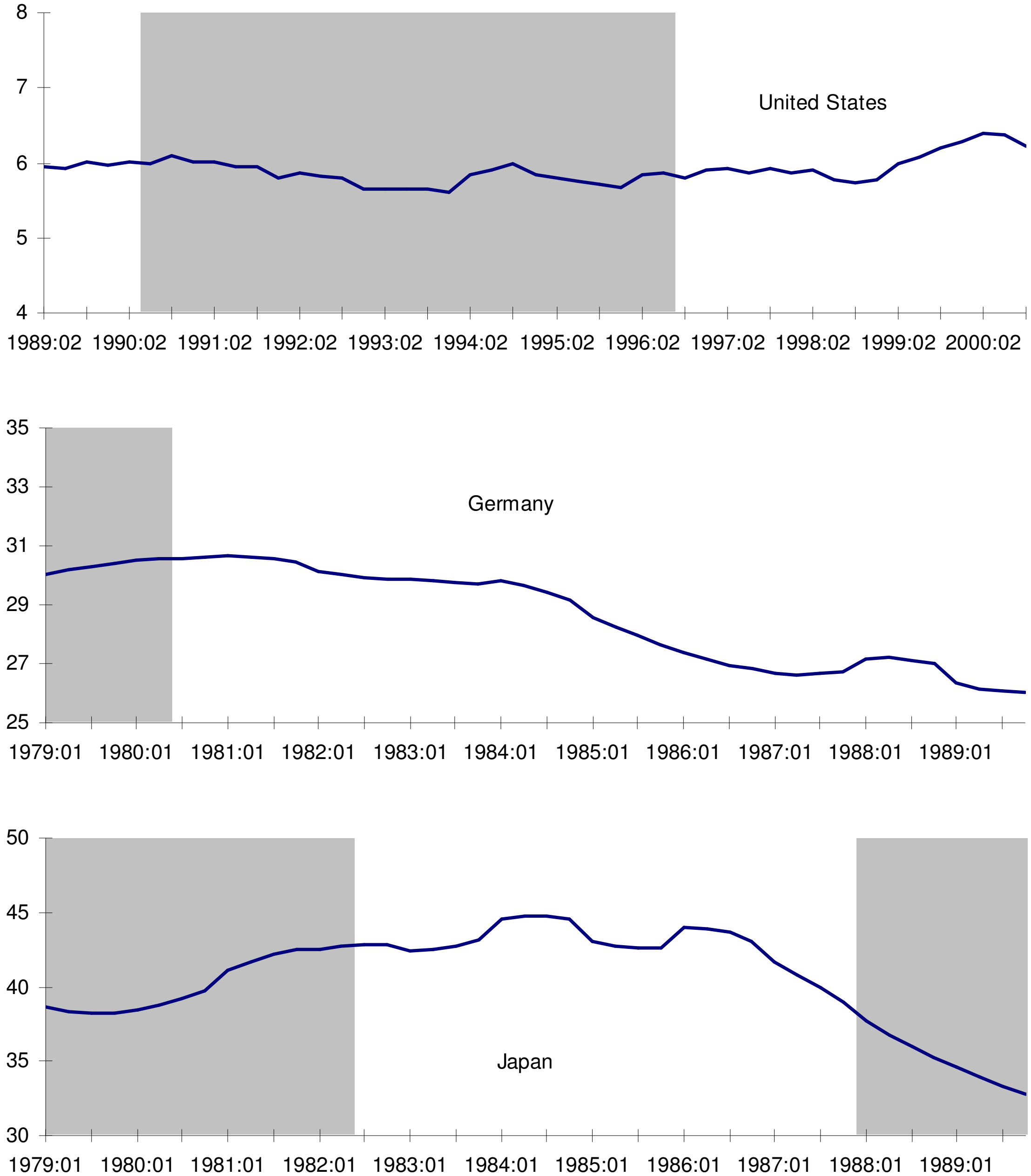

Figure 2.3: Leverage Ratios of the United States, Germany and Japan

CHAPTER 3

MORAL HAZARD IN BANKING AND PRUDENTIAL BANKING POLICIES

3.1 Introduction

A widely accepted explanation for pervasive bank failures is moral hazard. That is, inasmuch as depositors cannot monitor banks effectively, banks can engage in activities that are undesirable from the depositors' perspective. The undesirable action that banks may take is to choose risky assets when they would choose prudent assets if they were using their own money. Moral hazard occurs when depositors are exposed to losses from excessive risks taken by banks without receiving adequate compensation for the risks entailed. The moral hazard in the banking industry also influences other aspects of the economy. For instance, in a simple model, Allen and Gale (2000) show that moral hazard in banking causes asset bubbles through banks' excessive risk-taking.

A broadly supported notion concerning moral hazard suggests that the degree of moral hazard is related to how banks bear downside risks. According to the Franchise Value Hypothesis, when a bank has a high franchise value (the bank's expected future value as an ongoing institution), it engages in prudent activities. In other words, the more the bank will lose in case of insolvency, the more the bank avoids taking excessive risks. Some economists argue that the inevitable decline of banks' franchise values[8] [9] in the past two decades has exacerbated moral hazard in banking.

To control moral hazard and ensure the soundness of the banking system, bank supervisors and regulators are given the authority to keep banks' risk-taking in check, using tools like on-site examination, off-site surveillance, capital adequacy requirements and deposit insurance. This chapter studies the joint impact of capital requirements and deposit insurance, and, how these policies work together to control moral hazard.

[8] In the last two decades, the franchise value of banks has declined for several reasons. The first reason is deregulation. In the United States, The Douglas Amendment to the Bank Holding Company Act of 1956 forbad bank holding company (BHC) from acquiring an out-of-state bank unless such activity was allowed by the statute of that state. This Act effectively prohibited banks from operating across states since no state allowed its bank be acquired by banks from other states. In addition, before 1970, about 70 percent of the states restricted intrastate branching. These are the example of market-related sources of franchise values, as labeled by Demsetz (1996). But during the period from the mid-1970s to the mid-1990s, most regulatory barriers on interstate and intrastate banking were removed. From 1975 to 1992, two-thirds of the states lifted limitations on intrastate branching. During the same period, banking holding companies were allowed to operate across the state lines. The most famous law is the Reigle-Neal Interstate Banking and Branching Efficiency Act passed in September 1994, allowing countrywide interstate banking and, with state approval, interstate branching. Moreover, by the mid-1980s, the interest rate ceiling based on Regulation Q were fully lifted. This adds one more dimension that banks compete with each other, that is, banks can attract deposits by paying higher interest rates. As a result, the competition between US banks reduced banks' franchise values during this period.

The second reason for the decline in franchise values is technology- or innovation-related. Financial innovations like ATM (automatic teller machines) and money market mutual funds lower the costs of delivering financial service to consumers. As a result, competition is elevated and franchise values are eroded.

The main source that helps to maintain banks' franchise values rather than to erode the value is bank-related. These bank-related factors include the situation of banks branch networks, the efficiency of management and lending relationship. For instance, if a universal banking holding company, such as mutual funds and insurance, has an extensive branch network, this could induce the economy of scale in selling multiple classes of financial products operated by the company. The long-time relationships between a bank and its customers could bring the bank comparative advantage in collecting private information about its customers.

[9] Edwards and Mishkin (1995) has a more complete description about the changes in US banking industry since 1970s.

Neither capital requirements and deposit insurance are new. However, there have been many debates about these policies in the past two decades. While it has become more and more difficult to supervise individual transactions due to the increased complexity involved, capital adequacy requirements have evolved as the most important policy to monitor a bank's risk-management system. These regulations stipulate that the bank must maintain capital in proportion to its carefully-measured risk exposures, ensuring that the bank's owners bear some downside risks. Nevertheless, concerns remain. First, there is the procyclical effect of this regulation addressed in chapter 2. In addition, some people have criticized the capital regulation as inefficient in controlling excessive risks taken by banks.

To preclude the possibility of depositor runs, governments can insure deposits and protect depositors from financial losses if banks fail. In many countries, deposit insurance has become an important component of a financial safety net. But once deposit insurance is provided, depositors no longer have an incentive to monitor their bank's risk-taking, exacerbating the moral hazard. This concern gives rise to a debate about what kind of deposit insurance should be provided. Some support making deposit insurance more risk-based, so banks that take more risks pay higher deposit insurance premia. The logic of such a scheme is that banks should face the true cost of risks and be forced to appropriately balance the trade-off between risks and returns.

While this logic sounds correct, there are good reasons to believe that it may be difficult to implement such risk-based insurance based on the information available to insurers. The problem is that it is hard for deposit insurers to evaluate bank loans and complex financial contracts involving derivatives. In the end, deposit insurers cannot observe the risk characteristics of a bank's investment portfolio.

When information relevant to a contractual arrangement is known to only one of the participants, economists say that there is *private information*. There are many types of information that may be private. We focus on payoff-relevant information, that is, the risk characteristics of a bank's investment decisions. When a bank's investment decisions are hidden or a bank has private information, the usual remedy suggested by the literature on moral hazard is to use state-contingent payments to ensure that the bank has the right incentives[10]. These are analogous to a salesperson's commissions that are based on sales. Here, a bank's deposit insurance premium could be contingent upon the bank's performance. Such ex post insurance arrangements allow regulators the ability to control moral hazard more effectively.

Hellmann, Murdock and Stiglitz (2000) (hereafter HMS) present a model that combines capital adequacy requirements and deposit insurance. They focus on whether capital requirements are sufficient to control moral hazard. Assuming that the deposit insurance premium is flat (not risk-based), they conclude that deposit-rate control is important when capital requirements are present. Their assumption about deposit insurance is crucial to their results but does not reflect new developments in deposit insurance. Marshall and Prescott (2000) analyze bank capital regulation and deposit insurance in a model that ignores liabilities management and in which franchise values are exogenous. I use the modeling technology of HMS to examine a combination of capital adequacy requirements and flexible penalty regimes in the spirit of Marshall and Prescott (2000).

[10] Hart and Holmstrom (1987) and Prescott (1999) provide a comprehensive survey of moral-hazard models.

In the theoretical part of this chapter, I study the joint impact of capital adequacy requirements and deposit insurance on a bank's decisions about its asset allocation and liability management, with endogenous franchise values. The goal is to see how these two regulatory policies complement one another and also to see what the optimal prudential policies look like. In my model, capital regulation and deposit insurance can mitigate a bank's risk-taking. This provides theoretical underpinnings for the empirical study below.

In the empirical part of this chapter, I analyze bank data from 43 countries. The empirical work explains the variation of banks' risk-taking using banks' franchise values, as in Keeley (1990) and Demsetz (1996), and examines the impact of capital adequacy requirements and deposit insurance jointly. I find that when franchise values are lower, banks take more risks but risk-taking decreases when capital requirements are present and deposit insurance is provided.

The rest of the chapter is organized as follows: Section two presents a model associating a bank's moral hazard with its decisions on asset allocation and liability management. In this model, both capital adequacy requirements and deposit insurance are examined with variations in information availability to regulators. Section three presents the empirical model and results. Section four concludes.

3.2 A Model of Moral Hazard in Banking and Prudential Policies

I first develop a simple model that associates moral hazard with franchise values and a bank's decisions on its asset allocation and liability management. Then I use it to study the simultaneous impact of capital adequacy requirements and deposit insurance. The model is inspired by HMS, which builds upon the work of Bhattacharya

(1982). I extend the HMS model by making the following assumptions: (1) Deposit insurance premia are risk-sensitive when information is full and state-contingent when information is imperfect. (2) The payoff structure of risky assets is different from that of HMS in order to address the imperfect information case. (3) The expected return of the risky asset is greater than the return to the prudent asset. (4) The bank loses its capital if the risky asset generate low payoffs.

Overall, I extend the HMS model by using a more flexible deposit insurance policy. The flexibility allows me to derive a set of optimal prudential policies which has implications for the empirical analysis below. As far as the theoretical analysis is concerned, my model reaches a conclusion that is very different from the one in HMS. I first present the model with full information and then the model with private information.

3.2.1 Full information

The model

Consider a bank which operates for T periods. In each period, the bank (labeled bank i) competes with other banks (labeled bank $-i$) by offering an interest rate r_i on its deposits. Other banks offer depositors interest rate r_{-i}. Depositors have deposit insurance, so they focus only on the interest rates offered by different banks. The total volume of the bank's deposits $D(r_i, r_{-i})$ is increasing in the bank's own interest rate r_i ($D_1 > 0$) and decreasing in the interest rate r_{-i} offered by other banks ($D_2 < 0$).

With the deposits it raises, the bank can invest in two types of assets: a prudent asset with a riskfree return α, and a risky asset yielding high return γ with probability θ_1, medium return α (same as the return of prudent assets) with probability θ_2 and low return β with probability $1 - \theta_1 - \theta_2$. For simplicity, the low return of risky asset β is assumed to equal zero. The risky asset have a higher expected return $(\theta_1\gamma + \theta_2\alpha + (1 - \theta_1 - \theta_2)\beta > \alpha)$. It is convenient to denote the difference of the returns from risky and prudent asset as,

$$\theta_1\gamma + \theta_2\alpha + (1 - \theta_1 - \theta_2)\beta - \alpha \equiv w(1 - \theta_1 - \theta_2), \tag{3.1}$$

where w is a modified measure of the risk premium. The bank invests all of its deposits and own capital in these assets. If we denote the percentage of total capital to total deposit as k, we can write total funds invested as $(1 + k)D(r_i, r_{-i})$.

