Essays on International Financial Regulation

Gazi Ishak Kara

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Approved by:

Anusha Chari

Gary Biglaiser

Richard Froyen

Peter Norman

Sergio Parreiras

Abstract

GAZI ISHAK KARA: Essays on International Financial Regulation.
(Under the direction of Anusha Chari.)

The first chapter of this dissertation examines the incentives of national regulators to coordinate regulatory policies in the presence of systemic risk in global financial markets. In a two-country and three-period model, correlated asset fire sales by banks generate systemic risk across national financial markets. Relaxing regulatory standards in one country increases both the cost and the severity of crises for both countries in this framework. In the absence of coordination independent regulators choose inefficiently low level of macro-prudential regulation. A central regulator internalizes the systemic risk and thereby can improve the welfare of coordinating countries. Symmetric countries always benefit from coordination. Asymmetric countries choose different levels of macro-prudential regulation when they act independently. Common central regulation will voluntarily emerge only between sufficiently similar countries.

The second chapter investigates the empirical determinants of cross country and over time variation in the stringency of bank capital regulations. Despite the extensive attention that the Basel capital adequacy standards received internationally, there exists significant variation in the implementation of these standards across countries. Furthermore, a significant number of countries increase or decrease the stringency of capital regulations over time. The chapter investigates the empirical determinants of the variation that is seen in the data based on the theories of bank capital regulation. The results provide strong evidence that countries with high average returns to investment choose less stringent capital regulation standards. There is also some evidence that capital regulations are less stringent in countries with higher ratio of government ownership of banks where government ownership is used as a proxy for the regulatory capture: the degree to which regulators are captured by the financial institutions under their control. The results provide somewhat weaker evidence that countries with more concentrated banking sectors impose less strict capital regulation standards.

Dedication

To my wife Ayşenur and my parents Hamit and Serpil Kara.

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Chapter 1

Systemic Risk, International Regulation, and the Limits of Coordination

1.1 Introduction

The underlying shocks that precipitated the financial crisis of 2007-2009 quickly spread across global financial markets and were amplified at an unprecedented scale. The strikingly global nature of the crisis has revived interest in the international coordination of financial regulation. Regulatory reforms and the strengthening of coordination between national financial regulators are prominent items on the international reform agenda. The Financial Stability Board (FSB) was set up by the G-20 countries during the crisis to create guidelines for regulatory coordination and the supervision of systemic risk in the international financial system.[1]

This paper analyzes the incentives of national regulators towards international cooperation when there is systemic risk in global financial markets using a game-theoretic model. In the model, systemic risk in financial markets is generated through asset fire-sales. The model shows that in the absence of cooperation, independent regulators choose inefficiently low regulatory standards compared to regulation levels that would be chosen by a central regulator. A central regulator internalizes systemic risk and improves welfare in cooperating countries. The model also demonstrates that a common central regulation will voluntarily emerge only between sufficiently similar countries.

Key features of a third generation of bank regulation principles, popularly known as Basel III, strengthen capital regulations and add new elements to Basel bank regulation principles

[1]The Financial Stability Board (FSB) was established after the 2009 G-20 London summit in April 2009; it is the successor to the Financial Stability Forum (FSF). The FSF was founded in 1999 by the G-7 finance ministers and central bank governors.

such as liquidity and leverage ratio requirements. With Basel III, the objective of regulation aimed at creating a level playing field for internationally active banks is supported by an objective of creating sound regulatory practices that will contain systemic risk in national and international financial markets, and prevent pro-cyclical amplification of these risks over time.

In this paper, I revisit the issue of coordinating international financial regulation in the light of recent developments in the international regulatory infrastructure. Acharya (2003, 2009) and Dell'Ariccia and Marquez (2006) are notable studies in the literature on international financial regulation. All three of these studies focus on the level playing field objective of financial regulation, and examine the benefits to international coordination of financial regulation under externalities that operate through the competition in loan markets.

The paper diverges from the previous literature by focusing on systemic externalities across financial markets generated by fire-sales of assets. I examine the effects of systemic externalities on the nature of international financial regulation in the absence of cooperation between regulators, as well as its effects on the incentives of national regulators towards cooperation. The paper also makes a contribution to the literature by studying the effects of structural differences across countries on the choice of regulatory standards when countries are linked through systemic externalities in international financial markets. I show herein that common central regulation voluntarily emerges only between sufficiently similar countries.

During times of distress, asset prices can move away from the fundamental values and assets can be traded at fire-sale prices. When firms or financial intermediaries face liquidity shocks, and debt-overhang, collateral or commitment problems prevent them from borrowing or issuing new equity; as a result they may have to sell assets to generate the required resources. If the shocks are wide-spread throughout an industry or an economy, then potentially deep-pocket outsiders will emerge as the buyers of the assets. However, some assets are industry specific, and when they are redeployed by outsiders, they will be less productive. Industry-specific assets will be sold to outsiders at a discount. This idea finds its origins in Williamson (1988) and Shleifer and Vishny (1992), and later employed by fire-sales models such as Lorenzoni (2008), Gai et al. (2008), Acharya et al. (2010) and Korinek (2011).

Industry-specific assets can be physical, or they can be portfolios of financial intermediaries because many of these contain exotic tailor-made financial assets (Gai et al., 2008). The asset

specificity idea is captured in this paper through a decreasing returns to scale technology for outsiders, similar to Kiyotaki and Moore (1997), Lorenzoni (2008), Gai et al. (2008) and Korinek (2011). Decreasing returns to technology for outsiders make the situation even worse for distressed intermediaries because they have to accept higher discounts to sell more assets. Empirical and anecdotal evidence suggests that fire-sales of physical as well as financial assets exist.[2]

The discussion above suggests that when numerous intermediaries concurrently face the same type of shocks and sell assets simultaneously, asset prices can fall, forcing them to sell additional assets. An individual intermediary takes the market price as given and decides how much of its assets to sell to continue operating at an optimal scale. Therefore, each intermediary neglects the negative externality of its asset sales on others. In a financially integrated world, intermediaries from different countries sell assets in a global market to potentially the same set of buyers. Therefore, initial shocks that hit individual countries can be amplified in globally integrated financial markets, and this is the systemic externality considered in this paper.

I seek answers to the following questions: How do national regulators behave under this systemic externality if they act non-cooperatively? Would an individual regulator tighten or relax regulation when regulation is tightened in another country? Would national regulators relinquish their authority to a central international regulator who would impose the same set of regulatory standards across countries? How do asymmetries across countries affect the nature of regulatory standards and the incentives of national regulators towards international cooperation?

Briefly, I propose a three-period, two-good model that features two countries with independent regulators. In each country there is a continuum of banks. Banks are protected by limited liability, and there is deposit insurance in each country. Banks borrow consumption goods from local deposit markets and invest in a productive asset in the first period.

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[2] Using a large sample of commercial aircraft transactions, Pulvino (2002) shows that distressed airlines sell aircraft at a 14 percent discount from the average market price. This discount exists when the airline industry is depressed but not when it is booming. Coval and Stafford (2007) show that fire-sales exists in equity markets when mutual funds engage in sales of similar stocks. Fire-sales have been shown to exist in international settings as well. A surge in foreign direct investment into emerging markets was recorded during Asia and Latin America financial crises. In particular, Krugman (2000), Aguiar and Gopinath (2005), and Acharya et al. (2010) show that asset sales to outsiders during these crises were associated with high discounts, and many foreigners flipped the assets they purchased during crises to domestics once the crises abated at very high returns.

All uncertainty is resolved in the model at the beginning of the second period and one of the two states of the world is realized: a good or a bad state. In the good state there are no shocks and banks' investments produce net positive returns in the last period. However, in the bad state, banks' investments are distressed and they have to be restructured to produce the normal positive returns that are obtained in good times.

A continuum of global investors with large resources in the second period can purchase productive assets in the second period to produce consumption goods in the third and final period. Assets in different countries are perfect substitutes for global investors. However, global investors are not as productive as the domestic banks in operating domestic assets and face decreasing returns to scale from these assets.

I solve the equilibrium of this model by backwards induction. Following the shocks in the interim period, banks need to sell some fraction of their assets in a global capital market to pay for the restructuring costs. An asset sale in the bad state is unavoidable because other domestic resources required to carry out the restructuring process are unavailable. The price of the productive asset is determined in a competitive market in which banks from the two countries and global investors meet.

I show that a higher initial investment by banks in any of these countries will lead to a lower price for the productive asset in this market. If the asset price falls below a minimum threshold, return to the assets that can be retained by the banks is lower than the value of the initial investment, and the banks become insolvent. Once it is known that banks are insolvent, the deposit insurance fund requires bank owners to manage the productive assets to realize the returns in the last period, then liquidates bank assets and makes the payments that banks have promised to depositors. In this case the deposit insurance fund faces a deficit. In the presence of deposit insurance, depositors in the model are passive and always deposit their money with the bank. If the bank fails, the deposit insurance fund makes the necessary payments to depositors.

Regulation in this model can be interpreted as setting the maximum leverage ratio. Each regulator determines the initial regulatory standard by taking into account the equilibrium in the asset market in the interim period. Due to limited liability, banks always leverage up to the maximum by borrowing funds from the local deposit market. In other words, the maximum

leverage ratio always binds. Therefore, the initial investment level of banks in a given country is determined completely by the regulatory standard.

In the first period, regulators act simultaneously and choose the regulatory standard for their domestic banks by taking the regulatory standard in the other country as given. I show that when the countries are symmetric, there exists a unique symmetric Nash equilibrium of the game between the two regulators. Moreover, regulation levels in the two countries are strategic substitutes: if one regulator tightens the regulatory standard in its jurisdiction, the other regulator optimally loosens its regulatory standard. The intuition behind this result is as follows: When the first country reduces the maximum leverage level (i.e., tightens regulatory standards), the extent of the fire-sale of assets in the bad state by banks in that country are reduced, and a higher price is realized for the assets sold by these banks. This increases the expected returns in the bad state, which allows the regulator in the other country to relax regulation levels.

I show that, due to this systemic risk, regulatory standards in equilibrium when regulators act non-cooperatively will be inefficiently lax compared to regulatory standards that would be chosen by a central regulator. A central regulator aims to maximize the total welfare of the two countries, and internalizes these externalities. I assume that, for political reasons, the central regulator has to choose the same regulation levels in both countries. If the two countries are symmetric, I show that forming a regulatory union will increase welfare in both. Therefore, it is incentive compatible for the independent regulators of symmetric countries to relinquish their authority to a central regulator.

I also consider the incentives of regulators when there are asymmetries between countries. I focus on the asymmetries in the asset returns. In particular, I assume that banks in one country are uniformly more productive than the banks in the other country in terms of managing the long-term asset. I show that cooperation would voluntarily emerge only between sufficiently similar countries. In particular, the regulator in the high return country chooses lower regulatory standards in equilibrium and is less willing to compromise on stricter regulatory standards.

Interest in the international coordination of financial regulation is not an entirely recent phenomenon. Arguments in favor of coordination and harmonization of regulatory policies

across countries were made in the 1988 Basel Accord (Basel I) which focused on credit risk and set minimum capital requirements for internationally active banks and was enforced in the G-10 countries in 1992.[3]

However, Basel I did not create an entirely level playing field for internationally active banks because countries retained a significant degree of discretion about different dimensions of regulation. Furthermore rapid developments in financial markets, especially increasingly complex financial products brought about by financial innovation created significant differences about the stringency of capital regulations across countries in practice (Barth et al., 2008). These developments created a challenge for regulators and paved the way for Basel II.[4]

While progress on the implementation of Basel II was slower than expected, the global financial crisis renewed urgency about increased cooperation and the better regulation of international financial markets, in part because insufficient policy coordination between countries and deficiencies in Basel II regulatory mechanisms were blamed for the severe contagion of the crisis. Most of the international regulatory mechanisms proposed prior to the crisis had emphasized the soundness of financial institutions individually (micro-prudential regulation), but had neglected regulatory standards that could enhance the stability of the financial system as a whole by considering systemic risks (macro-prudential regulation). The model in this paper focuses on macro-prudential regulation in the context of regulating systemic risk in the international banking system.

The paper proceeds as follows. Section 2 contains a brief summary of related literature. Section 3 provides the basics of the model and presents the main results of the paper without resorting to a particular functional form. International financial regulation between asymmetric countries is considered in Section 4. Section 5 shows the set of parameter ranges for which systemic failures occur in the uncoordinated equilibrium when countries are symmetric. Section 6 investigates the robustness of the results obtained from the basic model to some changes

[3]The intent of Basel I was to strengthen the soundness and stability of the international banking system, and diminish competitive inequality among international banks by creating a level playing field (Basel 1988).

[4]Basel I was updated in 2004 with more sophisticated sets of rules and principles for capital regulation that intended to accommodate the developments in global financial markets. A survey done by Bank for International Settlements (BIS) in 2006 showed that 95 countries (comprising 13 BSBC member countries plus 82 non-BSBC jurisdictions) were planning to implement Basel II by 2015.

in the model environment. Conclusions are presented in Section 7. All proofs are provided in Appendix A.

1.2 Literature Review

This paper belongs to the international financial regulation theory that has developed in recent decades. This paper is closest to Acharya (2003), Dell'Ariccia and Marquez (2006), Acharya (2009), and Bengui (2011). In particular, Dell'Ariccia and Marquez (2006) investigate the incentives of national regulators to form a regulatory union in a two-country banking model, where a single bank from each country competes for loans in both markets in a Bertrand differentiated products setup. Therefore, if one of the banks is allowed to expand its balance sheet, low average returns to bank loans will be realized in both markets. Banks in this model are also endowed with a costly monitoring technology. Low average returns reduce incentives of banks to monitor, and hence undermines their stability. The authors show that, under this externality, independent national regulators will implement lower capital requirements compared to capital requirements that would be implemented by a central regulator. They also show that symmetric countries always gain from cooperation, whereas a cooperation emerges voluntarily only between sufficiently similar asymmetric countries. The coordination problem for asymmetric countries as presented in this paper is similar to Dell'Ariccia and Marquez (2006). However, in that model the asymmetry between countries was due to differences in regulators' exogenously specified tastes and preferences. In this paper I consider asymmetries that are due to structural differences across countries, such as differences in asset returns.

Acharya (2003) shows that convergence in international capital adequacy standards cannot be effective unless it is accompanied by convergence in other aspects of banking regulation, such as closure policies. Externalities in his model are in the form of cost of investment in the risky asset. He assumes that a bank in one country increases costs of investment for itself and for a bank in the other country as it invest more in the risky asset and thereby creates externalities for the bank in the neighboring country.

In the model considered by Acharya (2009), failure of a bank creates both negative and positive externalities for surviving banks. Negative externality is the increase in the cost of the deposits for surviving banks through a reduction in overall available funds. Positive

externalities are strategic benefits that arise either through depositor migration from the failing banks to surviving banks, or through acquisition of the failed banks' assets and businesses by surviving banks. He shows that that if the negative externality dominates positive externalities, banks in different regions will choose their investments to be highly correlated compared to globally optimal correlation levels. Acharya calls this fact "a systemic risk shifting".