The opportunity cost of holding capital ρ is greater than the return of prudent asset α. That is, bank capital is costly $(\rho > \alpha)$. Otherwise, the bank would be willing to hold sufficient capital to eliminate moral hazard.

Two kinds of prudential policies are available. Capital adequacy requirements stipulate that the bank hold capital in excess of the minimum statutory level. Deposit insurance administrators collect insurance premia from the bank and insure the deposits in the bank. In the full information case when insurers can observe whether the bank invests in the risky or prudent asset, we assume that the insurance premium is risk-sensitive. That is, only the bank that chooses the risky asset pays the insurance premium. Bank capital is monitored and the insurance premium is collected at the end of each period. If the bank chooses the risky asset but fails (the return is β), the bank cannot repay its deposits in full. In this case, the bank has negative net worth and bank supervisors will close down its operation.

Given the payoff structure of the assets, the per-period profits for the bank when it chooses the prudent asset $\pi_P(r_i, r_{-i}, k)$ are the total returns from the prudent asset $\alpha(1+k)D(r_i, r_{-i})$ minus the sum of the cost of capital $\rho k D(r_i, r_{-i})$ and deposit repayments $r_i D(r_i, r_{-i})$.

When the bank chooses the risky asset, there is moral hazard. The bank's per-period expected profits $\pi_G(r_i, r_{-i}, k, d)$ depend on the return of the risky asset. If the risky asset yields a high return γ or medium return α, the bank repays deposits $r_i D(r_i, r_{-i})$ and pays the risk-based deposit insurance premium $dD(r_i, r_{-i})$. If the risky asset yields a low return β, the regulator closes the bank. There are no distortions or inefficiencies in the owner/management relationship so that decision-makers in the bank take into account the potential capital loss. That is, we can write the bank's per-period profits as follows,

$$\begin{aligned} \pi_P(r_i, r_{-i}, k) &= m_P(r_i, k)D(r_i, r_{-i}) \\ &\quad \textit{if the bank chooses the prudent asset}, \qquad (3.2) \\ \pi_G(r_i, r_{-i}, k, d) &= m_G(r_i, k, d)D(r_i, r_{-i}) \\ &\quad \textit{if the bank chooses the risky asset}, \qquad (3.3) \end{aligned}$$

where

$$\begin{aligned} m_P(r_i, k) &= \alpha(1+k) - \rho k - r_i, \\ m_G(r_i, k, d) &= (\theta_1\gamma + \theta_2\alpha)(1+k) - (\theta_1+\theta_2)r_i - (\theta_1+\theta_2)d \\ &\quad -\rho k - (1-\theta_1-\theta_2)k. \end{aligned}$$

The bank maximizes discounted profits,

$$V = \sum_{t=0}^{T} \delta^t \pi_t, \qquad (3.4)$$

where δ is a discount factor and T is a very large finite number. We consider the limit when $T \to \infty$ so that, according to Diamond (1989) and HMS, "banks will thus choose strategies corresponding to the infinitely repeated static Nash equilibrium." (HMS, page 152.)

We summarize the timing of the game in each period as follows: the bank chooses the level of capital and the deposit rate at the same time. Depositors choose the bank in which they place their funds and the volume of deposits is based on the deposit rates offered by the banks. After funds have been raised, the bank chooses to hold either the prudent asset or the risky asset. Then the returns to assets are realized. Finally, deposit insurance administrators collect deposit insurance premia and bank regulators inspect the balance sheet of the bank.

The equilibrium where a bank chooses the risky asset

In order to study the effects of capital adequacy requirements and deposit insurance, we need to first demonstrate that these prudential policies are necessary. A natural way to do this is to show that the bank would take risks excessively in the equilibrium in the absence of external intervention. The purpose of this section is to compute the conditions under which the bank would choose the risky asset in the equilibrium.

Asset allocation and the threshold deposit rate The bank's expected profit from holding the prudent asset over a sufficiently long horizon is

$$V_P(r_i, r_{-i}, k) = \frac{\pi_P(r_i, r_{-i}, k)}{1-\delta}, \tag{3.5}$$

while the bank's expected profit from holding the risky asset over a sufficiently long horizon is

$$V_G(r_i, r_{-i}, k, d) = \frac{\pi_G(r_i, r_{-i}, k, d)}{1-\delta(\theta_1+\theta_2)}. \tag{3.6}$$

Given deposits $D(r_i, r_{-i})$ have been raised at the cost of r_i, the bank chooses the prudent asset if $V_P(r_i, r_{-i}, k) > V_G(r_i, r_{-i}, k, d)$ but chooses the risky asset otherwise. From this relationship, we can derive a threshold interest rate below which the bank will choose the prudent asset. That is,

$$The\ bank\ chooses\ the\ prudent\ asset,\ if\ r_i \ < \ \hat{r}(k,d), \tag{3.7}$$

$$The\ bank\ chooses\ the\ risky\ asset,\ if\ r_i \ > \ \hat{r}(k,d), \tag{3.8}$$

where

$$\hat{r}(k,d) = -(1+k)(1-\delta)w + \delta\alpha(1+k) - (\delta\rho + \delta - 1)k + \frac{(1-\delta)(\theta_1+\theta_2)d}{1-\theta_1-\theta_2}. \tag{3.9}$$

This condition is labeled the "no-risky-asset condition." Other things equal, a lower level of the threshold deposit rate $\hat{r}(k,d)$ implies a high incentive to choose the risky asset. Conversely, a higher level of the threshold deposit rate $\hat{r}(k,d)$ implies more incentive to choose the prudent asset.

Deposit market and bank capital Conditional on the choice of assets, the bank chooses its deposit rate r_i and the level of capital k optimally. I start with the assumption that the bank can choose its capital level freely, as long as it is nonnegative. Later on, I discuss the case in which a capital requirement stipulates that the bank keep capital above a minimum level.

The first case is that the bank chooses the prudent asset in equilibrium. In this case, the optimal deposit rate r_P and capital k_P solve the following problem

$$(r_P, k_P) = \arg\max_{r,k}\{V_P(r, r_{-i}, k)\}. \tag{3.10}$$

The first-order condition evaluated at a symmetric equilibrium (i.e., $r_{-i} = r_P$) yields the deposit rate that the bank will offer

$$r_P(k) = [\alpha(1+k) - \rho k]\frac{e}{1+e}, \tag{3.11}$$

where

$$e = \frac{r}{D}\frac{\partial D}{\partial r}. \tag{3.12}$$

is a measure of deposit market competition.

Meanwhile, the bank chooses the lowest possible capital level ($k_P = 0$) since

$$\frac{\partial V_P(r, r_{-i}, k)}{\partial k} < 0. \tag{3.13}$$

According to (3.9), the threshold deposit rate $\hat{r}(k, d)$ of a bank that does not discount future ($\delta = 1$) is $\alpha(1+k) - \rho k$ and is greater than the deposit rate $r_P(k)$ in (3.11). This means that the bank chooses the prudent asset regardless of the degree of market competition (the value of e).

The second case is the one in which the bank chooses the risky asset in equilibrium. In this case, the bank's optimal deposit rate r_G and capital k_G solve the following problem

$$(r_G, k_G) = \arg\max_{r,k}\{V_G(r, r_{-i}, k, d)\}. \tag{3.14}$$

According to the first-order condition, the deposit rate that the bank offers in this case is

$$\begin{aligned} r_G(k,d) &= [\frac{\alpha + w(1-\theta_1-\theta_2)}{\theta_1+\theta_2}(1+k) - d - \frac{(\rho+1-\theta_1-\theta_2)k}{\theta_1+\theta_2}]\frac{e}{1+e}, && (3.15)\\ &\equiv \tilde{r}_G(k,d)\frac{e}{1+e}. && (3.16)\end{aligned}$$

Similarly, we have

$$\frac{\partial V_G(r, r_{-i}, k, d)}{\partial k} < 0, \ if \ \rho > \alpha + (1-\theta_1-\theta_2)(w-1). \tag{3.17}$$

That is, the bank holds no capital ($k_G = 0$) if the cost of capital is sufficiently high ($\rho > \alpha + (1 - \theta_1 - \theta_2)(w - 1)$).

Having seen two deposit rates in (3.11) and (3.15), readers may wonder which rate the bank actually offers depositors. The answer is found by comparing these rates with the threshold rate in (3.9). If the deposit rate in (3.11) is below the threshold, the bank chooses to hold the prudent asset and offers r_P. Otherwise, the bank chooses to hold the risky asset and offers r_G.

The equilibrium without capital regulation and deposit insurance We start with a deposit insurance scheme adopted by HMS. That is, deposit insurance entails no expense to the bank ($d = 0$). With this deposit insurance scheme[11], when the bank has a positive discount rate ($\delta < 1$), the condition under which the bank will choose the risky asset is summarized in Proposition 1.

Proposition 1 *If* (1) *deposit insurance does not increase bank expense*($d = 0$); (2) *the bank discounts the future* ($\delta < 1$); (3) *bank capital is costly* ($\rho > \alpha + (1 - \theta_1 - \theta_2)(w - 1)$); (4) *there are no capital adequacy requirements, then the bank invests in the risky asset and pays*

$$r_G(0,0) = \frac{\alpha + w(1 - \theta_1 - \theta_2)}{\theta_1 + \theta_2} \frac{e}{1 + e} \tag{3.18}$$

to depositors when the deposit market is sufficiently competitive

$$e > \frac{\hat{r}(0,0)}{\tilde{r}_G(0,0) - \hat{r}(0,0)} \equiv \hat{e}(k,d)_{k=d=0}, \tag{3.19}$$

[11]I start with an assumption that depositors have deposit insurance. Without deposit insurance, the equilibrium result can still be that banks choose the risky asset and depositors go along. Normally, when the bank offers a deposit rate that violates the "no-risky-asset" condition, depositors realize that the bank is choosing the risky asset. This restricts the quantity of deposits the bank can attract. But, as shown by HMS, it does not preclude an equilibrium in which the bank holds the risky asset.

where

$$\begin{aligned}\hat{r}(0,0) &= -(1-\delta)w + \delta\alpha, \\ \tilde{r}_G(0,0) &= \frac{\alpha + w(1-\theta_1-\theta_2)}{\theta_1+\theta_2}.\end{aligned}$$

Proof *According to (3.13) and (3.17), without capital adequacy requirements, the bank will choose not to hold capital ($k_P = k_G = 0$). Since the bank keeps no capital and pays no deposit insurance premium, according to (3.8), the necessary and sufficient condition for the bank to invest in the risky asset is*

$$r_G(0,0) > \hat{r}(0,0), \tag{3.20}$$

where $r_G(0,0)$ and $\hat{r}(0,0)$ are defined in (3.15) and (3.9), respectively. This leads to

$$e > \frac{\hat{r}(0,0)}{\tilde{r}_G(0,0) - \hat{r}(0,0)} \equiv \hat{e}(k,d)_{k=d=0}, \tag{3.21}$$

where $\tilde{r}_G(0,0)$ is defined in (3.16).

According to (3.11) and (3.15), other things equal, greater the interest rate elasticity of deposits (e) the higher the deposit rate the bank will offer and the lower the bank's profits and expected future values as an ongoing institution (franchise values). To be more precise, we can verify that

$$\begin{aligned}\frac{\partial V_P(r_P, r_P, k)}{\partial e} &< 0, \\ \frac{\partial V_G(r_G, r_G, k, d)}{\partial e} &< 0.\end{aligned}$$

The conclusion is that the more competition the bank faces, the lower will be its franchise values and the more risk it will take. From this relationship, lower franchise values are related to more risk-taking. This is called the Franchise Value Hypothesis.

Since I intend to study prudential policies, I am more interested in the effects of capital regulation and deposit insurance. Rewriting $\hat{e}$ in (3.19) based on the definitions of $\hat{r}(k,d)$ and $\tilde{r}_G(k,d)$ in (3.9) and (3.16) yields,

$$e > \frac{\hat{r}(k,d)}{\tilde{r}_G(k,d) - \hat{r}(k,d)} \equiv \hat{e}(k,d), \tag{3.22}$$

it is clear that bank capital level k and insurance premium d affect the bank's risk-taking through the cut-off value for market competitiveness $\hat{e}$. Given market competitiveness e, if prudential policies tend to mitigate the bank's risk-taking, both bank capital k and insurance premium d should be increasing in the cut-off value $\hat{e}(k,d)$.

It is not difficult to check this conclusion. Applying the comparative static results ((3.23), (3.24), (3.25) and (3.26)) of (3.9) and (3.16) in (3.22), we have

$$\frac{\partial \hat{r}(k,d)}{\partial k} = -(1-\delta)w + \delta\alpha - \delta\rho + 1 - \delta, \tag{3.23}$$

$$\frac{\partial \hat{r}(k,d)}{\partial d} > 0, \tag{3.24}$$

$$\frac{\partial \tilde{r}_G(k,d)}{\partial k} = -\frac{\rho - \alpha + (1-\theta_1-\theta_2)(1-w)}{\theta_1+\theta_2}, \tag{3.25}$$

$$\frac{\partial \tilde{r}_G(k,d)}{\partial d} < 0. \tag{3.26}$$

Note that the cut-off point $\hat{e}(k,d)$ is increasing in d, as we expected. Higher insurance premium controls the bank's risk-taking. However, the result for bank capital k depends on the discount factor δ and the cost of bank capital ρ. Holding more capital mitigates risk-taking only when the bank is myopic. That is,

$$\hat{e}(k,d) \textit{ is increasing in } k \;\; \textit{if } \rho > \alpha + (1-\theta_1-\theta_2)(w-1) \textit{ and } \delta < \frac{1-w}{1-w+\rho-\alpha}. \tag{3.27}$$

For a patient bank ($\delta > \frac{1-w}{1-w+\rho-\alpha}$), the negative franchise-value effect of holding capital may dominate the effect that the bank bears the risk of losing the capital

(capital-at-risk effect). As a result, the bank may choose to take more risks even if it has more capital. In general, the relationship between $\hat{e}(k, d)$ and k becomes ambiguous.