This paper also differs from previously mentioned studies in terms of its source for the externalities between national financial markets. I focus on externalities between national financial markets that operate through asset markets and asset prices whereas the studies cited above considered externalities that operate through costs in the loan or deposit markets. In this paper, systemic risk in international financial markets arises as banks from two countries experience correlated liquidity shocks, and financial amplification effects are triggered due to fire-sales. In that regard, this paper is closest to Bengui (2011), but mainly differs from Bengui (2011) by considering the coordination problem under systemic risk for structurally different countries. On the other hand, Bengui (2011) considers the coordination problem for symmetric countries with risk averse individuals and imperfectly correlated shocks across countries. As this paper affirms, provision of macro-prudential regulation is insufficient when countries act independently, and regulatory standards are strategic substitutes across countries. He also shows that risk taking could be higher in nationally regulated economies compared to the competitive equilibrium, and that starting from a competitive equilibrium unilateral introduction of a (small) regulation could be welfare reducing for the country introducing the regulation.

Another branch of this literature considers regulation of a multi-national bank that operates across two countries. Two notable studies, Dalen and Olsen (2003) and Holthausen and Rønde (2004), focus on the tension between home and host country regulation of a multi-national bank where informational asymmetries are the driving force of regulatory competition. Unlike these studies, my paper focuses on a model in which banks invest in a single country and are therefore regulated only by their home country, but interact with each other in global asset markets. The tension between regulators in my model arises from the externalities that banks in different countries create for each other in global asset markets during times of distress.

This study can also be viewed as a part of the broader literature on macroeconomic policy

coordination that was especially active especially from late 1970s through the 1990s. Cooper (1985) and Persson and Tabellini (1995) provide extensive reviews of this literature. Hamada (1974, 1976) are the pioneer studies in the application of the game-theoretic approach to strategic interactions among national governments.

Last, this paper is also related to the literature that features asset fire-sales. The common theme across these studies is that, under certain conditions, asset prices can move away from the fundamental values and assets can be traded in markets at fire-sale prices. One reason for fire-sales is the combined effect of asset-specificity and correlated shocks that hit an entire industry or economy. Origins of this idea can be found in Williamson (1988) and Shleifer and Vishny (1992) which claim that fire-sales are more likely when major players in an industry face correlated shocks and the assets of the indusry are not easily redeployable in other industries. In such a scenario a firm needs to sell assets to restructure and continue operations at a smaller scale; however it cannot sell its assets at full value because other firms in the same industry are experiencing similar problems. Outside investors would buy and manage these assets but they are not as sophisticated as the firms in the industry. Therefore, they would be willing to pay less than the full value of the assets to the distressed firms. Moreover, unsophisticated investors may face decreasing returns in the amounts of assets they employ. This possibility makes the situation even worse for distressed firms because if many of them try to sell assets to outside investors simultaneously, they will have to accept higher discounts.

The closest papers in this literature to mine are Lorenzoni (2008), Gai et al. (2008) and Korinek (2011) which essentially address the same question: how do privately optimal borrowing and investment levels of financial intermediaries compare to the socially optimal levels under pecuniary externalities in financial markets generated through asset fire-sales? In these studies, the reason for fire-sales are limited commitment on financial contracts and the fact that asset prices are determined in a spot market. Lorenzoni (2008) and Gai et al. (2008) consider a single country, three-period model with a continuum of banks. Banks borrow from consumers and offer them state-contingent contracts. In the interim period, banks are hit by shocks and need to sell assets in some states to restructure distressed investments. These papers show that there exists over-borrowing and hence over-investment in the risky asset in a competitive setting compared to the socially optimal solution. Because in the competitive

setting each bank treats the market price of assets as given when it makes borrowing and investment decisions in the initial period, it does not internalize the externalities created for other banks through fire sales. The planner considers the fact that a higher investment will translate into lower prices for capital sold by banks during the times of distress. The main difference between my paper and these papers is that they focus on issues in single country cases to the exclusion of issues related to the international dimension of regulation.

Asset specificity is not the only reason for fire-sales. In Allen and Gale (1994, 1998) and Acharya and Yorulmazer (2008) the reason for fire-sales is the limited available amount of cash in the market to buy long-term assets offered for sale by agents who need liquid resources immediately. The scarcity of liquid resources leads to necessary discounts in asset prices, a phenomenon known as "cash-in-the-market pricing".

1.3 Model

There are three periods, $t = 0, 1, 2$; and two countries, $i = A, B$. In each country there is a continuum of banks and a continuum of consumers each with a unit mass and a financial regulator. There is also a unit mass of global investors. All agents are risk-neutral.

There are two goods in this economy: a consumption good and a capital good (i.e., the liquid and illiquid assets). Consumers are endowed with e units of consumption goods at $t = 0$, and none at later periods.[5]

Banks have a technology that converts consumption goods into capital goods one-to-one at $t = 0$. Capital goods that are managed by a bank until the last period yield $R > 1$ consumption goods per unit. Consumption goods are perishable, and the capital fully depreciates at $t = 2$. Capital goods can never be converted into consumption goods.[6]

Banks in each country $i = A, B$ choose the level of investment, n_i, in the capital good at

[5]I assume that the initial endowment of consumers is sufficiently large, and it is not a binding constraint in equilibrium.

[6]I focus on a simple, tractable model where there is no safe asset and the liquidity shock at the interim period has a degenerate distribution. I conjecture that relaxing the assumption of no safe asset will not change the qualitative results of this model. If we allow banks to hoard safe asset, and consider a more general distribution of liquidity shocks, banks will hold some optimum amount of safe asset at the initial period for precautionary reasons. This precautionary savings, however, will not be sufficient to cover liquidity needs under large realizations of shocks. In these states of the world, asset fire-sales will be unavoidable, and that inevitability will generate the externality between countries that is the crucial part of the current model.

$t = 0$, and borrow the necessary funds from domestic consumers. I consider deposit contracts that are in the form of simple debt contracts, and assume that there is a deposit insurance fund operated by the regulator in each country. Therefore banks can raise deposits from consumers at a constant and zero net interest rate. I also assume that banks are protected by limited liability.[7]

All uncertainty is resolved at the beginning of $t = 1$: a country lands in good times with probability q, and in bad times with probability $1-q$. In order to simplify the analysis, I assume that the states of the world at $t = 1$ are perfectly correlated across countries. In good times no banks are hit with shocks, therefore no further actions are taken. Banks keep managing their capital goods, and realize the full returns from their investment, Rn_i, in the last period. They make the promised payment, n_i, to consumers, and hence earn a net profit of $(R-1)n_i$. However, in bad times, the investments of all banks in both countries are distressed. In case of distress, the investment has to be restructured in order to remain productive. Restructuring costs are equal to $c \leq 1$ units of consumption goods per unit of capital. If c is not paid, capital is scrapped (i.e., it fully depreciates).

There are no available domestic resources (consumption goods) with which to carry out the restructuring of distressed investment at $t = 1$. Only global investors are endowed with liquid resources at this point. Due to a commitment problem, banks cannot borrow the required resources from global investors. In particular, I assume that individual banks cannot commit to pay their production to global investors in the last period.[8] The only way for banks to raise necessary funds for restructuring is to sell some fraction of the investment to global investors in an exchange of consumption goods.

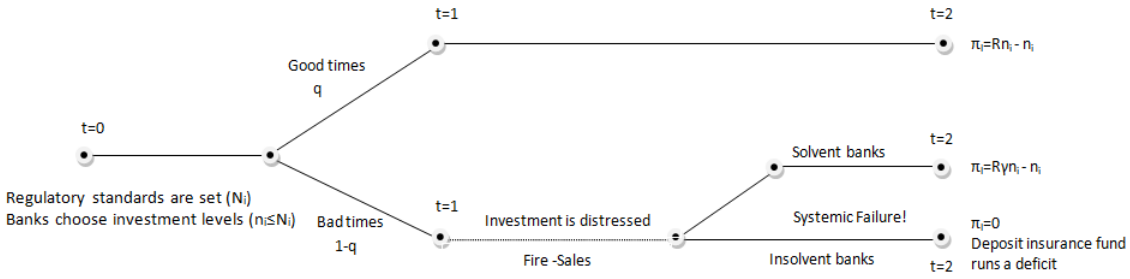
These capital sales by banks will carry the features of a fire-sale: the capital good will be traded below its fundamental value for banks, and the price will decrease as banks try to sell more capital. Banks in each country will retain only a fraction of their assets after fire-sales. If

[7]Limited liability and deposit insurance assumptions are imposed to match reality and to simplify the analysis of the model. All qualitative results carry on when these assumptions are removed as shown is Section 6.

[8]For simplicity, I assume that the commitment problem is extreme (i.e., banks cannot commit to pay any fraction of their production to global investors). Assuming a milder but sufficiently strong commitment problem where banks can commit a small fraction of their production, as in Lorenzoni (2008) and Gai et al. (2008), does not change the qualitative results of this paper.

the asset price falls below a threshold, the expected return on the assets that can be retained by banks will be lower than the value of the initial investment; hence, banks will become insolvent.[9] I call this situation a "systemic failure".

Figure 1.1: Timing of the Model



Once it is known that banks are insolvent, deposit insurance requires the bank owners to manage their capital goods to realize the returns in the last period. The regulator then seizes banks' returns, and makes the promised payments to depositors. The deposit insurance fund runs a deficit. If fire-sales are sufficiently mild, however, then banks will have enough assets to make the promised payments to the depositors. In this case banks remain solvent, but compared to good times they make smaller profits. This sequence of events is illustrated in Figure 1.1.

Banks are subject to regulation in the form of an upper limit on initial investment levels.[10] Regulatory standards are set, independently, by the individual national regulators at the beginning of $t = 0$. The regulator of country i determines the maximum investment allowed for banks in its jurisdiction, N_i, while taking into account the regulation in the other country, N_j, as given. Investment levels of banks in country i, have to satisfy $n_i \leq N_i$ at $t = 0$. The regulatory standard in a country is chosen to maximize the net expected returns on risky investments.

[9]Because all uncertainty is resolved at the beginning of $t = 1$, the expected return to capital retained by banks after fire sales, which is certain at that point, is R units of consumption goods per unit of capital.

[10]This regulation becomes equivalent to a minimum capital ratio requirement when we introduce a costly bank equity capital to the model as shown in Section 1.6. I abstract from costly equity capital in the basic model in order to simplify the exposition.

1.3.1 Global Investors

Global investors are endowed with unlimited resources of consumption goods at $t = 1$.[11] They can purchase capital, y, from banks in each country at $t = 1$ and employ this capital to produce $F(y)$ units of consumption goods at $t = 2$. For global investors capital supplied by the banks in these two countries are identical. Let P denote the market price of the capital good at $t = 1$.[12] Because we have a continuum of global investors, each investor treats the market price as given, and chooses the amount of capital to purchase, y, to maximize net returns from investment at $t = 2$

$$\max_{y \geq 0} F(y) - Py \tag{1.1}$$

The amount of assets they optimally buy satisfies the following first order conditions

$$F'(y) = P \tag{1.2}$$

The first order condition above determines global investors' (inverse) demand function for the capital good. Using this, we can define their demand function $D(P)$ as follows

$$y = F'(P)^{-1} \equiv D(P) \tag{1.3}$$

We need to impose some structure on the return function of global investors and the model parameters in order to ensure that the equilibrium of this model is well-behaved.

1.3.2 Basic Assumptions

Assumption 1 (CONCAVITY)**.**

$$F'(y) > 0 \text{ and } F''(y) < 0 \text{ for all } y \geq 0, \text{ with } F'(0) \leq R.$$

[11] The assumption that there are some global investors with unlimited resources at the interim period when no one else has resources can be justified with reference to the empirical facts during the Asian and Latin American financial crises. Krugman (2000), Aguiar and Gopinath (2005), and Acharya et al. (2010) provide evidence that, when those countries were hit by shocks and their assets were distressed, some outside investors with large liquid resources bought their assets.

[12] Price of capital at $t = 0$ will be one as long as there is positive investment, and the price of capital at $t = 2$ will be zero because capital fully depreciates at this point.

Assumption *CONCAVITY* says that although global investors' return is strictly increasing the amount of capital employed ($F'(y) > 0$), they face decreasing returns to scale in the production of consumption goods ($F''(y) < 0$), as opposed to banks that are endowed with a constant returns to scale technology as described above. $F'(0) \leq R$ implies that global investors are less productive than banks at each level of capital employed.

Concavity of the return function implies that the demand function of global investors for capital goods is downward sloping (see Figure 1.2). Global investors will require higher discounts to absorb more capital from distressed banks at $t = 1$. This assumption intends to capture that distress selling of assets is associated with reduced prices. Using a large sample of commercial aircraft transactions Pulvino (2002) shows that distressed airlines sell aircraft at a 14 percent discount from the average market price. This discount exists when the airline industry is depressed but not when it is booming. Coval and Stafford (2007) show that fire-sales exists in equity markets when mutual funds engage in sales of similar stocks. Furthermore, Krugman (2000), Aguiar and Gopinath (2005), and Acharya et al. (2010) provide significant empirical and anecdotal evidence that during Asian and Latin American crises, foreign acquisitions of troubled countries' assets were very widely spread across industries, and assets were sold at sharp discounts. These evidence suggests that foreign investors took control of domestic enterprises mainly because they had liquid resources whereas the locals did not, even though the locals had superior technology and know-how to run the domestic enterprises. Further support for this argument comes from the evidence in Acharya et al. (2010) that many foreigners eventually flipped the assets they acquired during the Asian crisis to locals, and usually made enormous profits from such trades.

The idea that some assets are industry specific, and hence less productive in the hands of outsiders has its origins in Williamson (1988) and Shleifer and Vishny (1992). Examples of industry-specific assets include oil rigs and refineries, aircraft, copper mines, pharmaceutical patents, and steel plants. These studies have claimed that when major players in such industries face correlated liquidity shocks, and cannot raise external finance due to debt overhang, agency or commitment problems, they may have to sell assets to outsiders. Outsiders are willing to pay less than the value in best use for the assets of distressed enterprises because they do not have the specific know-how to manage these assets well and therefore face agency costs

of hiring specialists to run these assets. The decreasing returns to scale technology assumption captures the inefficiency of outsiders, similar to Kiyotaki and Moore (1997), Lorenzoni (2008), Gai et al. (2008) and Korinek (2011).

Assumption 2 (ELASTICITY)**.**

$$\epsilon_{P,y} = -\frac{\partial y}{\partial P}\frac{P}{y} = -\frac{F'(y)}{yF''(y)} > 1 \quad \textit{for all } y \geq 0$$

Assumption *ELASTICITY* says that global investors' demand for the capital good is elastic. This assumption implies that the amount spent by global investors on asset purchases, $Py = F'(y)y$, is strictly increasing in y. Therefore we can also write Assumption *ELASTICITY* as

$$F'(y) + yF''(y) > 0$$

If this assumption was violated, multiple levels of asset sales would raise a given amount of liquidity, and multiple equilibria in the asset market at $t = 1$ would be possible. This assumption was imposed by Lorenzoni (2008) and Korinek (2011) in order to rule out multiple equilibria under fire-sales.[13]

Assumption 3 (REGULARITY)**.**

$$F'(y)F'''(y) - 2F''(y)^2 \leq 0 \quad \textit{for all } y \geq 0$$

Assumption *REGULARITY* holds whenever the demand function of global investors is log-concave, but it is weaker than log-concavity.[14] In order to see this, let $\phi(y) \equiv F'(y)$ denote the (inverse) demand function of global investors. We can rewrite Assumption *REGULARITY* as

$$\phi(y)\phi''(y) - 2\phi'(y)^2 \leq 0.$$

We can show that the demand function is log-concave if and only if $\phi(y)\phi''(y) - \phi'(y)^2 \leq 0$.

[13]Gai et al. (2008) provides the leading example where this assumption is not imposed and multiple equilibria in the asset market is therefore considered.

[14]A function is said to be log-concave if the logarithm of the function is concave.

Log-concavity of demand function is a common assumption used in the Cournot games literature (see Amir (1996)); it ensures the existence and uniqueness of equilibrium in a simple *n-player* Cournot game. Therefore, I call it a "regularity" assumption on $F(\cdot)$. Clearly Assumption *REGULARITY* holds whenever the demand function is log-concave. However, Assumption *REGULARITY* is weaker than log-concavity, and may also hold if the demand function is log-convex (i.e., if $\phi(y)\phi''(y) - \phi'(y)^2 \geq 0$).

Assumption *REGULARITY* will ensure that the objective functions of regulators are well-behaved. It will be crucial in showing that the equilibrium of this model exists and it is unique.

Many regular return functions satisfy conditions given by Assumptions *CONCAVITY*, *ELASTICITY* and *REGULARITY*. Here are two examples that satisfy all three of the above assumptions:

Example 1 $F(y) = R\ln(1+y)$

Example 2 $F(y) = \sqrt{y + (1/2R)^2}$

The following example satisfies Assumption *CONCAVITY*, but not Assumptions *ELASTICITY* and *REGULARITY*.

Example 3 $F(y) = y(R - 2\alpha y)$ where $2\alpha y < R$ for all $y \geq 0$.

Assumption 4 (RANGE)**.**

$$1 + (1-q)c < R \leq 1/q$$

Assumption *RANGE* says that the return on investment for banks must not be too low because otherwise equilibrium investment levels will be zero, and it must not be too high, because otherwise equilibrium investment levels will be infinite. This assumption, while not crucial for the results, allows us to focus on interesting cases in which equilibrium investment levels are neither zero nor infinite.

1.3.3 Equilibrium with Symmetric Countries

In this section I consider only symmetric countries and solve the model by backwards induction. First, I analyze the equilibrium at the interim period in each state of the world, for a given

set of investment levels; then I solve the game between the regulators at $t = 0$. Note that, if good times are realized $t = 0$, no further actions need to be taken by any agent. Therefore, at $t = 1$ we need only to analyze the equilibrium of the model for bad times.

I solve the model without resorting to some particular functional form. The results of this paper hold for any functional form that satisfy Assumptions *CONCAVITY*, *ELASTICITY*, and *REGULARITY*.

Crisis and Fire-Sales

Consider the problem of a bank in country i if bad times are realized at $t = 1$. The bank reaches $t = 1$ with a level of investment equal to n_i which was chosen at the initial period. The investment is distressed, and must be restructured using liquid resources. The investment will not produce any returns in the last period if it is not restructured.[15] The bank cannot raise external finance from global investors because it cannot commit to pay them in the last period. Therefore, the only way for the bank to raise the funds necessary for restructuring is to sell some fraction of the investment to global investors and use the proceeds to pay for restructuring costs, whereby it can retain another fraction of the investment.

At the beginning of $t = 1$ in bad times, a bank in country i decides what fraction of capital to restructure (χ_i), and what fraction of restructured capital to sell ($1 - \gamma_i$) to generate the resources for restructuring. Note that γ_i will then represent the fraction of capital that a bank keeps after fire-sales.[16] Thus the bank takes the price of capital (P) as given, and chooses χ_i and γ_i to maximize total returns from that point on

$$\max_{0 \leq \chi_i, \gamma_i \leq 1} \pi_i = R\gamma_i\chi_i n_i + P(1 - \gamma_i)\chi_i n_i - c\chi_i n_i \tag{1.4}$$

[15]For example, if the assets are physical, restructuring costs can be maintenance costs or working-capital needs.

[16]Following Lorenzoni (2008) and Gai et al. (2008), I assume that banks have to restructure an asset before selling it. Basically, this means that bank receive the asset price P from global investors, use a part, c, to restructure the asset, and then deliver the restructured assets to global investors. Therefore banks will sell assets only if P is greater than the restructuring cost, c. We could assume, without qualitatively changing our results, that it is the responsibility of global investors to restructure the assets that they purchase. However, the model is more easily solved using the current story.

subject to the budget constraint

$$P(1-\gamma_i)\chi_i n_i - c\chi_i n_i \geq 0 \tag{1.5}$$

The first term in (1.4) is the (certain) total return that will be obtained from the unsold part of the restructured assets, which are $\chi_i n_i$, in the last period. The second term is the revenue raised by selling a fraction $(1-\gamma_i)$ of the restructured assets, which are $\chi_i n_i$, at the given market price P. The last term, $c\chi_i n_i$, gives the total cost of restructuring. Budget constraint (1.5) says that the revenues raised by selling capital must be greater than or equal to the restructuring costs.

By Assumption *CONCAVITY*, the equilibrium price of capital must satisfy $P \leq F'(0) \leq R$, otherwise global investors will not purchase any capital. Later on, I will show that in equilibrium we must also have $c < P$. For the moment, we will assume that the equilibrium price of assets satisfies

$$c < P \leq R \tag{1.6}$$

Now, consider the first order conditions of the maximization problem (1) while ignoring the constraints

$$\frac{\partial \pi_i}{\partial \chi_i} = [R\gamma_i + P(1-\gamma_i) - c]n_i \tag{1.7}$$

$$\frac{\partial \pi_i}{\partial \gamma_i} = (R-P)\chi_i n_i \tag{1.8}$$

From (1.8) it is obvious that π_i is increasing in γ_i because $P \leq R$ by (1.6): when the price of capital goods is lower than the return that banks can generate by keeping them, banks want to retain a maximum amount. Choosing γ_i as high as possible implies that the budget constraint will bind. Hence, from (1.5), we obtain that the fraction of capital goods retained by banks after fire-sales is

$$\gamma_i = 1 - \frac{c}{P} \tag{1.9}$$

The fraction banks retain after fire-sales (γ_i) is increasing in the price of the capital good (P), and decreasing in the cost of restructuring (c). From (1.9) we can also obtain the total capital

supply of a bank in country i as

$$S_i(P, n_i) = (1 - \gamma_i)n_i = \frac{c}{P}n_i \tag{1.10}$$

for $c < P \leq R$. This supply curve is downward-sloping and convex, which is standard in the fire-sales literature. A negative slope implies that if there is a decrease in the price of assets banks have to sell more assets in order to generate the resources needed for restructuring. This is because banks are selling a valuable investment at a price below the fair value for them due to an exogenous pressure (e.g., paying for restructuring costs).

On the other hand, using (1.9) we can write the first order condition (1.7) as

$$\frac{\partial \pi_i}{\partial \chi_i} = R\gamma_i n_i \geq 0 \tag{1.11}$$

Equation (1.11) shows that revenues are increasing in χ_i at $t = 1$. Therefore, banks will optimally choose to restructure the full fraction of the investment ($\chi_i = 1$). In other words, scrapping of capital will never arise in equilibrium.

Note that if the capital price is greater than R, banks want to sell all the capital goods they have because they can get at most R per unit by keeping and managing them. If the price is lower than c, however, they will optimally scrap all of their capital ($\chi_i = 0$). As discussed above, prices above R and below c will never arise in equilibrium. The total asset supply curve of banks from the two countries is plotted in Figure 1.2 for an initial total investment in the two countries of $\overline{N}$.

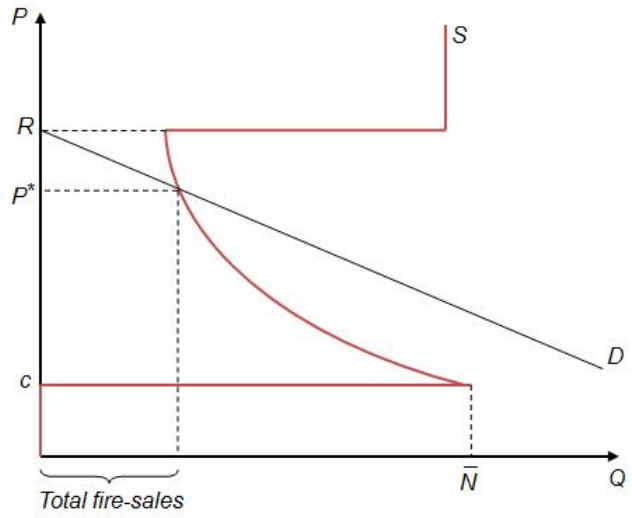
Equilibrium in the Capital Market at t=1

Equilibrium price of capital goods, P^*, will be determined by the market clearing condition

$$E(P^*, n_A, n_B) = D(P^*) - S(P^*, n_A, n_B) = 0 \tag{1.12}$$

The condition above says that the excess demand in the capital market, denoted by $E(P, n_A, n_B)$, is equal to zero at the equilibrium price. $D(P)$ in Equation (1.12) is the demand function of global investors which was obtained from the first order conditions of global investors' problem

Figure 1.2: Equilibrium in the Capital Goods Market



as shown by (1.3). $S(P, n_A, n_B)$ is the total supply of capital goods. We can obtain it as

$$S(P, n_A, n_B) = \frac{c(n_A + n_B)}{P} \tag{1.13}$$

by adding the individual supply of banks in each country given by (1.10).

This equilibrium is illustrated in Figure 1.2. Note that the equilibrium price of capital at $t = 1$ will be a function of the initial investment level in the two countries. Therefore, from the perspective of the initial period I denote the equilibrium price as $P^*(n_A, n_B)$.

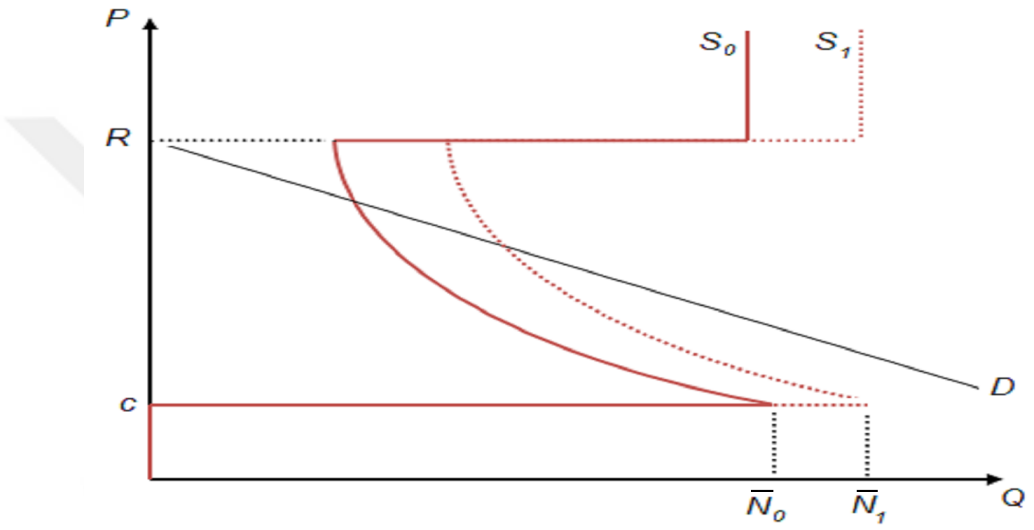
How does a change in the initial investment level in one of the countries affect the price of capital at $t = 1$? Lemma 1 shows that if investment into the risky asset in one country increases at $t = 0$, a lower price for capital will be realized in the fire-sales state at $t = 1$.

Lemma 1. *$P^*(n_i, n_j)$ is decreasing in n_i for $i = A, B$ and $j \neq i$ under Assumptions CONCAVITY and ELASTICITY.*

Lemma 1 implies that higher investment in the risky asset in one country (i.e., a higher n_i) increases the severity of the financial crisis for both countries by lowering the asset prices. This effect is illustrated in Figure 1.3. Suppose that initial investment level in country A increases, increasing the total investment in the two countries from $\overline{N}_0$ to $\overline{N}_1$. In this case, banks in country A will have to sell more assets at each price, as can be seen from individual supply

function given by (1.10). Graphically, the total supply curve will shift to the right, as shown by the dotted-line supply curve in Figure 1.3, which will cause a decrease in the equilibrium price of capital goods. Lower asset prices, by contrast, will induce more fire-sales by banks in both countries in the bad state due to the downward-sloping supply curve. This additional result is formalized in Lemma 2.

Figure 1.3: Capital Goods Market: Comparative Statics



Lemma 2. *Equilibrium fraction of assets sold in each country,* $1-\gamma^*(n_i, n_j)$*, is increasing in* n_i *for* $i = A, B$ *under Assumptions CONCAVITY and ELASTICITY.*

Together lemmas 1 and 2 imply that a higher initial investment in the risky investment in one country creates negative externalities for the other country by making financial crises more severe (i.e., via lower asset prices according to Lemma 1) and more costly (i.e., more fire-sales according to Lemma 2).

Banks' Problem

Each bank in country i at $t = 0$ chooses the investment level, n_i, to maximize expected profits given by

$$\max_{0 \le n_i \le N_i} \Pi_i(n_i) = \; q(R-1)n_i + (1-q)\, \max\left[R\gamma n_i - n_i, 0\right] \tag{1.14}$$

where γ is the equilibrium fraction of rescued assets by a bank in country i which is equal to $1 - c/P$ as shown by (1.9). A bank borrows from the local deposit market at a constant zero

interest and invests in the productive asset. With probability q both countries are in good times, and hence the investment produces returns as expected Rn_i. Banks make the promised payments to depositors, n_i, leading to a net profit of $(R-1)n_i$. With probability $1-q$ both countries are in the bad state. Banks from the two countries face restructuring costs, and hence are forced to fire-sale their assets. Since banks are price-takers in the capital market, the fraction of capital that they can save from the fire-sales, $\gamma = 1 - c/P$, is exogenous to them. In other words, because each bank is small compared to market size, it does not take into account the effect of its investment choice at $t = 0$ on the equilibrium price (P), and thus on the fraction of assets retained after fire-sales in equilibrium (γ).

Banks undoubtedly earn net positive returns in the good state since $q(R-1) > 0$. Moreover, due to the limited liability, they never receive negative profits in the bad state. Because banks do not internalize the effect of their initial investment on the stability of the financial system at $t = 1$, there is no counter-effect that offsets the positive returns on investment. Therefore, a bank's net expected return from risky investment at $t = 0$ is always positive, and a bank always makes itself better off by investing more. Therefore, the regulatory upper limit on the risky investment at $t = 0$ will bind (i.e., banks will choose $n_i = N_i$ at $t = 0$).

Fire-sales will be severe for some parameters and banks may become insolvent in equilibrium as analyzed in Section 5. I assume that when banks are insolvent after fire-sales they are required by law to manage remaining assets until the last period and transfer asset returns to the deposit insurance fund. This is a reasonable assumption because banks are the only sophisticated agents in our model domestic economy that can manage those assets. Furthermore, in practice, the dissolution process of insolvent banks usually does not happen immediately. It is a time-consuming process because, for example, loans have to be called-off or sold to third parties to make payments to debtors. This assumption also captures this time dimension of the dissolution process.