We have examined the impact of market competitiveness e, bank capital k and deposit insurance premium d on the bank's risk-taking behavior. Are these the only factors affect the bank's risk-taking? Certainly not. The cost of bank capital ρ and the attributes of assets (such as the risk premium w) influence the bank's behaviors as well. Using the framework presented above, we see that these factors affect the bank's risk-taking through the cut-off value $\hat{e}(k, d)$. Simple computation tells us that a higher risk premium w induces more risk-taking, that is,

$$\frac{\partial \hat{e}(k, d)}{\partial w} < 0. \tag{3.28}$$

However, the result for the cost of capital ρ is generally ambiguous. In the special case that the bank does not discount the future ($\delta = 1$) and deposit insurance is free ($d = 0$), it is possible to show that higher capital cost ρ induces more risk-taking,

$$\frac{\partial \hat{e}(k, d)_{\delta=1,d=0}}{\partial \rho} < 0. \tag{3.29}$$

Taken together, the bank's risk-taking depends on market competition, the cost of bank capital, investment opportunities and prudential policies. I summarize all the results obtained so far in Table 3.1.

Moral hazard in banking

We have seen that in an environment without regulation, so there is no capital regulation or costly deposit insurance, a bank will invest in the risky asset in equilibrium when the market is sufficiently competitive. In this section, we show that moral

Factors	**Change in factor**	**Change in risk-taking**
Degree of competition e	increase	increase
Deposit insurance premium d	increase	decrease
Bank capital k	increase	decrease if $\delta < \frac{1-w}{1-w+\rho-\alpha}$ uncertain if $\delta > \frac{1-w}{1-w+\rho-\alpha}$
Risk premium w	increase	increase
Cost of bank capital ρ	increase	uncertain

Table 3.1: Factors Affecting the Risk-taking of a Bank with Moral Hazard

hazard can lead the bank to invest in the risky asset excessively. This is relative to the behavior of the bank without moral hazard, which is discussed below. Prudential banking policies can help control this moral hazard. In addition, there is a consensus among both economists and policymakers that capital adequacy requirements and deposit insurance form an effective basis for prudential banking policies. While in reality capital regulation coexists with deposit insurance, little is known about how these two policies complement one another. A careful study of how the effects of one policy depend on the extent and quality of another policy is desirable. This is particularly important when the policymakers who conduct these two policies act separately. When facing a changing environment (such as the investment opportunities and the cost of raising capital) that could lead a bank to take excessive risk, these two groups of policymakers need to work together to formulate an optimal strategy in order to control the moral hazard in banking.

Before starting to study prudential policies (capital adequacy requirements and deposit insurance), it is worthwhile to examine the consequences of moral hazard in more detail. To see this, we need to compute a benchmark that represents the behavior of the bank in the absence of moral hazard. As a benchmark, when the bank makes decisions about its asset allocation and liability management, it fully considers downside risks as if the bank were using its own money. More concretely, when determining whether to hold the risky asset, the bank considers not only the likelihood that the asset will generate a high and medium return (γ and α), but also the consequence if the asset yield turns out to be low (β).

First of all, if investing in the prudent asset, the bank has no moral hazard problem since the return on the investment is riskfree. Therefore, the bank's per-period profit without moral-hazard are the same as in (3.2) and (3.5). That is,

$$\pi_{OP}(r_i, r_{-i}, k) = m_P(r_i, k)D(r_i, r_{-i}) \quad \textit{if the bank chooses the prudent asset,} \tag{3.30}$$

where

$$m_P(r_i, k) = \alpha(1 + k) - \rho k - r_i. \tag{3.31}$$

And the bank's profit from holding the prudent asset over a sufficiently long horizon is

$$V_{OP}(r_i, r_{-i}, k) = \frac{\pi_{OP}(r_i, r_{-i}, k)}{1 - \delta}. \tag{3.32}$$

Next, if investing in the risky asset, the bank's per-period profit without moral-hazard is

$$\pi_{OG}(r_i, r_{-i}, k) = m_{OG}(r_i, k)D(r_i, r_{-i}), \tag{3.33}$$

where

$$m_{OG}(r_i, k) = [\theta_1\alpha + \theta_2\gamma + (1 - \theta_1 - \theta_2)\beta](1 + k) - r_i - \rho k - (1 - \theta_1 - \theta_2)k. \tag{3.34}$$

The bank's expected profit from holding the risky asset over a sufficiently long horizon is

$$V_{OG}(r_i, r_{-i}, k) = \frac{\pi_{OG}(r_i, r_{-i}, k)}{1 - \delta(\theta_1 + \theta_2)}. \tag{3.35}$$

In the case without moral hazard, deposit insurance is not necessary from society's perspective. Therefore, the bank's profits do not depend on the size of the deposit insurance premium.

The benchmark bank holds no capital, since the partial derivatives of the discounted future profits with respect to bank capital k are negative (if the cost of capital ρ is sufficiently large) in (3.13) and (3.36).

$$\frac{\partial V_{OG}(r_i, r_{-i}, k)}{\partial k} = -(\rho - \alpha) - (1 - \theta_1 - \theta_2)(1 - w) < 0. \tag{3.36}$$

As for asset allocation, the bank chooses the prudent asset if $V_{OP}(r_i, r_{-i}, k) > V_{OG}(r_i, r_{-i}, k)$ and chooses the risky asset otherwise. From this relationship, we can derive a "no-risky-asset condition" for the bank in the absence of moral hazard. That is,

$$\textit{The bank chooses the prudent asset, if } r_i < \hat{r}_O(k), \tag{3.37}$$

$$\textit{The bank chooses the risky asset, if } r_i > \hat{r}_O(k), \tag{3.38}$$

where

$$\hat{r}_O(k) = -(1+k)(\frac{1-\delta}{\delta})w + \alpha(1+k) + \frac{1-\delta-\delta\rho}{\delta}k. \tag{3.39}$$

As for the deposit rate, if investing in the prudent asset, the bank offers the same deposit rate as (3.11),

$$r_{OP}(k) = [\alpha(1+k) - \rho k]\frac{e}{1+e}. \tag{3.40}$$

If investing in the risky asset, the bank offers a deposit rate r_{OG} that solves the following problem,

$$(r_{OG}, k_O) = \arg\max_{r,k}\{V_{OG}(r, r_{-i}, k)\}. \tag{3.41}$$

From the first-order condition with respect to the interest rate evaluated at a symmetric equilibrium, we can solve for

$$r_{OG}(k) = \frac{e}{1+e}\{[\alpha+(1-\theta_1-\theta_2)w](1+k)-\rho k-(1-\theta_1-\theta_2)k\} \equiv \tilde{r}_{OG}(k)\frac{e}{1+e}. \tag{3.42}$$

We are now ready to characterize bank behavior *without* moral hazard. In particular, we can compare the result with the result for the bank *with* moral hazard discussed earlier. The purpose is to see if the bank *with* moral hazard invests excessively in the risky asset. I summarize the result in Proposition 2.

Proposition 2 *If* (1) *the bank discounts the future* ($\delta < 1$)*; (2) bank capital is costly enough* ($\rho > \alpha + (1-\theta_1-\theta_2)(w-1)$); (3) *the bank does not have a moral hazard problem, that is, it fully considers downside risks; (4) there are no prudential banking policies, such as capital adequacy requirements and deposit insurance, then the bank without moral hazard invests in the risky asset and pays*

$$r_{OG}(0) = [\alpha + w(1-\theta_1-\theta_2)]\frac{e}{1+e} \tag{3.43}$$

to depositors when the deposit market is sufficiently competitive

$$e > \frac{\hat{r}_O(0)}{\tilde{r}_{OG}(0) - \hat{r}_O(0)} \equiv \hat{e}_O(k)_{k=0}, \tag{3.44}$$

where

$$\begin{aligned} \hat{r}_O(0) &= -\frac{1-\delta}{\delta}w + \alpha, \\ \tilde{r}_{OG}(0) &= \alpha + w(1-\theta_1-\theta_2). \end{aligned}$$

In addition, the cut-off value of market competition for the bank without moral hazard (defined in (3.44)) *is higher than that for the bank with moral hazard (defined in* (3.19)). *That is,*

$$\hat{e}_O(k)_{k=0} > e(k,d)_{k=d=0}. \tag{3.45}$$

This says that the bank with moral hazard tends to invest excessively in the risky asset.

Proof *According to (3.13) and (3.36), in the absence of capital adequacy requirements, the bank will choose not to hold capital. As the bank keeps no capital, according to (3.38), the necessary and sufficient condition for the bank to invest in the risky asset is*

$$r_{OG}(0) > \hat{r}(0), \tag{3.46}$$

where $r_{OG}(0)$ *and* $\hat{r}(0)$ *are defined in (3.42) and (3.39), respectively. This leads to*

$$e > \frac{\hat{r}_O(0)}{\tilde{r}_{OG}(0) - \hat{r}_O(0)} \equiv \hat{e}_O(k)_{k=0}, \tag{3.47}$$

where $\tilde{r}_{OG}(0)$ *is defined in (3.42).*

Comparing (3.39) *and* (3.9), *we see that the threshold rate for the bank without moral hazard* ($\hat{r}_O(k)$) *is greater than the threshold rate for the bank with moral hazard if* $d = 0$ ($\hat{r}(k,d)_{d=0}$). *Similarly, comparing* (3.42) *and* (3.15), *we see that the deposit rate for the bank without moral hazard* ($r_{OG}(k)$) *is lower than the rate for the bank with moral hazard when* $d = 0$ ($r_G(k,d)_{d=0}$). *That is,*

$$\begin{aligned} \hat{r}_O(k) &> \hat{r}(k,d)_{d=0}, \\ r_{OG}(k) &< r_G(k,d)_{d=0}. \end{aligned}$$

This leads to the conclusion that moral hazard distorts the bank's decisions on its asset allocation and liability management so that

$$\hat{e}_O(k)_{k=0} > e(k,d)_{k=d=0}, \tag{3.48}$$

which suggests that the bank will choose the risky asset when it should choose the prudent asset.

Optimal prudential policies

Following HMS, Marshall and Prescott (2000) and Prescott (2002), I focus exclusively on the distortion induced by moral hazard. I do not address other important distortions such as those caused by owner/management relationship, deadweight costs of failure resolution and taxation that is used to pay off depositors of failed banks. Given this, the policymaker's objective is to ensure that the behavior of the bank with moral hazard are the same as the behavior of the benchmark bank without moral hazard (or as close as possible). In other words, the optimal policies are defined as a set of (k^*, d^*) such that

$$\begin{aligned} \hat{r}_O(k^*) &= \hat{r}(k^*, d^*), \\ r_{OG}(k^*) &= r_G(k^*, d^*). \end{aligned}$$

By simple computation, we find the solution for optimal required bank capital k^* and optimal deposit insurance premium d^*. We summarize the result in Proposition 3.

Proposition 3 *If (1) the bank is required to hold minimum bank capital* k; *(2) deposit insurers can observe whether the bank invests in the risky or prudent asset;*

(3) deposit insurance is risk-based, that is, the bank that invests in the risky asset pays a deposit insurance premium d, while the bank that invests in the prudent asset does not pay the premium; (4) *the bank discounts the future* ($\delta < 1$)*; and (5) bank capital is costly enough* ($\rho > \alpha + (1 - \theta_1 - \theta_2)(w - 1)$)*; then there exists a set of optimal prudential policies* (k^*, d^*) *such that*

$$\hat{r}_O(k^*) = \hat{r}(k^*, d^*), \tag{3.49}$$

$$r_{OG}(k^*) = r_G(k^*, d^*). \tag{3.50}$$

The optimal policy is given by

$$k^* = \frac{w}{1-w}, \tag{3.51}$$

$$d^* = (\frac{1}{\theta_1 + \theta_2} - 1)\frac{\alpha - w\rho}{1 - w}. \tag{3.52}$$

Under this optimal prudential policy, the bank's excessive risk-taking is eliminated entirely. The bank chooses to invest in the prudent asset and offer a deposit rate

$$r_{OP}(k^*) = \frac{\alpha - w\rho}{1 - w}\frac{e}{1 + e}. \tag{3.53}$$

.

Proof *Following* (3.49) *and* (3.50) *and using* (3.9), (3.15), (3.39) *and* (3.42), *we obtain the results in* (3.51) *and* (3.52).