Regulators' Problem

Regulators of the two countries simultaneously determine the regulatory standards for the banks in their own jurisdictions before banks make their borrowing and investment decisions at $t = 0$. Regulation in each country $i = A, B$ takes the form of an upper limit, $N_i \geq 0$, on the

investment level allowed for domestic banks. Banks in country i have to abide by the regulation by choosing their investment levels as $n_i \leq N_i$. As they set the standards, regulators anticipate that banks will choose initial investment levels that are as high as possible, and incorporate this fact into their decision problem.

The objective of an independent national financial regulator is to maximize the net expected social welfare of its own country. Social welfare is defined as the expected return to the risky investment minus the cost of the initial investment. Therefore, regulator i chooses $N_i \geq 0$, to solve

$$\max_{N_i \geq 0} W_i(N_i, N_j) = \max_{N_i \geq 0} qRN_i + (1-q)R\gamma^*(N_i, N_j)N_i + (e - N_i) \tag{1.15}$$

while taking the regulatory standard in the other country, N_j, as given. Let $(\widehat{N}_A, \widehat{N}_B)$ denote the Nash Equilibrium of the game between the regulators at $t = 0$ whenever it exists. I assume that the initial endowment of consumers (e) is sufficiently large, and that it is not a binding constraint in equilibrium.

Social welfare given by (1.15) incorporates the fact that banks investment level, n_i, equals N_i, the regulatory upper limit. With probability q, the good state is realized when banks in country i obtain a total return of RN_i. With probability $1 - q$ both countries land in the bad state. In the bad state, banks perform asset sales as described previously, and manage the remaining assets, $\gamma^*(N_i, N_j)N_i$ until $t = 2$ to obtain a gross return of R per unit. Therefore the return to the investment in the bad state in country i is $R\gamma^*(N_i, N_j)N_i$. The cost of the initial investment (N_i) is subtracted to obtain net returns to the investment. Each regulator takes into account the effect of both countries' regulatory standards on the price of capital in the bad state. This is why the fraction of assets that banks can keep after the fire-sales, $\gamma^*(N_i, N_j) = 1 - c/P^*(N_i, N_j)$, is written as a function of the regulatory standards in the two countries.

The following equation gives the first order conditions of regulator i's problem in (1.15)

$$\frac{\partial W_i(N_i, N_j)}{\partial N_i} = qR + (1-q)R\left\{\frac{\partial \gamma^*(N_i, N_j)}{\partial N_i}N_i + \gamma^*(N_i, N_j)\right\} - 1 \tag{1.16}$$

By rearranging the terms, we can write this first order condition as a sum of the marginal

benefit and marginal cost of increasing N_i, the regulatory standard:

$$\frac{\partial W_i(N_i, N_j)}{\partial N_i} = \{qR + (1-q)R\gamma^*(N_i, N_j)\} + \left\{(1-q)R\frac{\partial \gamma^*(N_i, N_j)}{\partial N_i}N_i - 1\right\} \tag{1.17}$$

When regulator i increases N_i, there will be more investment in the risky asset. The first curly brackets give the expected gross marginal benefit from increasing N_i: with probability q the good state is realized and a total return of R is obtained from the additional unit of investment. With probability $1-q$, the bad state is realized, and a total return of $R\gamma^*(N_i, N_j)$ is obtained from the additional investment. In the bad state, the return can be obtained only from a fraction, $\gamma^*(N_i, N_j)$, of the original investment, because another fraction of the investment is sold to global investors.

The second curly brackets in (1.17) give the expected marginal cost of increasing N_i. Because $\gamma^*(N_i, N_j)$ is decreasing in N_i, as implied by Lemma 2, a smaller fraction of assets will be retained by banks if the bad state is realized for higher initial investment levels. The first term captures this fact: with probability $1-q$ the bad state is realized, and an additional unit of investment will decrease the fraction of capital that can be retained by banks of country i by $\partial\gamma^*(N_i, N_j)N_i$, causing a total loss of $(\partial\gamma^*(N_i, N_j)/N_i)N_i$. Last, "-1" in the second curly bracket gives the marginal cost of funds required for the risky investment.

An alternative formulation of regulators' objective function

We can alternatively write the regulators' objective function in a way that explicitly shows the returns to the investment and costs of fire-sales. Start by substituting $1 - c/P$ for $\gamma^*(\cdot)$ function using the derivation obtained in (1.9) to write (1.15) as

$$W_i(N_i, N_j) = qRN_i + (1-q)R\left\{1 - \frac{c}{P^*(N_i, N_j)}\right\}N_i + (e - N_i)$$

Add and subtract cN_i to the expression above to get

$$W_i(N_i, N_j) = qRN_i + (1-q)R\left\{RN_i - \frac{Rc}{P^*(N_i, N_j)}N_i + cN_i - cNi\right\} + (e - N_i)$$

Last, rearranging the terms inside the curly brackets gives

$$W_i(N_i, N_j) = qRN_i + (1-q)\left\{RN_i - [R - P^*(N_i, N_j)]\frac{cN_i}{P^*(N_i, N_j)} - cN_i\right\} + (e - N_i) \quad (1.18)$$

Consider this alternative objective function in detail. It is composed of two main terms as in (1.15): net expected returns in both the good state and the bad state. Because the first term, $q(R-1)N_i$, that gives the net expected return in the good state is clear, I focus on the latter. The first term inside the curly brackets gives the net total return that could be obtained from the investment if there were no fire-sales. The second term is the cost of fire-sales: $cN_i \backslash P^*(N_i, N_j)$ is the amount of assets sold in fire-sales as given by (1.10), where banks receive $P^* < R$ from these assets instead of R. The last term inside the curly brackets, cN_i, is the total cost of restructuring.

Because the two versions of the regulators' objective function are the same, I will use the first formulation in the rest of the paper for the sake of analytical convenience, even though the alternative formulation could be more intuitive.

Regulatory Standards in the Uncoordinated Equilibrium

Having analyzed the problem of regulators, we can turn to investigating the equilibrium of the game between regulators at $t = 0$ when they act independently. The aims are to show that there exists a unique symmetric equilibrium of this game, and then to perform comparative statics. I start by analyzing the properties of the best response functions of regulators. The following lemma establishes that independent regulators have a unique best response to each regulatory standard choice by the opponent country.

Lemma 3. *Under Assumptions CONCAVITY, ELASTICITY and REGULARITY, each regulator's best response is unique valued.*

An interesting question in this setup concerns how that unique best response behaves as regulation in the opponent country changes. Suppose that the regulator of country B decides to tighten regulation (i.e., reduce N_B). How would the regulator of country A optimally react? The next proposition shows that regulator A optimally chooses to relax its regulatory standard

(i.e., increase N_A), as regulator B imposes stricter regulations. In other words, the optimal regulatory standards in the two countries are *strategic substitutes.*

Proposition 1. *Under Assumptions CONCAVITY, ELASTICITY and REGULARITY, optimal regulatory standards in the uncoordinated equilibrium are strategic substitutes.*

The intuition for this result is as follows: If regulator B tightens its regulatory standard by reducing the upper limit on the investment level for its banks, there will be less distressed assets at $t = 1$ in the bad state; hence, a higher asset price, P^*, will be realized. Therefore, fewer assets will be sold in equilibrium as shown by Lemma 2, which means that banks in both countries will be able to retain a higher fraction of their initial investment after fire-sales. This retention will increase the marginal return to investment and initially allow regulator A to optimally choose a higher upper limit on the investment level (i.e. relax its regulatory standard).

The next lemma shows that in order to have finite and strictly positive equilibrium investment levels in the two countries, banks' return from investment R should not be too low, or too high. The exact condition on R is given by Assumption *RANGE*, which states that $1 + c(1 - q) < R \leq 1/q$.

Lemma 4. *The best responses of each regulator satisfy* $0 < N_i^* < \infty$ *for* $i = A, B$ *if Assumption RANGE holds, i.e. if* $1 + (1 - q)c < R \leq 1/q$.

$1 + (1 - q)c$ is the net expected cost of the investment: each unit of investment requires one unit of consumption good initially. With probability $1 - q$ bad times are realized, in which case banks have to incur an extra restructuring cost of c units of consumption goods per unit of investment. If the return on the investment, R, is less then this expected cost, $1 + (1 - q)c$, booth countries' social welfare will be higher without any investment at all. Therefore, if $R < 1 + (1 - q)c$, then equilibrium investment levels are zero in both countries. But if $R > 1/q$ then the expected return to the investment in the good state alone will be higher than initial cost of investment, which is 1. In this case, even when the entire initial investment is expected to be lost in the bad state, the net expected return to investment will always be positive. For sufficiently high initial endowment levels, this case leads to a corner solution in which social

welfare is maximized by having all endowments invested in the risky asset. I also impose $qR \leq 1$ in order to rule out these inconsequential details and focus on the interesting cases.

Now, we are ready to examine the existence of a Nash equilibrium in the game between regulators. The nice features of the objective functions of regulators established above help us to show that a Nash equilibrium exists.

Proposition 2. *Under Assumptions CONCAVITY, ELASTICITY, REGULARITY and RANGE, at least one pure strategy Nash Equilibrium exists in the game between two financial regulators at $t = 0$. Moreover there exists at least one symmetric pure strategy NE.*

The next natural question is whether there are multiple equilibria or there is a unique equilibrium. Fortunately, under the stated previously conditions, we have a unique symmetric equilibrium of the game between the regulators as shown by the following proposition.

Proposition 3. *Under Assumptions CONCAVITY, ELASTICITY, REGULARITY and RANGE, there exists a unique symmetric Nash Equilibrium of the game between the regulators at $t = 0$.*

Comparative Statics for the Uncoordinated Equilibrium

What happens to the unique regulatory standards of the uncoordinated equilibrium in the two countries as good state becomes more likely, or if bank's per unit return from investment, R, increases? The next proposition shows that in both cases regulatory standards in the two countries are relaxed (i.e., regulators increase the upper limit on the risky investment).

Proposition 4. *Regulatory standards in the uncoordinated symmetric equilibrium become more lax as q and R increase.*

This result is quite intuitive because as the good state becomes more likely (i.e., as q increases), regulators will face the cost of fire-sales less often and will allow more investment in equilibrium. But as R increases, returns to investment in both good and bad states also increase, making the investment socially more profitable.

I conclude this section by showing that in equilibrium, price of the capital good at $t = 1$ in bad times must be greater than restructuring costs (c). I tentatively assumed this while discussing banks' optimal fire-sales decisions at $t = 1$ after they receive bad shocks. Now

it is time to prove this claim formally. Under this result, as I have shown, banks optimally restructure all assets in equilibrium. In other words, as previously stated, scrapping of capital never arises in equilibrium.

Lemma 5. *Under Assumptions CONCAVITY, ELASTICITY, REGULARITY and RANGE, the equilibrium price of the capital good at $t = 1$ in bad times satisfies $P^* > c$.*

Lemma 5 holds because if regulators allow the investment level in their country (N_i) to be too high, they know that they will drive down the equilibrium price below the cost of restructuring in which case banks do not restructure any assets. Therefore, it is never optimal for any of the regulators to allow such high investment levels, independent of the choice of the competing regulator.

1.3.4 Internationally Coordinated Regulation

Suppose that there is a higher authority, call it the central regulator, that determines optimal regulatory standards in these two countries. In practice, the central regulator could be an international financial institution such as the International Monetary Fund or the Bank for International Settlements, or it could be an institution created by a binding bilateral agreement between the two countries. I assume that, for political reasons, the central regulator must choose the same regulatory standards for both countries. The question that I address in this section is as follows: Suppose that at the beginning of $t = 0$, national regulators can either set regulatory standards independently or simultaneously relinquish their authority to the central regulator. Would they choose the latter?

I define the central regulator's problem as follows: it chooses the regulatory standards in countries A and B, (N_A, N_B), to maximize the sum of expected social welfare of these countries as given below

$$\max_{N_A,N_B\geq 0} GW(N_A,N_B) = \max_{N_A,N_B\geq 0} \sum_{i=A,B;j\neq i} \{q(R-1)N_i+(1-q)[R\gamma^*(N_i,N_j)N_i-N_i]\} \quad (1.19)$$

In other words, the central regulator maximizes the sum of the objective functions of individual regulators. For symmetric countries, it is natural to assume that each country receives

an equal weight in the central regulator's objective function.[17] I denote the internationally optimal common regulatory standards by $(\widetilde{N}, \widetilde{N})$ and compare them to the regulatory standards in the uncoordinated symmetric equilibrium, $(\widehat{N}, \widehat{N})$.

Another way to state the central regulator's problem for symmetric countries involves thinking of the central regulator as choosing total investment level across the two countries, $N = N_A + N_B$, to maximize their overall welfare. After determining the optimal total investment level $\overline{N}$, it imposes $\widetilde{N}_i = \overline{N}/2$ for $i = A, B$ where

$$\overline{N} = \underset{N \geq 0}{\arg\max} \;\; q(R-1)N + (1-q)[R\widetilde{\gamma}^*(N)N - N] \tag{1.20}$$

It is easy to see that the two alternative problems for the central regulator given by (1.19) and (1.20) are the same due to the countries' symmetry.

Now, we can compare the internationally optimal regulatory standards to the standards that arise as a result of strategic interaction between regulators. The following proposition shows that a central regulator will impose tighter regulatory standards (i.e., a lower N) compared to what would have been chosen by independent regulators.

Proposition 5. *$\widetilde{N} < \widehat{N}$, i.e. the central regulator chooses tighter regulatory standards compared to the standards chosen by independent national regulators in the uncoordinated equilibrium.*

Proposition 5 shows that due to the systemic risk caused by asset fire-sales, standards chosen by independent national regulators are inefficiently lax compared to regulatory standards that would be chosen by a central regulator. A central regulator maximizes the total welfare in the two countries, and hence internalizes the systemic externalities that arise from fire-sales. A central regulator takes into account the fact that allowing more investment in the risky asset by relaxing regulatory standards in one country reduces the welfare of the other country due to higher numbers of fire-sales during distress times.

[17] Note that the central regulator does not consider the welfare of the global investors. However, the results of the paper are robust to this generalization.

Is voluntary cooperation possible?

We see that investment levels will be higher in both countries if regulators act strategically. But will countries ever benefit from relinquishing their regulatory authority to a central regulator that imposes tighter standards in both countries? The following proposition shows that symmetric countries always benefit from relinquishing their authority to a central regulator.

Proposition 6. *If the countries are symmetric then both regulators prefer to deliver their authority to a central systemic risk regulator, i.e.* $W_i(\widetilde{N}_i, \widetilde{N}_j) \geq W_i(\widehat{N}_i, \widehat{N}_j)$ *holds for* $i = A, B$.

When regulators act independently, each allows investment into the risky asset up to the point where the expected marginal benefit from the risky investment is equal to the expected domestic marginal cost of the investment. However, at this level of investment, the marginal total cost across the two countries far exceeds the sum of the marginal benefits. This happens because neither regulator considers the adverse effect of increasing investment level on the welfare of the other country. Yet, the central regulator can choose a total investment level in the risky asset where the total marginal benefit is equal to the total marginal cost, and hence can improve the overall welfare of the two countries. Therefore, it is in the interest of the regulators of symmetric countries to simultaneously surrender their authority to a central regulator.