Under the optimal policy, the bank chooses the prudent asset in equilibrium since the deposit rate $r_{OP}(k^*)$ *is lower than the threshold rate* $\hat{r}(k^*, d^*)$,

$$\hat{r}(k^*, d^*) = \frac{\alpha - w\rho}{1 - w} > \frac{\alpha - w\rho}{1 - w}\frac{e}{1 + e} = r_{OP}(k^*). \tag{3.54}$$

From (3.51) and (3.52), it is not surprising to see that the optimal policy changes with the cost of bank capital (ρ) and the attributes of the assets (such as the risk premium w) since these factors affect the bank's risk-taking.

Moreover, since the bank invests in the prudent asset in the optimal-policy equilibrium, no deposit insurance premium is collected and no bank becomes insolvent. However, there is a cost of having the bank hold capital k^*, which is not optimal for the bank without moral hazard.

We have shown in Proposition 2 that the bank will choose the risky asset when the deposit market is sufficiently competitive, as the bank without moral hazard does not hold capital unless it is required to do so, But if there is capital regulation as in Proposition 3, the bank without moral hazard may not want to choose the risky asset. We can verify this by evaluating the "no-risky-asset" condition. That is,

$$r_O(k^*) = \frac{1-\rho w}{1-w} > r_{OG}(k^*) = \frac{1-\rho w}{1-w}\frac{e}{1+e}. \tag{3.55}$$

This implies that the impact of capital regulation is twofold: On the one hand, it restricts the bank's *excessive* risk-taking; On the other hand, it tempers the bank's *legitimate* incentive to invest in the risky asset.

Finally, while HMS suggest using a combination of deposit rate control and capital adequacy requirements, we use their model to show that deposit rate control is not necessary. This result comes from the introduction of a risk-based deposit insurance scheme. HMS only considers an insurance scheme with flat-rate premium. In other words, the main difference between my work and that of HMS is that I take deposit insurance as an active policy tool to control moral hazard (along with other policies), while HMS did not consider deposit insurance as a control variable for policymakers.

3.2.2 Private Information

In this section, I develop a variant of the model in the previous section in which banks have private information. The goal is to demonstrate that a well-designed set of prudential policies can still control moral hazard. When regulators cannot observe the risk characteristics of a bank's investment decisions, we say that the bank has private information. There are good reasons to believe that this is the information environment that regulators are more likely to deal with.

The information structure of this model is as follows: Unlike in the previous section, now the insurer does not observe whether the bank chooses the prudent asset or the risky asset. Instead, I assume that the insurer observes the bank's realized returns from its investment. According to the assumed payoff structure of assets, the insurer will know that the bank chooses the risky asset if the return is high (γ) or low (β). Nevertheless, with a medium-level return (α), the insurer has no idea whether the bank chooses the prudent asset or the risky asset.

With this information structure, it is possible to introduce a performance-based deposit insurance. Assume that the insurer can charge a high insurance premium d_h if the bank's return is high (γ) and a low insurance premium d_l if the bank's return is at the medium level (α). If the return is low (β), the bank closes and does not pay premium.

This insurance scheme is *incentive compatible*. Banks with high return (γ) have no incentive to claim they choose the prudent asset since no one will believe them. Banks with the medium-level return (α) have no incentive to lie since the premium (d_l) is the same regardless of the strategy the bank takes.

with performance-based deposit insurance, the bank choosing the prudent asset is required to pay insurance premium d_l. The per-period profit of the bank when it invests in the prudent asset $\pi_P(r_i, r_{-i}, k)$ equals the return from the prudent asset $\alpha(1+k)D(r_i, r_{-i})$ minus the sum of (1) the cost of capital $\rho k D(r_i, r_{-i})$, (2) deposit repayments $r_i D(r_i, r_{-i})$ and (3) the deposit insurance premium $d_l D(r_i, r_{-i})$. When choosing the risky asset, the bank (as an ongoing institution) not only needs to repay deposits but also assumes that it will face the performance-based insurance. Putting all of this together, we can write the bank's per-period expected profit as

$$\begin{aligned} \pi_P(r_i, r_{-i}, k, d_l) &= m_P(r_i, k, d_l) D(r_i, r_{-i}) \\ &\quad \textit{if the bank chooses the prudent asset}, \qquad (3.56) \\ \pi_G(r_i, r_{-i}, k, d_h, d_l) &= m_G(r_i, k, d_h, d_l) D(r_i, r_{-i}) \\ &\quad \textit{if the bank chooses the risky asset}, \qquad (3.57) \end{aligned}$$

where

$$\begin{aligned} m_P(r_i, k, d_l) &= \alpha(1+k) - \rho k - r_i - d_l, \\ m_G(r_i, k, d_h, d_l) &= (\theta_1 \gamma + \theta_2 \alpha)(1+k) - (\theta_1 + \theta_2) r_i - \theta_1 d_h - \theta_2 d_l \\ &\quad - \rho k - (1 - \theta_1 - \theta_2) k. \end{aligned}$$

The bank's expected profit from holding the prudent asset over a sufficiently long horizon is

$$V_P(r_i, r_{-i}, k, d_l) = \frac{\pi_P(r_i, r_{-i}, k, d_l)}{1-\delta}, \qquad (3.58)$$

while the bank's expected profit from holding the risky asset over a sufficiently long horizon is

$$V_G(r_i, r_{-i}, k, d_h, d_l) = \frac{\pi_G(r_i, r_{-i}, k, d_h, d_l)}{1-\delta(\theta_1+\theta_2)}. \tag{3.59}$$

As for the bank's asset allocation, the bank chooses the prudent asset if $V_P(r_i, r_{-i}, k, d_l)$ is greater than $V_G(r_i, r_{-i}, k, d_h, d_l)$ but chooses the risky asset otherwise. From this condition, we can derive a "no-risky-asset condition." That is,

$$\textit{The bank chooses the prudent asset, if } r_i < \hat{r}(k, d_h, d_l), \tag{3.60}$$

$$\textit{The bank chooses the risky asset, if } r_i > \hat{r}(k, d_h, d_l), \tag{3.61}$$

where

$$\hat{r}(k, d_h, d_l) = -(1+k)(1-\delta)w+\delta\alpha(1+k)+(1-\delta-\delta\rho)k+\frac{(1-\delta)d_h\theta_1+(\theta_2+\delta\theta_1-1)d_l}{1-\theta_1-\theta_2}. \tag{3.62}$$

As for the deposit market, if the bank chooses to hold the prudent asset, it solves the following problem

$$(r_P, k_P) = \arg\max_{r,k}\{V_P(r, r_{-i}, , k, d_l)\}. \tag{3.63}$$

The first-order condition evaluated at a symmetric equilibrium (i.e., $r_{-i} = r_P$) yields the deposit rate the bank will offer

$$r_P(k, d_l) = [\alpha(1+k) - \rho k - d_l]\frac{e}{1+e}, \tag{3.64}$$

where

$$e = \frac{r}{D}\frac{\partial D}{\partial r}. \tag{3.65}$$

If the bank chooses to hold the risky asset, it solves the following problem

$$(r_G, k_G) = \arg\max_{r,k}\{V_G(r, r_{-i}, k, d_h, d_l)\}. \tag{3.66}$$

The deposit rate that the bank offers in this case is

$$r_G(k, d_h, d_l) = [\frac{\theta_1\gamma + \theta_2\alpha}{\theta_1 + \theta_2}(1+k) - \frac{\theta_1 d_h}{\theta_1 + \theta_2} - \frac{\theta_2 d_l}{\theta_1 + \theta_2} - \frac{(\rho + 1 - \theta_1 - \theta_2)k}{\theta_1 + \theta_2}]\frac{e}{1+e}. \quad (3.67)$$

It is easy to verify that the moral hazard problem remains in this case. The bank has an incentive to take excessive risks since

$$\hat{r}_O(k) > \hat{r}(k, d_h, d_l)_{d_h = d_l = 0},$$
$$r_{OG}(k) < r_G(k, d_h, d_l)_{d_h = d_l = 0}.$$

To see how moral hazard can be controlled, I find the optimal policies (k^{**}, d_h^*, d_l^*) under which the bank's behavior is the same as the benchmark behavior of the bank without moral hazard. That is, the following conditions need to hold in order for the policy to be optimal.

$$r_P(k^{**}, d_l^*) = r_{OP}(k^{**}), \quad (3.68)$$
$$r_G(k^{**}, d_h^*, d_l^*) = r_{OG}(k^{**}), \quad (3.69)$$
$$\hat{r}(k^{**}, d_h^*, d_l^*) = \hat{r}_O(k^{**}). \quad (3.70)$$

The results relating to the optimal policies are summarized in Proposition 4.

Proposition 4 *If (1) the bank is required to hold minimum bank capital k; (2) deposit insurers can observe the returns on the bank's investment but cannot observe whether the bank invests in the risky or prudent asset; (3) the deposit insurance is performance-based, that is, the bank pays high insurance premium d_h if the return is high (γ), and pays low insurance premium d_l if the return is medium-level (α) and pays no premium if the return is low (β); (4) the bank discounts the future ($\delta < 1$),* *(5) bank capital is costly enough ($\rho > \alpha + (1-\theta_1-\theta_2)(w-1)$), then there exists a set of optimal prudential policies (k^{**}, d_h^*, d_l^*) such that*

$$\begin{aligned} r_P(k^{**}, d_l^*) &= r_{OP}(k^{**}), \\ r_G(k^{**}, d_h^*, d_l^*) &= r_{OG}(k^{**}), \\ \hat{r}(k^{**}, d_h^*, d_l^*) &= \hat{r}_O(k^{**}). \end{aligned}$$

The optimal policy is given by

$$k^{**} = \frac{w}{1-w}, \tag{3.71}$$

$$d_h^* = (\frac{1-\theta_1-\theta_2}{\theta_1})\frac{\alpha - w\rho}{1-w}, \tag{3.72}$$

$$d_l^* = 0. \tag{3.73}$$

Under the optimal prudential policy, the bank's excessive risk-taking is eliminated entirely. The bank chooses to invest in the prudent asset and offer

$$r_P(k^{**}, d_l^*) = \frac{\alpha - w\rho}{1-w}\frac{e}{1+e}. \tag{3.74}$$

Proof *According to (3.71) and comparing the deposit rate in* (3.64) *to the benchmark rate in* (3.40)*, we can conclude that* $d_l = 0$.

Following (3.68), (3.69), (3.70) *and using* (3.39), (3.42), (3.40), (3.62), (3.64) *and* (3.67)*, we obtain the results in* (3.71), (3.72) *and* (3.73).

Under the optimal policy, the bank chooses the prudent asset in equilibrium since the deposit rate $r_P(k^{**}, d_l^*)$ is lower than the threshold rate $\hat{r}(k^{**}, d_h^*, d_l^*)$,

$$\hat{r}(k^{**}, d_h^*, d_l^*) = \frac{\alpha - w\rho}{1-w} > \frac{\alpha - w\rho}{1-w}\frac{e}{1+e} = r_P(k^{**}, d_l^*). \tag{3.75}$$

There is an alternative deposit insurance scheme, in which insurance premia are contingent upon both performance (the return on assets) and bank capital. Under that scheme, the optimal insurance premium for medium-level returns is still zero, while the premium for high returns is decreasing in bank capital. It can be shown that the optimal capital level and insurance premium for the bank with high returns are the same as those in (3.71) and (3.72). But this does not imply that such deposit insurance alone is sufficient to control moral hazard entirely since the bank has no incentive to hold bank capital. To ensure that the bank holds enough capital, capital adequacy requirements are necessary. The conclusion is that the result carries through when deposit payments are contingent upon bank capital.

3.3 Empirical Analysis

To date no comprehensive empirical study to date has investigated the simultaneous effects of franchise values, capital adequacy requirements and deposit insurance on risks in banking. The empirical part of this chapter is an attempt to fill this gap.

3.3.1 Related Literature

In the seminal work of Diamond and Dybvig (1983), deposit insurance is an optimal policy to control self-fulfilling depositors runs. As long as the insurance and guarantees are credible, the threat of depositors runs can be effectively eliminated. However, banking economists also realize the long-run adverse effect of deposit insurance. In the presence of deposit insurance, banks' ability to attract deposits no longer reflects the risk of their asset portfolio. Banks have an incentive to choose more risky assets, which is detrimental to depositors.

Moral hazard is often the focus of the literature relating to deposit insurance. Robert C. Merton (1977) viewed deposit insurance as a put option on bank assets at a strike price equal to the value of banks' liability at promised maturity. Banks have an incentive to maximize the value of the put option since they can transfer wealth from the insurance agency. But as shown by Marcus and Shaked (1984) and others, for most of its history before early the 1980s, the Federal Deposit Insurance Corporation (FDIC) had low payouts and insured banks had low failure rates. This is inconsistent with banks maximizing the option value. Why bank failures and insurance payouts had increased significantly since the early 1980s. Kling (1986) suggested that the economic downturn and more volatile interest rate could explain the deterioration of banks' balance sheets. In fact, the average market value for the 25 largest US banks (capitalized franchise values) had dropped below the book value during period 1974 - 1986. Furlong and Keeley (1987) argued that lower capital-to-asset ratios give banks more incentive to take risks. Keeley (1990) further pointed out that the degree of competition in the industry plays an important role. When bank charters are limited, banks are protected from competition and their franchise values are enhanced. All these regulatory barriers might explain why banks did not maximize the value of the put option (deposit insurance) before the early 1980s.