1.4 Asymmetric Countries

In the previous section, we saw that regulators of symmetric countries are always better off by relinquishing their authority to a central regulator. Can a similar argument be made for countries that are asymmetric in some dimensions? In other words, if there are differences across countries, would national regulators still benefit from relinquishing their authority to a central regulator? In this section, I answer this and the following questions that arise when there are asymmetries across countries: How would the asymmetries affect regulation levels in the two countries in equilibrium? How do central regulation levels compare to regulation levels chosen by national regulators independently? Which countries are more likely to accept a common central regulation?

I focus on differences in returns on the risky investment across countries. In particular, I assume that banks in country A are uniformly more productive than banks in country B. In terms of the parameters of the model, this assumption can be stated as $R_A > R_B$.[18]

Furthermore, to simplify the following analysis, I also assume that $F'(0) \leq 1$ in this section.[19] Under this assumption, global investors will purchase capital only if the price of capital falls below one. This assumption also ruled out possible multiple equilibria in the capital goods market at $t = 1$ when there are return differences between countries. Note that from global investors' perspectives, the capital goods in the two countries are still identical at $t = 1$.

The next proposition shows that when regulators act independently, the regulator of the high-return country chooses lower regulatory standards (i.e., a higher N) in equilibrium. This result complies with Proposition 4 in the previous section where we have seen that equilibrium investment levels increase in the return to investments given by R.

Proposition 7. *If $R_A > R_B$, then $\widehat{N}_A > \widehat{N}_B$ in the uncoordinated equilibrium.*

Now, we can compare common central regulatory standars to uncoordinated regulation levels when there are asymmetries between the countries. The next proposition shows that in order for a common central regulation to be acceptable to both regulators, it must require stricter regulatory standards in both countries compared to the uncoordinated regulatory standards.

Proposition 8. *There exists no central regulation level $N > \min\{\widehat{N}_A, \widehat{N}_B\}$.*

The proof of Proposition 8 makes use of the envelope theorem to show that welfare of

[18]This assumption is justified when there is segregation between the investment markets of the two countries. There is both a theoretical and a practical reason for making this assumption. From the theoretical perspective, this assumption shuts down the externality channel that operates through the competition between banks from different countries in loan markets and allows me to focus on regulatory spillovers that operate through asset prices during times of distress. The previous literature considered the regulatory spillovers operating through competition in loan and deposit markets, which shows us when cooperation is justified under those extarnalities (e.g., Dell'Ariccia and Marquez (2006)). From a practical point of view, there are well documented return differences accross countries and a large body of literature explains those differences based on levels of technology and human capital as well as institutional factors. I just take the return differences across countries as given, and examine the desirability of coordination of macro-prudential policies in a world characterized by those structural differences.

[19]This assumption simplifies the analysis by making the demand function of global investors independent of the return differences between the countries.

a country is decreasing in the investment level of the other country. In order to forego the authority to independently and optimally choose regulatory standards as a response to the regulatory standards chosen by the other country, each regulator must be compensated by a stricter regulatory standard (i.e., a lower N) in the other country. Therefore, any common regulation level above $\widehat{N}_B$, which is the minimum of the two regulation levels given the assumption that $R_A > R_B$, will always be rejected by regulator A.

This discussion implies that if a common regulation level is accepted by the regulator of the high return country, it will always be accepted by the regulator of the low return country. This happens because common regulation reduces investment levels in both countries, as shown by Proposition 11. However, it reduces investment levels more in the high return country, compared to the low return country. Therefore, if the regulator of the high return country is willing to accept a common regulation level, it will necessarily be accepted by the regulator of the low return country as shown by the following lemma.

Lemma 6. *For any common regulation level N such that $W_A(N,N) > W_A(\widehat{N}_A, \widehat{N}_B)$ we have $W_B(N,N) > W_B(\widehat{N}_B, \widehat{N}_A)$.*

Lemma 6 allows us to focus on the welfare of country A in search of mutually acceptable common regulatory standards. We may define N^m as the regulatory standard that maximizes the welfare of country A if it is uniformly imposed in both countries. Formally, I define N^m as follows:

Definition 1. $N^m \equiv \arg\max_N W_A(N,N)$

Given this definition, we can write the net maximum benefit from common central regulation to country A as $W_A(N^m,N^m) - W_A(\widehat{N}_A, \widehat{N}_B)$. The next proposition shows that this net maximum benefit is decreasing in the differences between the countries.

Proposition 9. *Suppose that $F'(0) \leq 1$. Let $s \equiv R_A - R_B > 0$. Then for any R_A, there exists $\widehat{s} \in (0, R_A - 1)$ such that $W_A(N^m,N^m) - W_A(\widehat{N}_A, \widehat{N}_B) \geq 0$ if $s \leq \widehat{s}$, and $W_A(N^m,N^m) - W_A(\widehat{N}_A, \widehat{N}_B) < 0$ otherwise.*

Proposition 9 provides the main result of this section: if the return differences between the two countries are above a threshold, then at least the high return country will be worse

off if a common regulation level is imposed across the two countries, even if the common regulation is chosen such that it maximizes the welfare of the high-return country. Large return differences will imply that such a common regulation level is too strict compared to the regulatory standard that would be chosen by the high-return country in the uncoordinated equilibrium. Therefore, welfare of the high return country will fall if it decides to accept common regulatory standards in the face of high return differences between countries. In other words, Proposition 9 shows that voluntary cooperation can exist only between sufficiently similar countries. If the differences across countries are sufficiently high, then at least one of them will be worse off by accepting common central regulation.

1.5 Systemic Failures in Regulated Economies

In this section I examine systemic failures when the two countries are symmetric. By systemic failures I refer to the fact that all banks in the two countries become insolvent after fire-sales. Systemic failures will occur if the asset prices in the crisis state are so low that the returns from investments that could be retained by banks after fire-sales are not enough to cover the promised return to depositors, which is simply equal to the initial value of the investment. Systemic failures might occur even in regulated economies. Because countries are symmetric and we assume perfectly correlated shocks across countries, systemic failures, if they occur, will happen in both countries at the same time. We can write the systemic failure condition in equilibrium as

$$R\gamma^*(\widehat{N},\widehat{N})\widehat{N} < \widehat{N} \tag{1.21}$$

where $\widehat{N}$ denotes symmetric equilibrium investment levels. The left hand side is the (expected) return from investments that could be retained by banks after the fire-sales, and the right hand side is the promised payments to depositors, which are simply the initial value of the investment.

For the rest of the analysis I will work with a particular functional form for which I can obtain a closed-form solution for equilibrium investment levels. The technology of global investors is given by: $F(y) = R\ln(1+y)$. I solve the model for this particular functional form in Appendix A. Using this closed form solution, we can show that the systemic failure

condition given by (1.21) above is

$$\widehat{N} > \frac{R}{2c}\left(\frac{R-1-c}{R-1}\right) \equiv N^c \tag{1.22}$$

where N^c is defined as the critical equilibrium investment level beyond which banks fail in the bad state (i.e., if $\widehat{N} > N^c$ then banks in the two countries become insolvent in the bad state). We have already seen that $\widehat{N}$ is increasing in q. This helps to prove the following result.

Proposition 10. *Let $F(y) = R\ln(1+y)$. If $1+c < R < \widehat{R}$ then there exists a $\widehat{q} \in (0, 1/R)$ such that for all $q \geq \widehat{q}$ we have that $\widehat{N}(q) \geq N^c$. In other words, for such R, if the probability of the good state is higher than $\widehat{q}$, banks fail in the bad state in the uncoordinated equilibrium. If $R \leq 1+c$ then banks always fail in the bad state, and if $R \geq \widehat{R}$ then banks never fail in the bad state where*

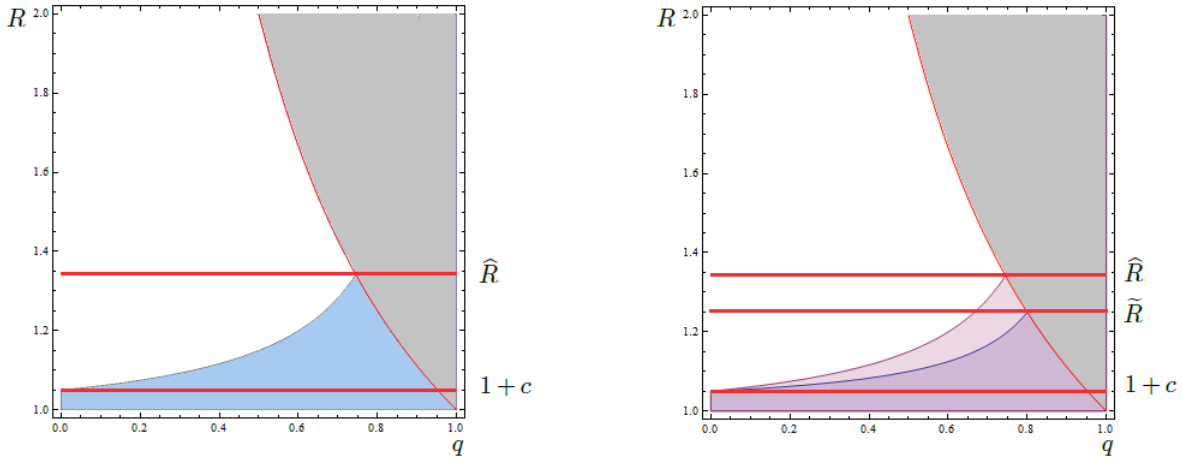
$$\widehat{R} \equiv \frac{1}{2}\left(2 + c + \sqrt{c}\sqrt{8+c}\right) \tag{1.23}$$

By Proposition 4 we have already seen that equilibrium investment level is increasing in q and R. Proposition 10 shows that if R is sufficiently high, then systemic failures do not occur. In order to prove this, I show that the difference $N^c - \widehat{N}$ is monotonically increasing in R, and that this difference is positive for any value of q if R is sufficiently high. Remember that banks fail if $N^c < \widehat{N}$, which means that they will not fail as long as the difference $N^c - \widehat{N}$ is positive. But if R has moderate values, given by $1+c < R < \widehat{R}$, then banks fail in the bad state only if the probability of good state, q, is sufficiently high. For moderate values of R, a sufficiently high q leads to systemic failures because $\widehat{N}$ is increasing q, whereas N^c is independent of q as can be seen from (1.22). Hence, for any value of R such that $1+c < R < \widehat{R}$, there is a sufficiently high q such that the difference $N^c - \widehat{N}$ is negative. Last, if R is sufficiently low, given by $R < 1+c$, then total return from maintained assets after fire-sales is never enough to cover the initial value of the investment, because $1+c$ is the marginal cost of funds for the investment, if the bad state is expected to occur with certainty. In order to prove this, I show that for these low values of R, the difference $N^c - \widehat{N}$ is negative for any value of q. Therefore in this case, systemic failures will surely happen in the bad state.

The region of parameters for which systemic failures occur in the bad state is illustrated

in the left panel of Figure 1.4. The horizontal axis in Figure 1.4 measures q, the probability of success, from 0 to 1, and the vertical axis measures R, the return to investment, from 1 to 2. Since we assume that $Rq \leq 1$, we should ignore the region where $Rq > 1$ in Figure 1.4. This region is shaded by grey. The blue region shows the set of R, q pairs for a given c, for which systemic failures occur in the bad state. Technically, in the blue region we have that $\widehat{N} > N^c$. There are two horizontal red lines in the left panel of Figure 1.4. The lower one shows $R = 1 + c$, and it is clear from the graph that banks fail for any value of q if $R \leq 1 + c$. The higher red line shows $R = \widehat{R}$, and it is again clear from the graph that systemic failures never occur if $R \geq \widehat{R}$. Last, if R is between the two red lines (i.e., if $1 + c < R < \widehat{R}$), then for any such R there exists some $\widehat{q} \in (0, 1/R)$ such that systemic failures occur if $q \geq \widehat{q}$, as claimed in Proposition 10.

Figure 1.4: Systemic Failures



It is clear from the analysis above that systemic failures are more likely when the initial investment level is high. Because central regulation reduces investment levels in both countries, we can claim that moving to a central regulation can eliminate systemic failures. This can be observed from the right panel in Figure 1.4 where the parameter values for which systemic crisis occurs under the common central regulation are shown in blue. The parameter set for which systemic crisis occurs in the uncoordinated equilibrium is the sum of the colored regions (the same area as in the left panel). It is clear from this right panel that when countries move to common central regulation, the parameter set for which systemic failures occur in the bad

state shrinks. The following lemma shows the parameter values under which systemic crisis does occur in the bad state in the uncoordinated equilibrium and moving to a common central regulation eliminates the crisis. Therefore, a common central regulation improves not only the social welfare, but also the financial stability of coordinating countries.

Lemma 7. *For any given $R < \widehat{R}$, there exists some $\widetilde{q} > \widehat{q}$, where $\widehat{q}$ is as defined in Proposition 10, such that if $q \in (\widehat{q}, \widetilde{q}]$ moving to a central common regulation from the symmetric uncoordinated equilibrium eliminates the systemic failures in the bad state.*

1.6 Extensions: Discussion of Assumptions

In this section, I examine the robustness of the main results with regard to changes in some of the assumptions in the basic model. I revisit the assumptions of deposit insurance, limited liability for bank owners, and nonexistence of initial equity capital for banks owners, and show that the qualitative results do not change when these assumptions are relaxed.

1.6.1 Deposit Insurance

With a deposit insurance fund, banks are able to borrow at constant and zero net interest rate from consumers because consumers are guaranteed by the fund that they will always recover their initial investment. If banks do not have sufficient funds to make the promised payments to consumers following a bad state, the deposit insurance fund steps in, and pays consumers the deficit between the promised payment and the resources available to a bank.

What happens if there is no deposit insurance? The answer depends on the competitive structure of the deposit market. I consider two polar cases: first, each bank is a local monopoly in the deposit market; and second, there is perfect competition between banks in the deposit market. I begin here with the local monopoly case and discuss the perfect competition case in Section 1.6.1. When each bank is a local monopoly as in the basic model, the interest on deposit contracts will be just enough to induce risk-neutral consumers to deposit their endowments with them. In technical terms, the individual rationality condition for consumers will bind. I restrict attention to deposit contracts that are in the form of simple debt contracts.[20]

[20]There are two justifications for this restriction. First, this assumption is realistic: the deposit contracts

A bank in country i will choose the amount to borrow and invest in the risky asset, n_i, and the interest rate on the deposits, r, to maximize the net expected profits:

$$\max_{r,n_i \geq 0} \quad q(R-r)n_i + (1-q)\max\{(1-c/P)Rn_i - rn_i, 0\} \tag{1.24}$$

subject to

$$qrn_i + (1-q)\min\{R(1-c/P)n_i, rn_i\} \geq n_i \qquad (IR) \tag{1.25}$$

$$n_i \leq N_i \tag{1.26}$$

where $1 - c/P = \gamma$ is the fraction of assets retained by banks at $t = 1$ after fire-sales (which, as before, banks take as given). The bank has to satisfy the individual rationality constraint of consumers given by (1.25): expected return to deposits must be greater than n_i, the initial deposit of a consumer. A consumer will receive a gross return of rn_i in the good state which happens with probability q. In the bad state, which arises with probability $1 - q$, he will obtain the minimum of the promised payment, rn_i, and the returns available to the bank after fire-sales $R\gamma n_i$. If $R\gamma n_i < n_i$ the consumer will experience a loss in the bad state.

As before, the bank is also subject to the maximum investment regulation $n_i \leq N_i$. Because the problem of a bank is still linear, it will yield a corner solution as before: there will be either a maximum investment ($n_i = N_i$), or no investment at all ($n_i = 0$). We can examine the choice of the investment level (n_i) and the choice of deposit rate (r) separately. First, consider the choice of optimal r for a given investment level. We can see from the problem of banks above that for a given P there are two cases to consider:

Case 1 $R(1 - c/P) > 1$. In this case, banks have sufficient resources to cover the initial borrowing from depositors even in the bad state. Therefore, they will offer zero net interest to consumers. Banks will set $r = 1$, and the IR condition will be satisfied with equality. Because banks make net positive profits in both states of the world, they want to invest as much as possible. Banks will borrow and invest in the risky asset until the regulatory requirement binds ($n_i = N_i$). Given that banks invest as much as possible, regulators will choose the

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are in the form of simple debt contracts in practice. Second, debt contracts can be justified by assuming that depositors can observe banks' asset returns only at a cost. According to Townsend (1979), in the case of costly state verification, debt contracts will be optimal.

same standards in equilibrium as in the basic model. Therefore, the symmetric equilibrium of Section 1.3 and its qualitative results will prevail.

Case 2 $R(1 - c/P) < 1$. In this case, returns on the assets retained by banks after fire-sales are not sufficient to cover the initial borrowing from depositors because $R(1-c/P)n_i < n_i$. Banks have to offer positive net interest rate to consumers in the good state to compensate for their losses in the bad state. For the *IR* condition of consumers to be satisfied, r has to be such that

$$r \geq \frac{1 - (1 - q)R(1 - c/P)}{q} \equiv r^* \tag{1.27}$$

This can be seen by rearranging the *IR* condition (1.25), and noting that $\min\{R(1-c/P)n_i, rn_i\} = R(1-c/P)n_i$ in this case. Banks will offer consumers the lowest r that satisfies (1.27) to maximize their profits, and hence will set $r = r^*$. I will check if there is an equilibrium where banks make maximum investment and regulators choose the same standards as before for such r^*. Suppose that regulators choose their standards assuming that banks will make the maximum allowed investment. We know, from the analysis in Section 1.3 that in this case there will be unique symmetric equilibrium regulatory standards given by $(\widehat{N}, \widehat{N})$. Banks will indeed make the maximum investment under these regulatory standards if their expected profit is positive. Because in this case banks receive zero returns in the bad state, their expected profit is equal to $q(R - r^*)n_i$, as can be seen from (1.24). The expected profit is positive if $R > r^*$ when $P = P^*(\widehat{N}, \widehat{N})$. Using the definition of r^* in (1.27) this condition can be written as

$$P > \frac{c(1 - q)R}{R - 1} \tag{1.28}$$

Because $\gamma = 1 - c/P$ this condition can be restated as

$$\gamma \frac{c(1 - q)R}{R - 1} \tag{1.29}$$

In order to see that this is indeed the case in the symmetric equilibrium obtained in Section 1.3 (when $\gamma = \gamma^*(\widehat{N}, \widehat{N})$), rearrange the FOCs of the regulator's problem given by (1.16) to get

$$\gamma^*(\widehat{N}, \widehat{N}) = \frac{1 - qR}{(1 - q)R} - \frac{\partial \gamma(\widehat{N}, \widehat{N})}{\partial N_i} N_i > \frac{1 - qR}{(1 - q)R} \tag{1.30}$$

since $\partial\gamma(\widehat{N},\widehat{N})/\partial N_i < 0$ as shown in the proof of Lemma 3. Therefore, the symmetric equilibrium obtained under the deposit insurance will prevail when this assumption is removed.

No deposit insurance and perfectly competitive deposit markets

Now, instead of assuming that each bank is a local monopoly in the deposit market, I assume that the deposit market is perfectly competitive, and analyze the robustness of the results to this change in the environment. If the deposit market is perfectly competitive banks will earn zero profits because consumers will get all of the returns on the risky investment. Each bank in country i will choose the amount of investment in the risky asset (n_i) to maximize the expected utility of a representative depositor:

$$\max_{0\leq n_i\leq N_i 0} \quad qRn_i + (1-q)R\gamma n_i - n_i \tag{1.31}$$

With probability q, the consumers will receive a gross return of Rn_i, and with probability $1-q$, they will receive $(1-c/P)Rn_i$, which is the return on the assets retained by their bank after fire-sales. The cost of the initial investment, n_i, is subtracted to obtain net expected return to deposits. For consumers who choose to deposit their endowments with the bank, the net expected return must be greater than zero, and if it is greater than zero, consumers will choose to invest everything they have. Hence, the regulatory requirement,$n_i \leq N_i$ will bind. But if regulators assume that banks will make the maximum investment, we know from Section 1.3 that there will be a unique set of regulatory standards given by $(\widehat{N},\widehat{N})$. Last, we have to check whether banks will indeed chose maximum investment if $(N_i, N_j) = (\widehat{N},\widehat{N})$. Rearranging (1.31) shows that the expected net utility of a representative depositor will be greater than zero if

$$P > \frac{c(1-q)R}{R-1} \tag{1.32}$$

This is the same condition as (1.28). We know from the analysis above that this condition is satisfied in the symmetric equilibrium of Section 1.3, i.e. when $P = P^*(\widehat{N},\widehat{N})$. Therefore, we can conclude that the symmetric equilibrium obtained under the deposit insurance will prevail when this assumption is removed regardless of whether the deposit market is competitive or each bank is a local monopoly in the deposit market.

1.6.2 Limited Liability

In the basic model, I assumed that banks are protected by limited liability. Limited liability assumption means that bank profits are (weakly) positive in each state of the world. If returns to the assets of a bank fall short of its liabilities, then the bank owners receive zero profits. Banks have always wanted to make unlimited investment in the risky asset under this assumption. Now instead, suppose that bank owners have some wealth, or endowment at the last period that can be seized by depositors if the returns on assets are not enough to cover the promised payments to depositors.[21]

When there is no limited liability, a bank in country i chooses $0 \leq n_i \leq N_i$ to maximize the expected profits:

$$\max_{0 \leq n_i \leq N_i 0} \quad qRn_i + (1-q)R(1-c/P)n_i - n_i \tag{1.33}$$

where P is the price of capital in the fire-sale market in the bad state at $t = 1$. Each bank takes this price as given. This problem is essentially the same as the problem of banks when there is no deposit insurance and the deposit market is perfectly competitive. This can be seen by comparing problems (1.24) and (1.33).

The first order conditions for the problem of banks is

$$\frac{\partial \pi}{\partial n_i} = qR + (1-q)R(1-c/P) - 1 \tag{1.34}$$

The first order condition will be positive if and only if

$$P > \frac{c(1-q)R}{R-1} \equiv \underline{P} \tag{1.35}$$

In other words, as long as $P \geq \underline{P}$, banks will still want to make unlimited investment in the risky asset. On the other hand, if regulators expect banks to set $n_i = N_i$, they will choose the same set of regulatory standards as in the case with limited liability. Note that as long as

[21] Instead, the negative utility of bank owners in this case can be interpreted as the disutility of legal punishment for bankruptcy.

regulators internalize the losses of bank owners due to fire-sales, their objective function will be the same as (1.15). Therefore, in order to show that equilibrium regulatory standards do not change when the limited liability assumption is removed, we have to check whether the price of capital in the uncoordinated equilibrium satisfies $P^*(\widehat{N}, \widehat{N}) \geq \underline{P}$. This is again the same condition as (1.28). The analysis in Section 1.6.1 showed that this condition indeed holds in equilibrium. Therefore, the symmetric equilibrium and the qualitative results obtained under the limited liability assumption will prevail when we remove this assumption.

1.6.3 Initial Bank Equity Capital

In the basic model, I also assumed that banks have no initial endowment of their own that they can invest in the risky asset. Because banks raised necessary funds for investment from the deposit market, the liability side of their balance sheets contained only debt and not any equity capital.[22]

In this section, I assume that banks have an initial endowment of E units of consumption good which they have to invest in the risky asset. This equity is costly: the opportunity cost of equity to bank owners, ρ, is greater than one, the cost of insured deposits. These two assumptions are a common way of introducing equity capital to a banking model (see Dell'Ariccia and Marquez (2006), Hellmann et al. (2000), Repullo (2004) among others). The assumption that the amount of equity capital is fixed captures the fact that it is difficult for banks to raise equity capital at short notice.

When there is bank equity capital, regulation will take the form of a minimum capital ratio requirement. Let $k_i = E/n_i$ be the actual capital ratio of a bank in country i. In this case, regulation will require banks to have $k_i \geq K_i$, where K_i is the capital adequacy requirement in country i.

Given its equity, and the price of capital goods in the bad state of $t = 1$, each bank chooses

[22]The term equity capital should not be confused with the capital good. Any initial endowment of bank owners will still be in the form of consumption good. I use the term "equity capital" to refer to bank owners' own endowments that they invest in the bank.

how much to invest in the risky asset (i.e., n_i as before) to maximize expected profits:

$$\max_{0\leq n_i\leq N_i 0} \quad q(Rn_i - (n_i - E)) + (1-q)max\left\{R\gamma n_i - (n_i - E), 0\right\} - \rho E \tag{1.36}$$

subject to the capital regulation

$$k_i = \frac{E}{n_i} \geq K_i \tag{1.37}$$

Note that $n_i - E$ is the amount of funds borrowed from the local deposit market. We can write the capital ratio requirement condition as

$$n_i \leq \frac{E}{K_i} \equiv N_i \tag{1.38}$$

This analysis shows that there is one-to-one mapping from capital regulations to the form of regulation used in the main text. The banks' problem does not change: they still want to invest in the risky asset as much as possible as long as the net expected return is positive. The minimum capital requirement binds (i.e., banks will choose $n_i = E/K_i$ in an equilibrium with positive investment levels).

Consider the regulators' problem after equity is introduced to the model. Regulators will anticipate that for a given capital ratio requirement, K_i, banks will choose their total investment level such that this requirement binds: $n_i = E/K_i$. Because banks will raise $E/K_i - E = (1-K_i)E/K_i$ units of consumption goods from the local deposit market, we can write regulators' objective function as

$$W_i(K_i, K_j) = q\left[R\frac{E}{K_i} - \frac{E}{K_i}\right] + (1-q)\left[R\widehat{\gamma}\left(\frac{E}{K_i}, \frac{E}{K_j}\right)\frac{E}{K_i} - \frac{E}{K_i}\right] \tag{1.39}$$

The function $\widehat{\gamma}(\cdot)$ is the same as the function $\gamma(\cdot)$ except that it is defined over the minimum capital ratios (K_i, K_j), not over the total investment levels. It represents the fraction of initial assets that a bank retains after fire-sales. If we define $N_i \equiv E/K_i$ we can express the objective function above as

$$\max_{N_i\geq 0} W_i(N_i, N_j) = \max_{N_i\geq 0} q(R-1)N_i + (1-q)[R\gamma^*(N_i, N_j)N_i - N_i] \tag{1.40}$$

This objective function is exactly the same as the regulators' problem in the main text. Therefore, all qualitative results in the main section will carry on when we introduce costly bank equity and redefine regulation as a minimum capital ratio requirement.

Note that when we introduce costly equity, the net expected return on the risky investment must be sufficiently large to cover the opportunity cost of internal bank equity, ρE, for banks. Otherwise, banks will choose not to invest in the risky asset at all. For this reason, the set of parameters where we have strictly positive investment in equilibrium is smaller under costly equity.

1.7 Conclusion

I have examined the incentives of national regulators to coordinate regulatory policies in the presence of systemic risk in global financial markets, using a two-country, three-period model. Banks borrow from local deposit markets and invest in risky long-term assets in the initial period. They may face negative shocks in the interim period that force them to sell assets. Asset sales of banks feature the characteristics of a fire-sale: assets are sold at a discount, and the higher the number of assets sold, the lower the market price of assets is. The asset market in the interim period is competitive. Each bank treats the asset price as given, and therefore neglects the effects of its sales on other banks. Due to this externality, correlated asset fire-sales by banks generate systemic risk across national financial markets.

If the regulatory standard is relaxed in one country, banks in this country invest more in the risky asset in the initial period. If the bad state arises in the interim period, these banks are forced to sell more assets, causing the asset price to fall further. A lower asset price will increase the cost of distress for the banks in the other country as well. Banks may even default in equilibrium if the asset prices fall below a threshold.

I have shown that, in the absence of cooperation, independent regulators choose inefficiently low regulation compared to regulatory standards that would be chosen by a central regulator. A central regulator takes the systemic risk into account and improves welfare in cooperating countries by imposing higher regulatory standards. Therefore, it is incentive compatible for national regulators of symmetric countries to relinquish their authority to a central regulator.

I have also considered the incentives of regulators when there are asymmetries between

countries with a focus on the asymmetries in asset returns. In particular, I have assumed that banks in one country are uniformly more productive than the banks in the other country in terms of managing long-term assets. I have shown that cooperation would voluntarily emerge only between sufficiently similar countries. In particular, the regulator in the high-return country chooses lower regulatory standards in equilibrium and is less willing to compromise on stricter regulatory standards.

Chapter 2

Explaining Cross-Country Differences in Bank Capital Regulations

2.1 Introduction

The first Basel capital adequacy standard signed by G-10 countries in 1988 focused on creating a level playing field for internationally active banks and improving their stability. Somewhat unexpectedly, Basel bank capital adequacy standards received an extensive attention from all around the world, and over hundred countries voluntarily adopted Basel I (Pattison, 2006). Basel I updated in 2004 with more sophisticated rules and principles, popularly known as Basel II. A survey done by Bank for International Settlements (BIS) in 2006 showed that 95 countries (comprising 13 Basel Committee on Banking Supervision (BCBS) member countries plus 82 non-BCBS jurisdictions) were planning to implement Basel II by 2015. These interests suggest that Basel principles have become a model for capital regulation of national banking systems in both developed and developing countries.

The adoption of Basel principles by the majority of countries around the globe is an important fact, however what is more important is how countries are actually implementing those principals in practice. The Basel bank regulation principles are rich and complex in nature and this gives countries a substantial amount of leeway in their implementation (Concetta Chiuri et al., 2002). A country may announce adoption of 8% minimum capital ratio (the percentage of a bank's capital to its risk-weighted assets) that is required by Basel I and Basel II. However, the effective capital adequacy ratio will be determined by how the regulator of this country allows domestic banks to choose the numerator (equity capital) and the denominator (risk weighted assets) of this ratio. For example, a regulator can loosely define the items that banks could include in the equity capital. In another example, the risk weights in the denominator

may not reflect the market risk or credit risk of a bank contrary to the Basel recommendations.