Regulatory liberalization eroded franchise values (such as the Depository Institutions Deregulation and Monetary Control Act of 1980 and the Garn-St. Germain Depository Institutions Act of 1982) and increased competition after the early 1980s. This may explain the lower capital-to-asset ratios, less prudent risk-taking activities and the rise in banking failures starting from the early 1980s through the early 1990s. Keeley (1990) employed a state preference model to show the relationship between franchise values and market power. He studied the factors determining banks' risk-taking. The most important is franchise values, proxied by the market power of banks. The measures of bank risk-taking include: the market-value capital-to-asset ratio and the interest cost on large, uninsured CDs. The result is that higher market power leads to higher franchise values and lower risk-taking by banks.

Normally, even when facing external pressures from competition, banks will not invest their own money in highly risky projects. But with limited liability, they are willing to take excessive risks. Therefore, it is impossible to exclude risk-shifting as an explanation for the large number of bank failures. However, moral hazard cannot explain the cross-section variation among banks' risk-taking. Hence, the question is how to explain the variation in bank's risk-taking within a framework of moral hazard. An important result as summarized by Park (1997) is that "Moral hazard models show that the expected wealth of stockholders is a monotonically increasing function of risk. For banks with larger charter values, the option value arising from limited liability is smaller but still increases risk." This result suggests that without any regulation banks should take the maximum amount of risks. In other words, the general solution to the problem lies on the boundary, not in the interior of parameter space. The natural conjecture about why banks do not take maximum risks is that bank regulations prevent them (see Bhattacharya and Thakor, 1993 for a detailed review of this literature).

There is a vast literature on bank regulation. Kahane (1977) modeled bank regulation as restrictions on both capital-to-asset ratios and asset portfolio composition, but with a framework that does not focus on moral hazard. That is, Kahane studied banks that minimize the variance of income for a given level of income. Buser et al.

(1981) assumed that banks restrict themselves from taking excessive risks since they do not want regulators to classify them as risky banks and be forced to pay a high deposit insurance premium. But the regulation they considered is leverage only and they did not explain why banks would hold excessive buffer capital. Cambell et al. (1992) investigated socially optimal regulation in terms of both capital requirements and direct monitoring but without looking at how banks react to the regulations. Besanko and Kanatas (1996) considered the relationship between the value of banks and capital requirements but again in a framework emphasizing manager's efforts rather than moral hazard.

Park (1997) studied bank regulation in terms of both capital requirements and asset portfolio restrictions within a framework of moral hazard, assuming that banks maximize the value of the put option. The key feature is that "a bank cannot expect a positive option value arising from limited liability if it is classified as risky by regulators." To explain the variation of risk-taking across banks, Park (1997) assumed that banks face different investment opportunities and have different franchise values. An interesting result is that when regulation is lax, banks with high franchise values may take more risks. It is also possible that tight regulation will lower the optimal capital-to-asset ratio because banks will reduce their assets in order to avoid being classified as risky by regulators. That is, the banks' control variables are not necessarily monotonic functions of regulatory parameters. One interesting result in Park (1997) is that a larger franchise value may induce higher risk-taking unless regulation is effective[12]. However, Park (1997) did not conduct any empirical work. Lee (1998) reported that the franchise values of banks in Asian countries did

[12] Park (1997)'s model also can show that a small change of regulation can induce banks with a larger franchise value to switch from taking more risks to taking no risks.

not generate prudent behaviors during the five years preceding the financial crisis. Saunders and Wilson (2001) conducted a test for the franchise value hypothesis and concluded that the relationship between franchise values and bank's leverage ratio is sensitive to market condition.

While both capital and franchise values temper moral hazard, Demsetz et al. (1996) argued that franchise values will "more consistently align the incentives of the bank owner with those of the supervisor", since the determinants of franchise values are more stable and less specific. In contrast, bank capital, even minimum capital requirements, should generally vary depending on each bank's investment opportunities, interest rate, franchise value and general economic situation. Demsetz et al. (1996) found a negative relationship between risk-taking and franchise values. The measure of risk-taking they employed is based on the volatility of bank stock returns, which incorporate the risks of all aspects of bank's balance sheets, such as asset, liability, off-balance-sheet and leverage, etc.

The recent empirical evidence about deposit insurance is in Demirguc-Kunt and Detragiache (2002). They report that deposit insurance tends to increase the likelihood of banking crises. While economists criticize classical deposit insurance for inducing moral hazard, Hovakimian, Kane and Laeven (2003) find that external risk-control measures (such as risk-sensitive deposit insurance premiums, coverage limits and coinsurance) can temper the risk-shifting incentive significantly. According to the summary statistics of their data, the insurance schemes in more than 20 percent of the countries in their sample are risk-sensitive. Again, based on their summary statistics, deposit insurance has coinsurance characteristics in about 15 percent of the countries in their sample.

Finally, an appropriate ownership structure (managerial risk aversion) also helps to mitigate moral hazard. Demsetz et al. (1997) considered the ownership structure using a unified model with both franchise values and the owner/manager agency problem. They found owner/agency problems are important only for banks with a low franchise value and no insider holding. But since most banks increase their insider holding shortly, the owner/agency problems are usually resolved quickly.

3.3.2 Data Description

The data come from several sources. Data on banks' balance sheet variables and stock markets (share prices) come from Datastream International (DS accounting items and capital items). These banks are listed on stock markets in different countries. Datastream picks these banks to represent the banking sector of each country based on their market capitalization.

As in Demsetz et al. (1996), I measure banks' risk-taking using stock-return volatility (RT_{jt})[13], incorporating the risks of banks' assets, liabilities, capital, off-balance sheet positions and leverage[14]. I compute the standard deviation of weekly

[13] In this section, the subscripts j, i and t denote bank j, country i and year t, respectively.

[14] Generally speaking, using stock return deviation as a measure of risk-taking is standard in the banking literature. According to Demsetz, Sadenberg and Starhan (1996), stock returns reflect changes in the market's perceptions of future profitability. Therefore, a high standard deviation in the returns indicates that the expected profits of a bank are fluctuating rapidly - a sign that the bank is pursuing risky activities. Flanney (1998) summarizes that empirical literature provided broad support for the hypothesis that bank equity investors incorporate risk-related information into bank's stock prices. Demsetz, Sadenberg and Strahan (1997)'s primary measure of risk is the annualized standard deviation of the weekly stock return (equity risk) for a give bank in a given year. Akhigbe and Whyte (2001) found that FDICIA had a generally positive effect on bank stock returns and resulted in a significant reduction in bank risk. Brewer, Genay, Hunter and Kaufman (2003) argued that despite the alleged opaqueness of banking activities, bank shareholders were able to use available indications of financial condition both to incorporate new information quickly into stock prices and to differentiate among banks. Dahiya (2003) finds that stock prices of lead lending BHC's fall significantly when a major corporate borrower announces its default or bankruptcy. Finally, in Konishi, Masaru and Yasuda, Yukihiro (2004), the total risk of a bank is defined as the standard deviation of a bank's stock returns for each fiscal year measured in percentage points.

stock returns to measure the risk-taking of the bank during that year. I quantify a bank's franchise value (FV_{jt}) as the ratio of market value and net book value, which is similar to the definition of Tobin's q. The market value is defined as the share price multiplied by the number of ordinary shares outstanding, while the book value is measured by net tangible assets[15].

I also collect information on the capital adequacy ratio for each bank (CAD_{jt}), as calculated using the guidelines suggested by the Basel Committee on Banking Regulations. This equals 'total net capital resources' comprising the Tier 1 (consisting of the main shareholders' funds) and Tier 2 capital (consisting of subordinated debt, general allowances for bad and doubtful debt and fixed asset revaluation reserves) divided by the risk-weighted assets. Datastream also provides the information on total assets ($SIZE_{jt}$) and the capital-to-asset ratio (CAR_{jt}) for each bank.

The growth rates of GDP per capita ($GDPG_{it}$), the percentage of banks with more than 50% foreign-owned assets (FSH_{it}) and the percentage of banks with more than 50% government-owned assets (GSH_{it}) are collected from World Development Indicators (WDI) and Barth, Caprio and Levine (2001), respectively.

Certainly, the stock-return deviation is not the only measure used in the literature to measure the bank's risk-taking. Other measures used in the literature include the interest rate cost of the bank's CD, credit rating of the bank and the default rate of the banking industry. However, these measures all require data that are not available to this author.

[15] Net tangible assets are defined as total assets, excluding intangible assets less total liabilities, minority interest and preference stock.

Country	**Period**	**Banks**	**Country**	**Period**	**Banks**
Argentina	1995-2002	7	Korea	1991-2002	8
Australia	1995-2002	10	Mexico	2000-2002	1
Austria	1991-2002	5	Malaysia	1993-2002	9
Belgium	1991-2002	6	Netherlands	1991-2002	4
Brazil	1992-2002	8	Norway	1995-2002	5
Canada	1991-2002	9	Pakistan	1993-2002	4
Chile	1993-2002	4	Peru	1992-2002	4
China	2000-2002	1	Philippines	1992-2002	11
Columbia	1993-2002	7	Poland	1994-2002	6
Czech Rep.	1996-2002	2	Portugal	1991-2002	6
Denmark	1991-2002	10	Singapore	1992-2002	3
Finland	1991-2002	1	Sir Lanka	1993-2002	6
France	1992-2002	6	South Africa	1993-2002	5
Germany	1991-2002	12	Spain	1991-2002	16
Greece	1991-2002	4	Sweden	1994-2002	5
Hong Kong	1991-2002	10	Switzerland	1991-2002	18
Hungary	1996-2002	2	Thailand	1992-2002	9
Indonesia	1993-2002	10	Turkey	1991-2002	6
India	1995-2002	8	Taiwan	1993-2002	4
Ireland	1991-2002	4	UK	1991-2002	11
Israel	1994-2002	6	US	1991-2002	27
Italy	1991-2002	16			

Table 3.2: Summary Statistics: Countries, Banks and Periods

From Hovakimian, Kane and Laeven (2003), I construct a dummy variable indicating whether a country has explicit deposit insurance. That is, the dummy variable is one if deposit insurance is provided to banks, and zero otherwise. The dummy variable for the implementation of capital adequacy requirements is one if Datastream has the data of risk-adjusted capital adequacy ratios, and zero otherwise. I use this proxy since it is very difficult to know when a country begins to implement capital regulation.

Table 3.2 reports the countries covered, the number of banks selected in each country and the data period for each country. The sample includes a total of 43 countries and 316 banks. A large proportion of the banks are from developing countries.

After deleting observations for Franchise values (FV_{jt}) that fall outside one standard deviation, I have in total 2148 observations. The summary statistics are presented in Table 3.3. The standard deviation of (weekly) bank stock returns (RT_{jt}) ranges from 1.02 to 34.61, with mean 8.28. The average franchise value (FV_{jt}) is 1.43, with a minimum value of 0.30 and a maximum value of 3.19. That is, the market value of capital is on average about 43 percent higher than the net book value. Looking at the dummy variable that describes the implementation of capital adequacy requirements ($CADD_{it}$), I find that 18 percent of the observations occur during a period when capital requirements are in place. Similarly, the dummy variable for deposit insurance ($DIDM_{it}$) tells us that 82 percent of the observations are from periods that deposit insurance has been provided. Bank size ($SIZE_{jt}$) is defined as the logarithmic value of banks' assets denominated in US dollars (divided by

Variables	Obs.	Mean	St. Dev.	Min	Max
Banks' risk-taking (RT)	2148	8.28	4.86	1.02	34.61
Franchise value (FV)	2148	1.43	0.67	0.30	3.19
Dummy of capital regulation ($CADD$)	2148	0.18	0.39	0.00	1.00
Dummy of deposit insurance($DIDM$)	1817	0.82	0.38	0.00	1.00
Bank size ($SIZE$)	2066	8.57	2.51	1.19	13.54
Capital adequacy ratio CAD ($tie1$)	379	7.97	2.10	3.3	23.70
Capital adequacy ratio CAD ($tie2$)	395	11.34	2.50	2.74	24.80
Capital-to-asset ratio (CAR)	2065	8.43	8.45	1.18	95.79
Local stock market index (LOC)	2048	0.94	0.61	0.29	5.54
Foreign ownership (FSH)	1412	11.54	11.97	0.00	62.0
Government ownership (GSH)	1779	14.47	18.46	0.00	80.0

Table 3.3: Summary Statistics: Regression Variables

1000). Based on Datastream accounting data, about 380 observations have information about risk-based capital adequacy ratios (CAD_{jt}). The percentage of banks with more than 50% foreign-owned assets (FSH_{it}) ranges from zero percent to 62 percent, and the maximum percentage of banks with more than 50% government-owned assets (GSH_{it}) is 80 percent.

3.3.3 Panel Data Analysis: Cross-sectional and Time Series Evidence

To explain the variation in banks' risk-taking, I employ a panel data analysis. This allows me to analyze the cross-sectional and time-series factors that influence the bank's risk-taking. I estimate a multivariate regression model using maximum likelihood. Standard errors are robust to heteroscedasticity. The model is estimated with and without bank-specific fixed effects. The objective of this general estimation framework is to capture the dynamics of banks' risk-taking over time as they relate to franchise value, capital adequacy requirements and deposit insurance.

I estimate the following panel data model:

$$\begin{aligned} RT_{jt} &= b_0 + b_1 RT_{jt-1} + b_2 FV_{jt} + b_3 FV_{jt}^2 + b_4(FV_{jt} \times CADD_{it}) + \\ &\quad b_5(FV_{jt} \times DIDM_{it}) + b_6 FSH_{it} + b_7 GSH_{it} + b_8 SIZE_{jt-1} + \\ &\quad b_9 CAR_{jt-1} + b_{10} GDPG_{it-1} + \varepsilon_{jt.} \qquad (3.76) \end{aligned}$$

where RT_{jt} is bank j's risk-taking in year t, FV_{jt} is bank j's franchise value in year t, $CADD_{it}$ is a dummy variable equal to unity if country i has implemented capital adequacy requirements in year t and zero otherwise, $DIDM_{it}$ is a dummy variable equal to unity if country i has provided deposit insurance to the banking system in year t and zero otherwise, FSH_{it} is the percentage of country i's banking system with more than 50 percent foreign-owned assets in year t, GSH_{it} is the percentage of country i's banking system with more than 50 percent government-owned assets in year t, $SIZE_{jt-1}$ is the asset size of bank j in year $t-1$, CAR_{jt-1} is the capital-to-asset ratio of bank j in year $t-1$, $GDPG_{it-1}$ is country i's growth rate of GDP per capita in year $t-1$.

According to the theoretical model and the comparative static results in Table 3.1, we should control for some other factors, such as investment opportunities (w) and the cost of capital (ρ). Considering the differences in investment opportunities and costs of capital across banks and countries, I choose to proxy these factors using three groups of variables. The first group contains the control variables in the regressions. They are foreign ownership (FSH_{it}), government ownership (GSH_{it}), bank size $(SIZE_{jt-1})$, capital-to-asset ratio (CAR_{jt-1}) and GDP growth rate $(GDPG_{it-1})$.

The second group contains the fixed-effect bank-specific dummy variables. Finally, since these factors may be persistent, the autoregressive structure of the regression model also helps to capture the impact of these factors. Taken together, this regression model can capture the effects of bank-specific, country-specific and policy-related factors in a dynamic framework.

Since this chapter emphasizes the impact of banking policies, the coefficients b_4 and b_5 are the most important. Tables 3.4 and 3.5 present the results of the panel regressions for Equation (3.76) without and with bank-specific fixed effects, respectively. Eight different specifications are reported with coefficient estimates and associated heteroscedasticity-consistent standard errors. I investigate different combinations of the explanatory variables in models (1) - (4) for the estimation without a bank-specific fixed effect and in models (5) - (6) for the estimation with a bank-specific fixed effect. Model (1) allows for the dynamics of banks' risk-taking with one year lagged value. There is significant persistence in the series up to one year. The first-lag coefficient is 0.58. It has a significant t-statistic of 24.63 which implies a strong autoregressive process in the series. The adjusted R^2 is 0.37, which confirms the importance of modeling the dynamics of banks' risk-taking before modeling any fundamental inferences with other variables. The autoregressive feature of a bank's risk-taking is strong in all specifications and is present even in the fixed-effect estimation.

Models (2) and (3) present the specifications that include all variables except a quadratic term of franchise value and interactive terms with dummy variables $CADD_{jt}$ and $DIDM_{jt}$. In model (2), the autoregressive dynamics are ignored. This is costly in terms of adjusted R^2 which drops to less than 18 percent compared to almost 45 percent for model (3), which includes the one lagged value of banks' risk-taking.

RHS variables	Model (1)	Model (2)	Model (3)	Model (4)
Lagged risk-taking (RT_{jt-1})	0.5802*** (0.0236)		0.5434*** (0.0283)	0.4737*** (0.0325)
Franchise value (FV_{jt})		-0.5340** (0.2242)	-0.3210* (0.1855)	-2.0437** (0.9695)
Franchise value square $(FV_{jt})^2$				0.4222 (0.2671)
Capital regulation dummy $(CADD_{it}) \times (FV_{jt})$				0.2871 (0.2406)
Deposit insurance dummy $(DIDM_{it}) \times (FV_{jt})$				0.5403** (0.2259)
Foreign ownership (FSH_{it})		0.0466*** (0.0125)	0.0094 (0.0123)	0.0214* (0.0118)
Government ownership (GSH_{it})		0.1134*** (0.010)	0.0499*** (0.0089)	0.0420*** (0.0098)
Lagged bank size ($SIZE_{jt-1}$)		0.1569*** (0.0422)	0.0625* (0.0363)	0.0648* (0.0392)
Lagged capital-asset ratio (CAR_{jt-1})		0.1034*** (0.0318)	0.0567** (0.0221)	0.0414 (0.0289)
Lagged economic growth ($GDPG_{it-1}$)		0.0056 (0.0614)	0.0689 (0.0432)	0.1198** (0.0490)
constant	3.3272*** (0.1807)	4.800*** (0.5927)	2.0854*** (0.5012)	3.1226*** (0.9075)
Adjusted R^2	0.3688	0.1781	0.4529	0.3843
Number of observations	1890	1208	1194	1007

The dependent variable is each bank's risk-taking (RT_{jt}). Maximum likelihood estimates are reported with standard errors using White (1980) methods robust to heteroscedasticity. R^2 is adjusted for degree of freedom. ***, **, and * denote that estimates are significant at 1, 5 and 10 percent significance level, respectively.

Table 3.4: Panel Regressions of Annual Risk-taking on Franchise Values, Capital Adequacy Requirements and Deposit Insurance (without Fixed Effects)

The variables that are significantly related to banks' risk-taking across bank-years in both models are franchise values, FV_{jt}, with a negative coefficient, the percentage of banks having more than 50 percent government ownership GSH_{jt}, bank size $SIZE_{jt}$ and capital-to-asset ratio CAR_{jt}, with positive coefficients.

The result that bank's risk-taking is larger for lower franchise values is not surprising. It has been reported and termed the franchise value hypothesis in Keeley (1990) who used a similar panel model from an earlier sample period. The positive signs before bank size $SIZE_{jt}$ and capital-to-asset ratio CAR_{jt} are a bit surprising since they are different from Demsetz et al. (1996). The ownership result is a new one that has not been uncovered in the previous studies. While bank size $SIZE_{jt}$ is significantly positive across all the specifications, the signs of capital-to-asset ratio CAR_{jt} and government ownership GSH_{jt} are sensitive to whether bank-specific fixed effects are included in the model.

Model (4) adds the interactive terms with $CADD_{jt}$, $DIDM_{jt}$ and a quadratic term for franchise value, and the overall coefficient before franchise value is still negative (-0.944) and the standard error is 2.37, evaluated at the mean value of FV_{jt}, $CADD_{jt}$ and $DIDM_{jt}$. The most important result in this empirical study is that the coefficients before $CADD_{jt}$ and $DIDM_{jt}$ are both positive (significant for the coefficient before $DIDM_{jt}$), implying that both capital adequacy requirements and deposit insurance moderate the negative relationship between franchise values and the measure of risk. That is, capital regulation and deposit insurance help to enhance the stability of the banking sector. This result is robust to the inclusion of important dynamics and other explanatory variables for the risk-taking. The moderate adjusted R^2 of 0.38 suggests that I should include a bank-specific fixed effect.

The results for estimation with bank-specific fixed effects are presented in model (5) - (8) in Table 3.5. In model (5) which has only one lagged value and bank-specific fixed effects, the adjusted R^2 reaches 0.89 compared to only 0.38 for model (4). That is, there are significant bank-specific factors in the data.

Again, models (6) and (7) present the benchmark model including all fundamental variables except those interactive variables with $CADD_{jt}$ and $DIDM_{jt}$ and the quadratic term of franchise value. In model (6), the autoregressive dynamics are ignored and it is not very costly in terms of adjusted R^2 which only drops slightly compared to the adjusted R^2 of model (7). It says that the autoregressive dynamics are not that important after bank-specific fixed effects are modeled. In fact, the coefficient before RT_{jt-1} (0.17) becomes smaller in model (7) compared to the same coefficient (0.54) in model (3). Now, franchise values are not significantly related to banks' risk-taking, which is not surprising to us given the result in model (4). The explanation for this is that capital adequacy requirements and deposit insurance help to moderate the risk-shifting incentive. Other variables that are significantly related to risk-taking include bank size $SIZE_{jt}$ and government ownership GSH_{jt}. But in model (8), the coefficient before GSH_{jt} becomes insignificant.

As in model (4), the coefficient before franchise value FV_{jt} is significantly negative in model (8). This is consistent with the Franchise Value Hypothesis. After adding the interactive terms with $CADD_{jt}$, $DIDM_{jt}$ and a quadratic term for franchise value in model (8), I find that the overall coefficient before franchise value is still negative (-1.094) and the standard error is 4.11, evaluated at the mean value of FV_{jt}, $CADD_{jt}$ and $DIDM_{jt}$. The autoregressive dynamics are still significant but the coefficient becomes even smaller (0.08). In model (8), I also find that the quadratic term of

RHS variables	Model (5)	Model (6)	Model (7)	Model (8)
Lagged risk-taking (RT_{jt-1})	0.1923*** (0.0426)		0.1718*** (0.0400)	0.0767* (0.0454)
Franchise value (FV_{jt})		0.3779 (0.2534)	0.1813 (0.2428)	-3.0465*** (1.1608)
Franchise value square $(FV_{jt})^2$				0.6200** (0.2924)
Capital regulation dummy $(CADD_{it}) \times (FV_{jt})$				0.0226 (0.3654)
Deposit insurance dummy $(DIDM_{it}) \times (FV_{jt})$				1.3107*** (0.3602)
Foreign ownership (FSH_{it})		0.1000 (0.1195)	0.0645 (0.1210)	0.0619 (0.1008)
Government ownership (GSH_{it})		0.1244*** (0.0335)	0.1035*** (0.0330)	0.0120 (0.0758)
Lagged bank size ($SIZE_{jt-1}$)		1.0877*** (0.3467)	1.0579*** (0.3379)	1.2274*** (0.3743)
Lagged capital-asset ratio (CAR_{jt-1})		-0.0204 (0.0469)	0.0002 (0.0390)	-0.0866 (0.0597)
Lagged economic growth ($GDPG_{it-1}$)		-0.1423 (0.0484)	-0.0716 (0.0484)	-0.1064** (0.0520)
constant				
Adjusted R^2	0.8919	0.8941	0.8983	0.8989
Number of observations	1890	1208	1194	1007

The dependent variable is each bank's risk-taking (RT_{jt}). Maximum likelihood estimates are reported with standard errors using White (1980) methods robust to heteroscedasticity. R^2 is adjusted for degree of freedom. ***, **, and * denote that estimates are significant at 1, 5 and 10 percent significance level, respectively.

Table 3.5: Panel Regressions of Annual Risk-taking on Franchise Values, Capital Adequacy Requirements and Deposit Insurance (with Fixed Effects)

franchise value is significantly positive with associated heteroscedasticity-consistent t-statistics being 2.12. The positive coefficients before FV_{jt}^2 in models (4) and (8) imply a nonlinear relationship between franchise values and risk-taking, that is, while franchise values generally mitigates moral hazard, it mitigates even more for larger franchise values.

The important result that the coefficients before $CADD_{jt}$ and $DIDM_{jt}$ are both positive (significant for the coefficient before $DIDM_{jt}$) also holds in model (8). Actually, the coefficient before capital regulation becomes smaller and the coefficient before deposit insurance becomes larger. The positive coefficients of $SIZE_{jt}$ are robust over all the specifications, in contrast to the results of Demsetz (1996).

After including a bank-specific fixed effect, the adjusted R^2 increases to 0.90, suggesting that our model is reasonably well specified. In particular, the coefficients before deposit insurance are robust and significantly positive in both models (4) and (8), suggesting that deposit insurance is statistically more important than capital regulation, .

Due to the lack of information about the characteristics of deposit insurance for each country, I am unable to investigate whether our results about deposit insurance come entirely from the loss-control characteristics (such as risk-based deposit insurance and coinsurance) of deposit insurance. But I believe that the loss-control characteristics of deposit insurance play an important role in our results[16].

[16] According to Hovakimian, Kane and Laeven (2003) (Table 1, Panel A), deposit insurance is risk-based in more than 20 percent of countries in their sample. Again, based on the summary statistics in their paper, deposit insurance has coinsurance characteristics in about 15 percent of countries in their sample.

To see how deposit insurances can be risk-sensitive, we take a look at the method used by Federal Deposit Insurance Corporation (FDIC). The FDIC maintains the Bank Insurance Fund (BIF) and the Savings Association Insurance Fund (SAIF) by assessing depository institutions an insurance premium twice a year. The amount each institution is assessed is based both on the balance of insured

3.4 Conclusion Remarks

In this chapter, I have evaluated theoretically and empirically the simultaneous effects of capital adequacy requirements and deposit insurance in enhancing the stability of the banking sector.

The analytical part of this chapter develops a model of moral hazard to examine the joint impact of capital regulation and deposit insurance in a framework where franchise values are determined endogenously. Competition exacerbates risk-taking in the banking sector. Moral hazard not only distorts a bank's asset allocation decision but also affects its liability management. To effectively control moral hazard, I argue that a coordinated combination of capital adequacy requirements and risk-based deposit insurance is necessary.