Fortunately, a carefully executed survey series by the World Bank allows us to compare the actual implementation of Basel bank capital regulations across over hundred countries. These surveys, conducted four times between 1999 and 2012, reveal that the stringency of bank capital regulations not only differ by significant amount across countries (see Figure B.1), but also varies over time for a given country (see Figure B.2). The aim of this paper is to investigate the empirical determinants of this variation based on theories of capital regulation and previous empirical studies. I develop testable hypotheses from the literature in order to investigate the effects of the structure of the banking system and overall economic characteristics of countries on the stringency of bank capital regulations.

Theoretical motivations for bank capital regulations mainly focus on the role of capital in creation of incentives for bank owners to take socially efficient levels of risk. Moral hazard and agency problems often cause bank owners and managers to take excessive risks. Incorrectly priced deposit insurance, created to prevent bank runs in the first place, and limited liability are widely blamed for distorting risk behavior of bank owners (Kroszner, 1998; Allen and Gale, 2003). Deposit insurance and limited liability provide a safety net for bank owners in which they reap the benefits of excessive risk taking in "good times" but do not bear the full costs in "bad times". Regulators expect bank owners to behave more prudently and responsibly if they have "a skin in the game", which happens when bank owners invest their own capital in the bank. Another justification for capital regulations is the existence of welfare-relevant pecuniary externalities (Allen and Gale, 2003; Lorenzoni, 2008). An important example of a pecuniary externality is the systemic risk, where failure of a single or a group of banks trigger others and force the whole system into distress or complete collapse.

In a recent study, Kara (2013) justifies capital regulations under the existence of a pecuniary externality that creates systemic risk within and across borders. The objective of Kara (2013) is to examine the incentives of national regulators to coordinate minimum capital ratios in the presence of systemic risk in global financial markets. In a two-country and three-period model, correlated asset fire-sales of banks in different countries generate systemic risk across national financial markets. Relaxing regulatory standards in one country increases both the cost and the severity of crises for both countries in this framework. In the absence of coordination

independent regulators choose inefficiently low levels of macro-prudential regulation. A central regulator internalizes the systemic risk and hence can improve the welfare of coordinating countries. Kara (2013) shows that common central regulation voluntarily emerges only between sufficiently similar countries. This is due to the fact that, asymmetric countries choose different levels of macro-prudential regulation when they act independently. In particular, a high return country chooses a lower minimum capital ratio than a low return country because higher average returns allows the country to take on more risk. For example, according to Kara (2013), everything else equal, a country where average return to investment is high such as China, is expected to choose a lower capital ratio than a country with low average return to investment such as the US. This is the first hypothesis tested in this paper.

Stock market returns or real GDP growth rate can be used as a proxy for the average returns to investment in Kara (2013). In this paper, I choose the latter for a couple of reasons.[1] First, GDP growth rate is a good proxy for average returns to investment in an economy, and it is the most important benchmark for an economy that policy makers base decisions upon. Second, there are many under-capitalized developing countries in our sample, and GDP growth rate is more representative of overall average returns than the stock market gains for this group. Lastly, GDP growth rate data is more easily available for a large number of countries and much less volatile than stock market returns.

I derive the second testable hypothesis from Dell'Ariccia and Marquez (2006) who justify capital regulations based on limited liability and existence of deposit insurance. They show that regulators who are more concerned about the profits of the banking sector as opposed to financial stability choose less stringent capital regulations. This the second hypothesis that is tested in this paper. Dell'Ariccia and Marquez (2006) consider a two-country model with a single bank in each country. Regulators of the two countries compete by setting the minimum capital ratios. A lower capital ratio allows domestic banks to extend loans in both countries but at the same time decreases average returns. Banks can make their loans safer by costly monitoring. However, lower returns, induced by a lower capital ratio in one country, decreases the marginal benefit of monitoring for the banks in both countries. This results in

[1] I performed robustness check using available stock market return data and the qualitative results did not change.

lower monitoring effort, and hence the whole financial system becomes less stable. Therefore, the capital regulation introduces an externality that national regulators do not internalize when they act independently. Regulators choose capital ratios to maximize expected domestic social welfare which is a weighted average of bank profits and a measure of financial stability. Regulators can differ in terms of the weights that they attach to bank profits in their objective functions. This weight reflects the degree to which regulators are captured by the financial institutions under their control. They show that the country with a higher regulatory capture chooses a lower minimum capital ratio.

I use the fraction of government ownership of banks as a proxy for the regulatory capture. One would expect that if the government owns an important fraction of banks, it will have a larger stake in the financial sector, and hence its incentives would be more aligned with those of the banks. Therefore, I will test if there is a negative relationship between the fraction of banks owned by the government and the stringency of capital regulations.

Third, I test if the stringency of capital regulations is significantly related to the competitiveness of the banking sector. Since one main theoretical justification for capital requirements is to limit excessive risk taking by banks, one would expect regulators to respond to measures that affect how much risk banks are willing to take.[2] Competitiveness of the banking sector has been considered as one of the main determinants of risk taking incentives of banks (Allen and Gale, 2004). In other words, it has always been thought that there is a close connection between competitiveness and riskiness of financial sectors. The literature traditionally measured the competitiveness of a financial sector by the inverse of *n-bank concentration ratio* or the *Herfindahl-Hirschman Index*.[3]

There are two contradicting views on the relationship between concentration and financial stability. The conventional view, which is also called the *"concentration-stability"* view by Berger et al. (2004), posits that more concentrated financial sectors with a few large banks are more stable. This view predicts that large banks in concentrated markets are more efficient

[2]Both theoretical and empirical literature produce mixed predictions on the effectiveness of capital regulations in limiting the risk taking behavior of banks. See VanHoose (2007) for an extensive survey of this literature.

[3] Claessens and Laeven (2004) empirically challenge this traditional approach. They create an index of competitiveness, which they call *H-statistics*, from a structural model, and using bank level data from 50 countries find no evidence that this index is negatively correlated with the concentration ratios.

and better diversified, and they have larger charter values at stake. Therefore, they are less inclined to take excessive risks. Furthermore, it is easier for regulators and market participants to monitor the health of a few large banks than many small banks. In short, conventional view asserts that there is a trade-off between competition and financial stability. Keeley (1990), Allen and Gale (2000, Chapter 8), Hellmann et al. (2000), Acharya (2001), Repullo (2004) provide theoretical support for this view. This argument is also supported by the empirical evidence provided in Rhoades and Rutz (1982) (using a sample of 6,500 unit banks in the US between 1969-78), Keeley (1990), Dick (2006) and Beck et al. (2006) (using data on 69 countries from 1980 to 1997). The latter study shows that crises are less likely in more concentrated banking systems even after controlling for differences in commercial bank regulatory policies, national institutions affecting competition, macroeconomic conditions, and shocks to the economy.

The conventional framework also creates a justification for bank regulation because the only way to remove the trade-off between competition and financial stability would be a government intervention into the financial sector. Regulation of bank capital has been one of the most common instruments used by regulators around the world to ensure the existence of competition and financial stability at the same time (Allen and Gale, 2003).

Acharya (2001) establishes a direct theoretical connection between optimal capital regulations and the intensity of competition in the deposit market. He considers both single-country and multi-country models, and shows that as the competition in the deposit market becomes more stringent, banks take on more risk. He measures competition by the number of banks in the deposit market where larger number of banks corresponds to more competitive banking sector.[4] Therefore, it may be optimal for the regulator to tighten the stringency of capital regulations as a response to increasing competition in the deposit market.

On the opposite side, the "concentration-fragility" view asserts that there is a negative relationship between concentration and financial stability: an increase in concentration reduces the stability of the banking sector. In other words, this view predicts that more competitive banking sectors are more stable. Boyd and De Nicolo (2005) show that the trade-off between

[4]Number of banks is used, in a similar way to the concentration ratio, as a proxy for competitiveness by some other studies as well such as Boyd and De Nicolo (2005).

competition and financial stability, as is supposed by the conventional view, crucially depends on the assumption that banks' optimal asset allocations are determined by solving a portfolio problem that takes asset prices and return distributions as given. They show that when same number of banks are allowed to compete in the loan market as well as the deposit market, and if banks are facing moral hazard from borrowers in the loan market, the banking sector becomes less risky as it gets more competitive. They measure competitiveness with the number of banks. Proponents of this view also argue that existence of a few large banks generates an implicit "too-big-to-fail" guarantee, and create incentives for banks to take excessive risks. Jayaratne and Strahan (1998) (using US bank data between 1975-92), De Nicoló (2000), Nicoló et al. (2004), Boyd et al. (2006), De Nicolò and Loukoianova (2007) and Schaeck et al. (2009) provide empirical support for the "concentration-fragility" view.

In addition to studies that take a particular view in this discussion, some studies argue that relationship between competition and financial stability is complex. Allen and Gale (2004) consider a series of models and show that different models provide different predictions. The models considered include general equilibrium models of financial intermediaries and markets, agency models, models of spatial competition, Schumpeterian competition, and contagion. Their analysis suggest that general equilibrium and Schumpeterian competition models require coexistence of competition and financial stability for efficiency, as opposed to the trade-off between those two as is conventionally supposed.

To sum, the theoretical and empirical evidence with respect to the relationship between concentration ratio and riskiness of the banking sector is mixed: higher concentration ratio may increase or decrease banks' incentive to take excessive risks. If regulators respond higher concentration in the banking sector by relaxing capital regulations, they must be perceiving lower risks in the sector as a result of higher concentration. Hence, a negative relationship between the stringency of bank capital regulations and concentration ratio in our regressions will support the conventional "concentration-stability" hypothesis. On the other hand, if regulators respond higher concentration by tightening capital regulations they must be perceiving higher risks in the sector as a result of higher concentration. Therefore, in the regressions, a positive relationship between the stringency of bank capital regulations and concentration ratio will support the "concentration-fragility" hypothesis.

The paper proceeds as follows. Section 2 provides a brief review of the related literature. Section 3 describes the data and provides descriptive statistics for the dependent and explanatory variables. Section 4 explains the econometric methodology. Section 5 contains the results for the static model. Section 6 presents a dynamic model and the results under the dynamic model. Section 7 contains robustness checks. Two extensions are presented in Section 8: A logistic regression using the individual components of the capital stringency index, and estimation of different coefficients for advanced and emerging countries using interaction terms. Section 9 is the conclusion. Some graphs and tables are included in the Appendix.

2.2 Literature Review

This paper is a part of the broad literature that investigates the determinants of bank regulations in general. To the best of my knowledge, this is the first paper that investigates the empirical determinants of cross country and over time variation in the stringency of bank capital regulations in particular. There are three competing theories that explain choice of a broader set of bank regulations. These are the private interest, public interest and political-institutional theories of regulatory change. Kroszner and Strahan (1999) and Barth et al. (2006) provide a comparative summary of these three theories.

Briefly, the private interest theory, which is also called the economic theory, posits that private interest groups use political power to enact regulations that maximize their private benefits at the expense of more dispersed groups. Public interest theory suggests that government intervention corrects market failures and maximizes social welfare. The third group of views stress the role of beliefs and ideology or the institutional structures in shaping regulatory choices.

Kroszner and Strahan (1999) use a hazard model to investigate which of the three theories better explain the deregulations in the US banking sector after 1970s. They show that the private-interest theory of regulation can account for the pattern of bank branching deregulation of the 1970s and 1980s. In particular, they argue that branching deregulations affect small banks differently than large banks and therefore relative power of these groups influence regulatory choices.

On the other hand, Barth et al. (2006) asses whether cross-country differences in political

institutions explain national choices of supervisory and regulatory policies. They use a cross-sectional data from the 1999 World Banks survey of bank regulations (one of the four surveys that is used in this study). They show that the organization and operation of political systems shape bank supervisory and regulatory practices.

This study has a couple of differences from Barth et al. (2006). First, the aim of the study is to explain the cross-country and over-time variation in the stringency of capital regulations in particular whereas Barth et al. (2006) focus on the cross-country variation in broader bank supervisory and regulatory practices such as bank activity restrictions, strength of private monitoring and power of banking supervisors. Second, the focus of this study is to explain the variation seen in the data based on the the economic and financial structure of countries, while Barth et al. (2006) are mainly interested in investigating the institutional and political determinants of bank regulations. In this study, I explicitly and implicitly control for such political and institutional characteristics of countries. Third, different than Barth et al. (2006) I employ a panel data set which allows explaining not only the cross-country differences in capital regulations but also the change that occurs over time in these regulations.

The discussion above suggests that this study can be viewed as a public interest explanation of capital regulations across countries. I assume that given a country's tastes, endowments and economic structure, each nation chooses an efficient level of bank capital regulation. Barth et al. (2006) call this view the "Coasian Theorem of Bank Regulation" after Nobel Laureate Ronald Coase. While the focus of this paper is on the public interest view of regulation, the estimation strategy controls for the fact that the regulations may not be set from a welfare maximizing point of view by using the fixed effects and dynamic panel data regressions, or by including appropriate control variables.

There is also a literature that examines the variation in actual bank capital ratios but not the overall stringency of bank capital regulations. An important part of this literature discusses whether capital ratios in practice are pro-cyclical or counter-cyclical. Some studies focus on bank data from a single country, whereas some others use bank data from several countries. Notable studies in this literature include Bikker and Metzemakers (2004), Ayuso et al. (2004), and Andersen (2011).

In a related study, Brewer et al. (2008) investigate the cross country differences in actual

bank capital ratios of internationally active banks in 12 developed nations. Their explanatory variables include bank-specific factors such as the bank size, country-specific macroeconomic factors such as the real GDP growth rate, country-specific public and regulatory policy factors, and control variables such as the differences in accounting standards. This study differs from Brewer et al. (2008) mainly in its interest of explaining the regulatory choices of bank capital regulations, not the actual capital ratios of individual banks. Furthermore, their focus is only on 12 developed countries, whereas I investigate the determinants of capital regulations using a sample of 22 developed and 61 developing economies.

2.3 Data and Descriptive Statistics

This study employs an unbalanced panel data set. The measure used for the stringency of bank capital regulations is the "Overall Capital Stringency" index created by James R. Barth, Gerard Caprio, and Ross Levine based on extensive World Bank surveys on bank regulations initiated by these authors in late 1990s. These surveys were conducted four times and represent the situation of bank regulations around the world at the end of 1999, 2002, 2006 and 2011.[5] The last survey includes around 300 hundred questions, and 180 countries responded to at least one of the four surveys.

This study restricts attention to a smaller set of countries. Our sample consist of 83 major countries that are included in a recent study by Gourinchas and Obstfeld (2012). This smaller sample does not include low income countries and tiny countries some of which are known as offshore financial centers such as British Virgin Islands or Mauritius. Using the classification in Gourinchas and Obstfeld (2012), there are 22 advanced and 61 emerging countries in our sample. Table B.1 list the names of the countries in each group according to the income categories defined by the World Bank (high income, upper middle income and middle income). All 22 advanced economies are in the high per capita income group. Of the 61 developing countries, 18 of them are in the high income, 30 are in the upper middle income and 13 are in the middle income group.

World Bank regulation surveys are carefully executed. Surveys were sent to senior officers

[5]I use the recently compiled panel data from responses to all four surveys by the same authors. See Barth et al. (2013) for an extensive discussion of this panel data set.

in the main regulatory agency in each country and whenever there are conflicting or confusing answers to questions, authors double-checked the information by contacting regulators in the corresponding country and also by referring to other sources including the information collected by Office of the Comptroller of the Currency (OCC), and the Institute of International Bankers (Barth et al., 2004).