In the empirical part of this chapter, with a data set covering 316 banks from 43 countries, I exploit the information in the cross-sectional and time-series variation of the risk-taking to estimate a panel regression model, seeking to associate the variation with various explanatory variables. I find that my model can explain up to 90 percent of the cross-sectional and time-series variation of banks' risk-taking. The most important explanatory variables include the franchise value of the bank and the dummy variables indicating the presence of capital adequacy requirements and deposit insurance. That is, a lower franchise value stimulates risk-taking by banks,

deposits held during the preceding two quarters as well as on the degree of risk the institution poses to the insurance fund. In order to assess premiums on individual institutions, the FDIC places each institution in one of nine risk categories using a two-step process based first on capital ratios (the capital group assignment) and then on other relevant information (the supervisory subgroup assignment). The FDIC uses a risk-based premium system that assesses higher rates on those institutions that pose greater risks to the Bank Insurance Fund (BIF) or the Savings Association Insurance Fund (SAIF). The risk-based deposit insurance premium ranges from zero basis points (bp) per 100 dollars of assessable deposits (annual rate) to 27 basis points (bp).

but risk-taking decreases when capital adequacy requirements and deposit insurance are present. I interpret these findings as evidence consistent with the Franchise Value Hypothesis and also in support of the hypothesis that capital adequacy requirements and deposit insurance are effective in mitigating moral hazard.

What lessons can be drawn for bank regulators? Banks tend to act prudently either because they want to maintain their franchise values or because they do not want to pay high deposit insurance premia. A well-designed deposit insurance scheme which complements the capital regulation is important. Two suggestions for developing countries to ensure the soundness of their banking system are that they should maintain the appropriate level of franchise value of the banking system and provide a well-designed and coordinated regulatory system.

CHAPTER 4

DISCUSSIONS AND CONCLUSIONS

The past two decades have witnessed dramatic changes in the financial systems of many countries. Significant banking sector problems have led financial supervisors and regulators to strengthen the prudential banking policies in an effort to achieve financial stability. At the same time, central banks have done a better job stabilizing inflation at a low level while keeping growth at a high level. While in reality different banking policies and monetary policy coexist, little is known about how these policies complement one another. The questions addressed in this dissertation include how to create a sound banking sector that does not magnify economic fluctuation, how to avoid the conflicts between macroeconomic stability and financial stability and how to employ different banking policies efficiently.

The general conclusions are: Policymakers can achieve their goals and avoid working at cross-purposes if monetary policy and different banking policies (capital requirements and deposit insurance) are conducted in a coordinated way. That is, as suggested in chapter two, the optimal monetary policy should respond to the states of bank capital constraints so as to neutralize the procyclical effect of capital regulation. Meanwhile, as presented in chapter three, the regulatory environment that helps banking stability should include both optimal bank capital regulation and a well-designed deposit insurance scheme.

In chapter two, we start with an observation that changes in bank lending are an important determinant of economic fluctuations. Central banks, in working to meet their stabilization goals, strive to ensure a sufficient supply of loans. In their effort to maintain a stable financial system, bank regulators can work against the objective of central banks. Capital requirements are a clear example. By dictating that all banks must maintain sufficient capital with respect to their risk exposures, capital requirements can limit the lending capacity of the banking system. Although the need for avoiding working at cross-purposes is recognized, it is not clear whether central banks have formulated an optimal strategy, namely, taken into account the impact of the capital requirements.

Chapter two focuses on three things. First, I confirm the results derived by Blum and Hellwig (1995) that in the presence of completely passive monetary policy capital requirements will amplify business fluctuation. Namely, when banks become capital constrained, shocks to the economy generate larger movements in output. The second result is to establish that optimal monetary policy will neutralize the procyclical impact of capital requirements. That is, the prudential regulation does not encumber monetary policymakers in their pursuit of stable growth. Finally, I present evidence suggesting that while the Federal Reserve has been reacting as the model suggests, lowering (raising) interest rates by more during downturns (upturns) in which bank capital constraint binds, the German and Japanese central banks clearly have not. Blum and Hellwig need not be right in theory, but they may very well be right in practice.

In chapter three, I evaluate theoretically and empirically the effects of capital adequacy requirements and deposit insurance in enhancing the stability of the banking sector. The analytical part of chapter three develops a model of moral hazard to examine the joint impacts of capital regulation and deposit insurance in a framework where franchise values are determined endogenously. In this model, competition exacerbates risk-taking in the banking sector. Moral hazard not only distorts a bank's decisions on its asset allocation but also affects bank's decisions on its liabilities management. I argue that, to effectively control moral hazard, policymakers need to conduct capital adequacy requirements and risk-based deposit insurance optimally which requires that two policies coordinate with each other.

With a data set covering 316 banks from 43 countries, I exploit the information in the cross-sectional and time-series variation of the risk-taking across the banks to estimate a panel regression model, seeking to associate the variation with various explanatory variables. I find that my model can explain up to 90 percent of the cross-sectional and time-series variation of banks' risk-taking. The most important explanatory variables include the franchise value of the bank and whether capital adequacy requirements and deposit insurance are implemented. That is, a lower franchise value stimulates risk-taking, but less so if capital adequacy requirements and deposit insurance are implemented. These results are consistent with the Franchise Value Hypothesis and also support the hypothesis that capital adequacy requirements and deposit insurance are effective in mitigating moral hazard.

In addition, this study delivers interesting implications for some related issues. A potentially important observation from chapter three is that the optimal capital level and deposit insurance premium depend on characteristics of assets and the cost of bank capital. While countries are encouraged to adopt the best practices in banking policies like the ones studied here, banks in different countries may face different investment opportunities and equity-market situations. This implies that the optimal bank capital and insurance premium will not be the same across countries.

Chapter three also suggests implementing a non-flat-rate deposit insurance instead of using deposit-rate ceilings as proposed by some economists recently. Based on the model, a deposit-rate ceiling is not necessary. Moreover, it is much easier to implement deposit insurance than to impose a deposit-rate ceiling. When banks are prevented from setting deposit rates freely, they may go for other forms of non-price competition, which are socially inefficient. Meanwhile, it is difficult to implement deposit-rate ceilings when there are significant macroeconomic fluctuations. In the United States, the nominal deposit-rate ceilings imposed by Regulation Q induce a negative real interest rate during the years following the oil shock in 1973.

Finally, as shown in chapter three, capital adequacy requirements alone certainly cannot control moral hazard completely. If monetary policymakers do not take banks' capital constraints into consideration, capital adequacy regulation may undermine macroeconomic stability. These two concerns about capital regulation could easily induce people to criticize capital regulation. Nevertheless, the solution suggested by this dissertation is to strengthen the coordination between capital requirements, deposit insurance and monetary policy. This seems to be more important than any proposals that focus on improving the capital regulation only. The bottom line is that, in order to achieve financial stability and macroeconomic stability at the same time, policymakers need to ensure that different policies function coordinately.

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APPENDIX A

PROCYCLICAL EFFECT OF CAPITAL REQUIREMENTS IN THE DYNAMIC MACROECONOMIC MODEL IN CHAPTER TWO

We show that capital requirements could amplify shocks in this appendix. According to (2.36), we write the conditional expectation of period-$t+1$ inflation as a function of the variables known at period t.

$$\pi_{t+1|t} = \pi_t + \beta_y y_t. \tag{A.1}$$

To see the impact of bank capital regulation on real output, as a first step, we put (A.1) into the loan market conditions ((2.32) - (2.35)) to solve for the equilibrium loan rate. Substituting the equilibrium loan rate back into (2.35), we see

$$y_{t+1} = -\phi_i^j (i_t - \pi_t) + \phi_y^j y_t + \eta_{t+1}, \tag{A.2}$$

where ϕ_i^j and ϕ_y^j are complicated functions of model parameters and have accounted for the impact of bank activities, and so differ depending on whether $j = c$ or $j = u$. That is,

$$\phi_i^u = \alpha_i + \frac{\alpha_\rho}{L_\rho}(1-\theta)D_i, \tag{A.3}$$

$$\phi_y^u = \alpha_y + \alpha_i\beta_y - \frac{\alpha_\rho}{L_\rho}L_y + \frac{\alpha_\rho}{L_\rho}B_y + \frac{\alpha_\rho}{L_\rho}(1-\theta)D_y + \frac{\alpha_\rho}{L_\rho}(1-\theta)D_i\beta_y, \tag{A.4}$$

$$\phi_i^c = \alpha_i, \tag{A.5}$$

$$\phi_y^c = \alpha_y + \alpha_i\beta_y - \frac{\alpha_\rho}{L_\rho}L_y + \frac{\alpha_\rho}{L_\rho}cB_y. \tag{A.6}$$

Since the short-term interest rate is controlled by central banks, we fix it at zero to see how the economy develops without an active monetary policy. With (A.2) and (2.36), using a lead operator, we write the real output process as a second-order difference equation (after adjusting the time subscript) as follows:

$$y_t = (1+\phi_y^j)y_{t-1} + (\phi_i^j\beta_y - \phi_y^j)y_{t-2} + w_t, \tag{A.7}$$

where $w_t = \eta_t - \eta_{t-1} + \alpha_i\epsilon_{t-1}$.

This second-order difference process is generally explosive since one eigenvalue is greater than unity (unless either β_y or α_i is zero, which are not interesting cases). The larger-than-unity eigenvalue is

$$e_1^j = \frac{1+\phi_y^j + \sqrt{(1-\phi_y^j)^2 + 4\phi_i^j\beta_y}}{2}, \tag{A.8}$$

while another eigenvalue is

$$e_2^j = \frac{1+\phi_y^j - \sqrt{(1-\phi_y^j)^2 + 4\phi_i^j\beta_y}}{2}. \tag{A.9}$$

As a function of ϕ_y^j and ϕ_i^j, eigenvalues depend on whether $j = c$ or $j = u$.

The dynamic multiplier of the output process is eventually dominated by an exponential function of the larger-than-unit eigenvalue e_1:

$$\lim_{k\to\infty} \frac{\partial y_{t+k}}{\partial w_t}\frac{1}{(e_1^j)^k} = \frac{e_1^j}{e_1^j - e_2^j}. \tag{A.10}$$

Our interest is in the reaction of future output to a current transitory shock ($\left\{\frac{\partial y_{t+k}}{\partial w_t}\right\}$) and how this changes as banks go from being unconstrained to constrained (from $j = u$ to $j = c$). In (A.10), $\left\{\frac{\partial y_{t+k}}{\partial w_t}\right\}$ will become greater as $k \to \infty$ since the output follows an explosive process. Equation (A.10) also tells us that the greater the values of $\frac{e_1^j}{e_1^j - e_2^j}$ and the larger-than-unit eigenvalue e_1^j the faster $\left\{\frac{\partial y_{t+k}}{\partial w_t}\right\}$ grows as $k \to \infty$. If $B_y > \frac{1-\theta}{c-1} D_y$, from computation we know that

$$\frac{e_1^c}{e_1^c - e_2^c} > \frac{e_1^u}{e_1^u - e_2^u}. \tag{A.11}$$

We don't know if $e_1^c > e_1^u$ ($e_1^c < e_1^u$) but this is quantitatively less important than the difference between $\frac{e_1^c}{e_1^c - e_2^c}$ and $\frac{e_1^u}{e_1^u - e_2^u}$. Therefore, we can conclude that $\left\{\frac{\partial y_{t+k}}{\partial w_t}\right\}$ grows faster when banks are constrained if $B_y > \frac{1-\theta}{c-1} D_y$. This is to say that the impacts of current shocks on output are amplified by capital requirements under the same condition as the static model.

APPENDIX B

SOLUTION FOR THE DYNAMIC MACROECONOMIC MODEL IN CHAPTER TWO

This dynamic problem in (2.39) is solved using a backward method. That is, the central bank first chooses $y_{t+2|t+1}$ to solve the following Bellman equation:

$$V(\pi_{t+2|t+1}) = \min_{y_{t+2|t+1}} \{\frac{1}{2}[\lambda\pi^2_{t+2|t+1} + (1-\lambda)y^2_{t+2|t+1}] + \delta E_{t+1}V(\pi_{t+3|t+2})\}, \tag{B.1}$$

subject to

$$\pi_{t+3|t+2} = \pi_{t+2|t+1} + \beta_y y_{t+2|t+1} + \epsilon_{t+2} + \beta_y \eta_{t+2}. \tag{B.2}$$

The first-order condition with respect to $y_{t+2|t+1}$ is

$$(1-\lambda)y_{t+2|t+1} + \beta_y \delta E_{t+1} V_\pi(\pi_{t+3|t+2}) = 0. \tag{B.3}$$

Since the objective function is quadratic and the constraint is linear, the value function $V(\cdot)$ in (B.1) is of the form

$$V(\pi_{t+3|t+2}) = l_0 + \frac{l}{2}\pi^2_{t+3|t+2}, \tag{B.4}$$

where the coefficients l_0 and l needs to be determined. Substitute (B.4) into (B.3), we see

$$(1-\lambda)y_{t+2|t+1} + \beta_y \delta l \pi_{t+3|t+2} = 0. \tag{B.5}$$

By substituting $\pi_{t+3|t+2}$ in (B.5) using (B.2), we get that

$$y_{t+2|t+1} = -\frac{\beta_y \delta l}{(1-\lambda) + \beta_y^2 \delta l} \pi_{t+2|t+1}. \tag{B.6}$$

This first-order condition in (B.6) is similar to the first-order condition in the static model but depends on more parameters in a more complicated way. To see this, we need to solve l.

By substituting $y_{t+2|t+1}$ in (B.2) using (B.6), we get

$$\pi_{t+3|t+1} = \varphi(\beta_y, \delta, \lambda)\pi_{t+2|t+1}, \tag{B.7}$$

where $\varphi(\beta_y, \delta, \lambda) = \frac{1-\lambda}{(1-\lambda)+\beta_y^2 \delta l}$.

Applying the envelope theorem to the value function in (B.1) with respect to the state variable $\pi_{t+2|t+1}$ and using (B.7), we get

$$V_\pi(\pi_{t+2|t+1}) = \lambda \pi_{t+2|t+1} + \delta l \pi_{t+3|t+1} = [\lambda + \varphi(\beta_y, \delta, \lambda)\delta l]\pi_{t+2|t+1}. \tag{B.8}$$

Adjusting time subscribes, we know from (B.4) that

$$V_\pi(\pi_{t+2|t+1}) = l\pi_{t+2|t+1}. \tag{B.9}$$

Combining (B.8) and (B.9), we see

$$\lambda + \frac{(1-\lambda)\delta l}{(1-\lambda) + \beta_y^2 \delta l} = l. \tag{B.10}$$

The unique positive solution of l that satisfies $l \geq \lambda$ is

$$l = \frac{1}{2}\left(\lambda - \frac{(1-\lambda)(1-\delta)}{\beta_y^2 \delta} + \sqrt{\left(\lambda + \frac{(1-\lambda)(1-\delta)}{\beta_y^2 \delta}\right)^2 + \frac{4\lambda(1-\lambda)}{\beta_y^2}}\right) \geq \lambda. \tag{B.11}$$

In general, the following equation holds for any period $t+k$ $(k \geq 1)$.

$$y_{t+k|t+1} = -\frac{\beta_y \delta l}{(1-\lambda) + \beta_y^2 \delta l} \pi_{t+k|t+1}, \;\; k \geq 1. \tag{B.12}$$

Based on (B.12), (2.31) and (2.36), we can back out central banks' optimal reaction functions:

$$i^*_{c,t+1} = A^c_\pi \pi_{t+1} + A^c_y y_{t+1}, \tag{B.13}$$

$$i^*_{u,t+1} = A^u_\pi \pi_{t+1} + A^u_y y_{t+1}, \tag{B.14}$$

where

$$A^j_\pi = 1 + \frac{1}{\phi^j_i} \frac{\beta_y \delta l}{1 - \lambda + \beta^2_y \delta l} > 0, j = \ c\ or\ u, \tag{B.15}$$

$$A^j_y = \frac{\phi^j_y}{\phi^j_i} + \frac{1}{\phi^j_i} \frac{\beta^2_y \delta l}{1 - \lambda + \beta^2_y \delta l} > 0, j = \ c\ or\ u. \tag{B.16}$$

The general way to present the optimal policy rule is

$$\begin{aligned} i^*_{c,t+k|t+1} &= A^c_\pi \pi_{t+k|t+1} + A^c_y y_{t+k|t+1},\ k > 1, \\ & \quad if\ the\ capital\ constraint\ is\ expected\ to\ be\ binding\ in\ t+k \\ & \quad based\ on\ the\ information\ in\ t+1, \end{aligned} \tag{B.17}$$

$$\begin{aligned} i^*_{u,t+k|t+1} &= A^u_\pi \pi_{t+k|t+1} + A^u_y y_{t+k|t+1},\ k > 1, \\ & \quad if\ the\ capital\ constraint\ is\ expected\ to\ be\ non-binding\ in\ t+k \\ & \quad based\ on\ the\ information\ in\ t+1. \end{aligned} \tag{B.18}$$

Under the optimal policy here, the policymaker is able to neutralize the impact of the capital constraint but with control lags. Given a realization of a shock at period $t+1$, the optimal interest rate i_{t+1} will set the output and inflation in the next period ($\pi_{t+2|t+1}$ and $y_{t+2|t+1}$) on the optimal path specified by (B.6) and (B.7). Starting from period $t+2$, output and inflation do not depend at all on the existence of a capital constraint. (See (2.46) for the solution for output. The equivalent expression for inflation is obtained by substituting this equation into (B.6)). What this means is that for the purpose of minimizing the weighted average of the variance of output and the variance of inflation, only the state of banking system in period $t+1$ matters for i_{t+1} and the probabilities of hitting the capital constraint in future periods just don't make any difference at all.

There are two ways to demonstrate that the solution is optimal for the question at hand. First, we can simplify our problem that minimizes (2.39) subject to (2.31)-(2.37) into a problem that minimizes (2.39) subject to only (2.36). This says that the constraints other than (2.36) are not binding, which (if possible) certainly is a part of optimal solution. In the simplified problem, the pseudo control variable is expected output $y_{t+2|t+1}$.

According to the first-order condition of the simplified problem (B.6), the pseudo control variable ($y_{t+2|t+1}$) at its optimal level should not depend on the state of capital constraints. However, based on (2.31), one component of expected output is the equilibrium loan rate ρ_{t+1} which depends on the capital constraint. According to (2.32)-(2.35) and (2.37), the (ex post) real loan rates can be solved based on the equilibrium condition of the loan market.

$$\begin{aligned}
\rho_{c,t+1} - \pi_{t+1} &= \frac{1}{L_\rho}(L_y + L_\rho\beta_y - cB_y)y_{t+1}, \qquad \text{(B.19)} \\
&\quad \textit{if the capital constraint binds in } t+1, \\
\rho_{u,t+1} - \pi_{t+1} &= \frac{1}{L_\rho}(L_y + L_\rho\beta_y - B_y - (1-\theta)D_y - (1-\theta)D_i\beta_y)y_{t+1} \\
&\quad + \frac{1}{L_\rho}(1-\theta)D_i(i_{u,t+1} - \pi_{t+1}), \qquad \text{(B.20)} \\
&\quad \textit{if the capital constraint doesn't bind in } t+1.
\end{aligned}$$

The next question is if monetary policy (i_{t+1}), another component of $y_{t+2|t+1}$, can counteract the impact of capital constraint (on $y_{t+2|t+1}$) entirely. In the left-hand-side of (B.6), we substitute the equilibrium loan rate with (B.19) and (B.20) and take conditional expectation; in the right-hand-side of (B.6), we use (2.36) and take conditional expectation. This yields an equation that can be used to solve for optimal short-term interest rate. The solution is (B.13) and (B.14).

There is an alternative way to simplify the problem. If we use $\alpha_i(i_{t+1} - \pi_{t+1}) + \alpha_\rho(\rho_{t+1} - \pi_{t+1})$ in (2.31) as the pseudo control variable and denote it as r_{t+1}. The original problem can be simplified as follows: In period $t+1$, the central bank minimizes

$$Min \frac{1}{2} E_{t+1} \sum_{k=1}^{\infty} \delta^k [\lambda \pi_{t+k}^2 + (1-\lambda) y_{t+k}^2], \quad 0 < \lambda, \delta < 1, \tag{B.21}$$

subject to

$$\pi_{t+k} = \pi_{t+k-1} + \beta_y y_{t+k-1} + \epsilon_{t+k}, \qquad k > 1 \tag{B.22}$$

$$y_{t+k} = (\alpha_y + \alpha_i \beta_y + \alpha_\rho \beta_y) y_{t+k-1} - r_{t+k-1} + \eta_{t+k}, \qquad k > 1. \tag{B.23}$$

Using the Bellman equation and the assumption that the value function is quadratic, we find the optimal r_{t+1}. That is,

$$r_{t+1}^* = \gamma_y y_{t+1} + \gamma_\pi \pi_{t+1}, \tag{B.24}$$

where

$$\gamma_y = \alpha_y + \alpha_i \beta_y + \alpha_\rho \beta_y + \frac{\beta_y^2 \delta l}{1 - \lambda + \beta_y^2 \delta l}, \tag{B.25}$$

$$\gamma_\pi = \frac{\beta_y \delta l}{1 - \lambda + \beta_y^2 \delta l}. \tag{B.26}$$

The important feature of the optimal r_{t+1} is as follows: *It is optimal that the pseudo control variable r^*_{t+1} is independent on the state of capital constraints.* But one component of r^*_{t+1} is the equilibrium loan rate $(\rho_{j,t+1} - \pi_{t+1})$ which depends on the capital constraint. The next question is if monetary policy $(i_{t+1} - \pi_{t+1})$, another component of r^*_{t+1}, can counteract the impact of capital constraints (on $\rho_{j,t+1} - \pi_{t+1}$) entirely so that

$$\alpha_i(i_{t+1} - \pi_{t+1}) + \alpha_\rho(\rho_{j,t+1} - \pi_{t+1}) = r^*_{t+1} = \gamma_y y_{t+1} + \gamma_\pi \pi_{t+1}. \tag{B.27}$$

Since we have

$$r^*_{t+1} = \alpha_i(i^*_{t+1} - \pi_{t+1}) + \alpha_\rho(\rho_{j,t+1} - \pi_{t+1}), \tag{B.28}$$

we can solve for optimal real (ex post) policy-controlled interest rate $i^*_{j,t+1} - \pi_{t+1}$ (now depends on j also) as

$$i^*_{j,t+1} - \pi_{t+1} = \frac{1}{\alpha_i}[r^*_{t+1} - \alpha_\rho(\rho_{j,t+1} - \pi_{t+1})], \tag{B.29}$$

where r^*_{t+1} is in (B.24) and $\rho_{j,t+1} - \pi_{t+1}$ is given by (B.19) and (B.20). The resulting optimal interest rates are the same as (B.13) and (B.14). Taken together, we have demonstrated that the solutions in (B.13) and (B.14) are optimal for the question at hand.

APPENDIX C

DATA DESCRIPTIONS FOR CHAPTER TWO

C.1 Converting Data Frequency

When I convert high frequency data into low frequency data, I use the average observation. When interpolating low frequency to high frequency data (the leverage ratios of Germany and Japan), I fit a local quadratic polynomial for each observation of the low frequency series, then use this polynomial to fill in all observations of the high frequency series associated with the period. The quadratic polynomial is formed by taking sets of three adjacent points from the source series and fitting a quadratic so that the average of the high frequency points matches to the low frequency data actually observed. For most points, one point before and one point after the period currently being interpolated are used to provide the three points. For end points, the two periods are both taken from the one side where data is available.

C.2 Data Sources

1. US short-term interest rate: quarterly average of weekly effective federal funds rate from http://research.stlouisfed.org/fred2/.

2. US consumer price index: quarterly average of monthly data from

http://research.stlouisfed.org/fred2/.

3. US potential real gross domestic product: quarterly data from http://research.stlouisfed.org/fred2/.

4. US real gross domestic product: quarterly data from http://research.stlouisfed.org/fred2/.

5. Total assets of US banks: RCFD2170 in Call Reports available at http://www.chicagofed.org/economicresearchanddata/data/bhcdatabase/.

6. Total loans of US banks: RCFD2122 in Call Reports available at http://www.chicagofed.org/economicresearchanddata/data/bhcdatabase/.

7. Total equity of US banks: RCFD3210 in Call Reports available at http://www.chicagofed.org/economicresearchanddata/data/bhcdatabase/.

8. Subordinated debt of US banks: RCFD3200 in Call Reports available at http://www.chicagofed.org/economicresearchanddata/data/bhcdatabase/.

9. US money supply (M2) growth: quarterly average of annualized growth of monthly data from http://research.stlouisfed.org/fred2/.

10. US long-term bonds interest rate: quarterly average of monthly 10-year Treasury rate from http://research.stlouisfed.org/fred2/.

11. US producer price index: quarterly average of monthly data from http://research.stlouisfed.org/fred2/.

12. Germany short-term interest rate: quarterly average of monthly call money rate from International Financial Statistics.

13. Germany consumer price index: quarterly average of monthly data from International Financial Statistics.

14. Germany potential real gross domestic product: quarterly data from Economic Outlook 73 as published by the OECD.

15. Germany real gross domestic product: quarterly data from Deutsche Bundesbank.

16. Total assets of banks, Germany: OECD bank database. The annual data are interpolated into quarterly data using the conversion method discussed above.

17. Total equity of banks, Germany: OECD bank database. The annual data are interpolated into quarterly data using the conversion method discussed above.

18. Germany money supply (M3) growth: quarterly average of annualized growth of monthly data from International Financial Statistics.

19. Germany long-term bonds interest rate: quarterly average of monthly government bond rate from International Financial Statistics.

20. Germany producer price index: quarterly average of monthly data from International Financial Statistics.

21. Japan short-term interest rate: quarterly average of monthly call money rate from International Financial Statistics.

22. Japan consumer price index: quarterly average of monthly data from International Financial Statistics.

23. Japan potential real gross domestic product: quarterly data from Economic Outlook 73 as published by the OECD.

24. Japan real gross domestic product: quarterly data from Economic Planning Agency.

25. Total assets of banks, Japan: OECD bank database. The annual data are interpolated into quarterly data using the conversion method discussed above.

26. Total equity of banks, Japan: OECD bank database. The annual data are interpolated into quarterly data using the conversion method discussed above.

27. Japan money supply (M2) growth: quarterly average of annualized growth of monthly data from International Financial Statistics.

28. Japan long-term bonds interest rate: quarterly average of monthly government bond rate from International Financial Statistics.

29. Japan producer price index: quarterly average of monthly data from International Financial Statistics.