Barth et al. (2004) defines the "Overall Capital Stringency" index as *"whether the capital requirement reflects certain risk elements and deducts certain market value losses from capital before minimum capital adequacy is determined".* The index is originally based on the responses to seven questions in the Capital Regulatory Variable section of the surveys. In this study, I create the index using six of the seven questions. These six questions are given in Table 2.1 below.[6] A value of one is assigned to each "yes" answer, and a value of zero is assigned to each "no" answer. Therefore, the index takes values between 0 and 6, and higher values of the index correspond to greater stringency of bank capital regulations.

The six questions used in the creation of the index are derived from Basel bank capital adequacy principles. The questions in Table 2.1 can be considered in two broad groups. The first group of questions (3.1.1, 3.2 and 3.3) measure a country's compliance with Basel risk guidelines, and the second group of questions concern the calculation of capital. Basel capital adequacy ratio is equal to the equity capital divided by risk weighted assets. Therefore, the first group of questions concern the determination of the weights in the denominator of the capital ratio whereas the second group of questions deal with the determination of capital in the numerator of this ratio. Hence, countries' stance on these issues determine their effective minimum capital adequacy ratio. A country might have 10% minimum capital ratio, which is above the Basel recommended value of 8%, but if the country is quite lenient on what banks can include in regulatory capital or how they determine risk weights, the effective capital ratio will actually be lower. Therefore, this index gives us a measure of stringency of bank capital regulations that is comparable across countries and over time.

Figure B.1 shows the distribution of overall capital stringency index for each survey. The

[6]I exclude the following question from the calculation of the index: "What fraction of revaluation gains is allowed as part of capital?". First, the answers to this question are not as objective as the answers to other six questions and quantification of those answers poses serial challenges. Second, including this question severely reduces the data availability.

Table 2.1: Capital Stringency Index Questions

3.1.1 Is the minimum capital ratio risk weighted in line with the Basle guidelines? Yes/No
3.2 Does the minimum ratio vary as a function of an individual bank's credit risk? Yes/No
3.3 Does the minimum ratio vary as a function of market risk? Yes/No
3.9 Before minimum capital adequacy is determined, which of the following are deducted from the book value of capital?
3.9.1 Market value of loan losses not realized in accounting books? Yes/No
3.9.2 Unrealized losses in securities portfolios? Yes/No
3.9.3 Unrealized foreign exchange losses? Yes/No

figure reveals that there is a significant variation in the stringency of bank capital regulations across countries for each of the four survey years. The mean of the index for each survey years are 3.34, 3.51, 3.42, and 5.27 with standard deviations of 1.61, 1.47, 1.71 and 1.32, respectively. The percantage of countries with an index value that is below the mean is 47% in 1999, 39% in 2002, 55% in 2006 and 24% in 2011. The average capital stringency index rises by a significant amount after the global recession, and its standard deviation shrinks, however the cross-country variation does not disappear. Figure B.1 shows that after the global recession, the distribution becomes significantly skewed to the right indicating that there is an overall increase in the stringency of capital regulations around the world.

Figure B.2 shows that there is also a significant variation in the stringency of bank capital regulations over time. Each panel shows the distribution of the change in the capital stringency index for for individual countries compared to the previous survey (i.e. the distribution of $\textit{capital stringency}_{it} - \textit{capital stringency}_{i,t-1}$). Strikingly the direction of the change in capital regulations is not positive for all countries over time. Among 61 countries that responded to both 2002 and 1999 surveys, 10(17%) countries reduced the stringency of capital regulations compared to the previous survey, whereas 33(53%) countries kept the regulation level the same, and 19(30%) countries strengthened their regulations. A larger percentage of countries relaxed their regulatory standards between 2002 and 2006. Among 61 countries that responded to both 2002 and 2006 surveys, 19(31%) countries relaxed the stringency of capital regulations compared to the previous survey whereas 19(31%) countries kept the regulation level the same, and 23(38%) countries strengthened their regulations. The distribution changes significantly after the recent financial crisis and it becomes right skewed. Among 60 countries

that responded the last two surveys, only 6(10%) of them reduced the stringency of capital regulations, 13(22%) of them kept the regulation at the same level whereas 41(68%) countries increased the stringency of bank capital regulations.

2.3.1 Discussion of variables

Table B.2 summarizes the dependent variable, main independent variables, and legal origin control variables. It is striking that capital regulation index has a higher within variation than between variation. In other words, in our sample the stringency of capital regulations varies more over time for a given country than it varies across countries in a given year. This fact suggests the use of panel data methods as an estimation strategy. In particular, using fixed effect estimation that is mainly identified through within variation will be the natural choice.

There are three main explanatory variables derived from the previous theoretical and empirical literature which was reviewed in the introduction. I use three year average real GDP growth rates as a proxy for the average return to investment in Kara (2013) who predicts that high return countries choose less stringent capital regulations.[7] GDP growth rate is a good proxy for average returns of assets in an economy, and it is the most important benchmark for an economy that policy makers base decisions upon. GDP growth rate data is more easily available for a large number of countries and much less volatile than some other measure of average returns such as stock market returns. Furthermore, there are many under-capitalized developing countries in our sample, and GDP growth rate is more representative of overall average returns than the stock market gains for this group. I obtain GDP growth rate data from the World Development Indicator's database of the World Bank. Similar to the capital stringency index, within country variation in average growth rate is considerably higher than between country variation in our sample. I test if there is a negative relationship between the stringency of capital regulations and real GDP growth rate as predicted by Kara (2013).

The second explanatory variable, *government-owned banks* is the percentage of banking system's assets in banks that are 50% or more government owned. This data is also obtained from the World Bank regulation surveys. Table B.2 shows that the government ownership

[7]For example, for the second survey that represents the stance of capital regulations at the end of 2002 I use average of growth rates for 2002, 2001 and 2000.

of banks varies significantly across countries but it is relatively stable for a given country over time. The ratio takes values between 0% and 80% in our sample. A closer look at the data show that most advanced countries have very low to none government ownership in the banking sector before the recent crisis.[8] The last survey reveals that this ratio is increasing for some advanced economies (Austria, Switzerland, UK, Ireland, Iceland, Netherlands) in the aftermath of the global recession in most part due to nationalizations and bailouts.

I use fraction of government-owned banks as a proxy for regulatory capture. If a country has high ratio of government-owned banks, then one would expect the regulator of the country to be more concerned about the banking sector profits as opposed to financial stability, and hence choose more lax regulations as suggested by Dell'Ariccia and Marquez (2006). Therefore, I test if there is a negative relationship between the stringency of capital regulations and government-owned banks.

The third explanatory variable is the 3-bank concentration ratio. This variable is obtained from "Financial Institutions and Markets Across Countries and over Time: Data and Analysis" database prepared by Thortsen Beck and Asli Demirgüç-Kunt (Beck and Demirgüç-Kunt, 2012). The variable is the ratio of the assets of three largest banks to the assets of all commercial banks in a country. The authors calculated this ratio from Fitch's BankScope database. I use two year averages of this data to smooth potential short term volatility in bank concentration mainly due to mergers and acquisitions.[9] Table B.2 shows that concentration ratio varies between 15.32% and 100%, and the between country variation is almost twice as much as the within country variation in our sample.

The intensity of competition in the banking sector, which is usually measured by the inverse of the concentration ratio, has always been considered as one of the major determinants of how much risk that banks want to take. Since a major motive for capital regulation is to limit incentives to take excessive risks in the banking sector, this study includes concentration

[8]Germany, Portugal, Grece and Switzerland are exceptions in that regard with 40%, 25%, 23% and 11.5% government-owned bank ratios respectively, according to the last figures before the crisis.

[9]For example, for the second survey that represents the stance of capital regulations at the end of 2002 I use the average of bank concentration ratios in 2002 and 2001. I performed robustness checks using single year values and 3-year averages but the coefficients or standard errors did not change significantly.

ratio in the regressions. However, there are two conflicting theories on the relationship between concentration ratio and bank risk taking that are broadly discussed in the introduction. A priori, this study does not take a particular side on this theoretical and empirical divide. In the regressions of this study, a negative relationship between the stringency of bank capital regulations and concentration ratio will support the "concentration-stability" hypothesis, whereas as positive relationship will support the "concentration-fragility" hypothesis.

Lastly, I control for institutional characteristics of countries in the pooled OLS regressions. Barth et al. (2006) argue that institutional structure of a country largely impacts the objectives of regulators and they provide strong empirical evidence that supports this argument. I use legal origin dummies introduced by La Porta et al. (1998) to control for the institutional background of a country. La Porta et al. (1998) argue that legal heritage differences across countries is an important determinant of the degree of centralized government influence in the financial system. Legal origin controls are also used in Barth et al. (2006) in regressions that explain cross-country differences in overall bank regulations. Barth et al. (2006) provide the following example to motivate the legal origin dummies: " to the degree that British common countries grant judges greater discretion and independence, this may influence the types of regulations that are enacted and the ways in which the courts interpret and enact enforce those regulations." In Section 7, as a part of the robustness checks, I use other political and institutional control variables.

2.3.2 Relationships between the variables

Table B.3 gives the pairwise correlation coefficients between the dependent variable, the main explanatory variables (GDP growth, government-owned banks and concentration ratio), legal origin dummies, and two categorical variables: *emg* is a dummy that equals 1 if the country is an emerging economy, and 0 if the country is an advanced economy (using the classification in Gourinchas and Obstfeld (2012)); *inc* is a categorical variable that is equal to 1 if the country is in the 'high income' group, 2 if in the 'upper-middle income' group, and 3 if in the 'middle income' group. Table B.3 shows that capital stringency index has a significant and negative correlation with the average GDP growth rates. Correlation of the index with government-owned banks or with concentration ratio is negative but not statistically different

from zero. The index is negatively and significantly correlated with the emerging country dummy, indicating that emerging countries tend to have lower levels of capital regulation, however there is no significant correlation between index and country income groups. There is also no significant correlation between the capital stringency index and legal origin dummies.

Correlation of the emerging country dummy with other explanatory variables indicates that emerging countries have higher average GDP growth rates and higher ratio of government bank ownership in our sample. However, there is no indication from the correlation table that emerging countries have more or less concentrated banking sectors compared to the advanced economies. Nevertheless, concentration ratio has a significant negative correlation with income groups, indicating that higher income countries have more concentrated banking sectors. Table B.3 shows that higher income countries also tend to have lower government ownership of banks and lower GDP growth rates in our sample.

Figure B.4 shows the mean of the capital stringency index for advanced and emerging countries separately for each survey. In all surveys, the average capital stringency index for the advanced economies is larger than the average for the emerging economies. The difference is larger in 1999 and 2006 surveys. Following the world business cycle downturns in early 2000s and late 2000s, the gap between advanced and emerging country capital regulations shrinks. A *t-test* for the null hypothesis that the difference of the means for the advanced and emerging country groups is equal to zero against the alternative that the difference is greater than zero is rejected for 1999 and 2006 surveys, but it could not be rejected at the 10% level for 2002 and 2011 surveys. The mean of the index for the pooled sample is 4.20 and 3.77 for the advanced and emerging countries respectively, and they are significantly different from each other. The equality of means over all four surveys is rejected with a p-value of about 7%. I also perform the Wilcoxon rank test for the equality of the medians for these two group of countries for the pooled sample. The test significantly rejects the equality of medians with a p-value of about 2%.

The mean of the capital stringency index for all countries shows an interesting negative correlation with the world business cycle trend. The mean of the index is 3.34, 3.51, 3.42, and 5.27 respectively for the four surveys. A scatter plot of the mean of the capital stringency index and 3-year average GDP growth rates shows this negative relationship clearly (see Figure

B.3). Most remarkably, high growth rates of the first half of 2000s is followed by a relaxation of average capital regulations, and the global recession of 2007-2009 is followed by a tightening of capital regulations. The increase in the stringency of capital regulations happens for both advanced and emerging countries after the great recession. This graph also indicates the effect of a financial crisis on the behavior of the regulator: a recent strong financial crisis makes the society and policy makers more concerned about the financial stability and hence empowers regulators.

Table 2.2 provides another look at the relationship between the capital stringency and the main independent variables. I divide stringency of capital regulations into three categories: low, medium and high where 'low' corresponds to index values less than three, 'medium' corresponds to index values of three or four, and 'high' corresponds to index values of five and six. Table 2 shows that higher stringency levels are associated with lower average growth rates, lower government ownership of banks, and lower concentration ratios.

Table 2.2: Mean Values of Independent Variables for Regulation Categories

	Level of Capital Stringency		
	Low	Medium	High
GDP Growth	3.89	3.83	2.68
Government-owned banks	19.28	18.51	13.33
Concentration ratio	60.02	58.69	57.99

2.4 Methodology

This study estimates the following panel data specification

$$CS_{it} = \beta_1 \overline{R}_{it} + \beta_2 GB_{it} + \beta_3 Con_{it} + \gamma X_{it} + \alpha_i + \epsilon_{it} \tag{2.1}$$

where time variable (t) denotes survey years, and cross-sectional index (i) denotes countries. The dependent variable is the standardized value of the capital stringency index. I use the standardized value of the index in order to obtain the effects of independent variables in terms of standard deviations of the stringency of capital regulations. This transformation does not effect the qualitative results, but brings a more natural and intuitive interpretation to the

coefficients given the discrete nature of dependent variable.

$\overline{R}_{it}$ is 3-year average real GDP growth rate which is a proxy for overall asset returns, GB_{it} is government-owned banks which is the percentage of banking system's assets in banks that are 50% or more government owned and it is a proxy for the regulatory capture: the degree to which regulators are captured by the financial institutions under their control. Con_{it} is the three-bank concentration ratio which indirectly captures the risk taking incentives in the banking sector, and lastly X_{it} will be control variables such as institutional structure in some specifications.

Fixed effects model is the natural choice for estimation of this model for a couple of reasons. First, it is quite likely that unobserved country-specific heterogeneity, caputred by α_i terms, is correlated with the regressors $\overline{R}_{it}$, GB_{it} and Con_{it}. Fixed effects model yields consistent estimates of the model parameters under this type of correlation. Secondly, the fixed effects model is mainly identified through over time (within) variation in the data because the model is estimated after transforming each variable by subtracting time-average for each country from the original variable. For that reason, the fixed effects model is also called the *within* model. In our sample, the within variation dominates the between variation for the dependent variable and GDP growth rates. There is also a significant amount of within variation in the two other main explanatory variables. Third, the fixed effects model is recommended when the sample is an exhaustive list of the population (mostly occurs in cross-country studies such as ours) rather than a random draw from a large population (mostly occurs when individuals from a large population are sampled). Since our sample is an exhaustive list of all systemically important countries in the world, the third criteria also points to the use of fixed effects model.

The fixed effect model assumes that $\epsilon_{it} \sim IID(0, \sigma^2_\epsilon)$, and considers α_i's as fixed parameters that can be estimated along side with other parameters. The within transformation eliminates any variables that do not change over time, including α_i terms and other observed country specific characteristics such as the institutional characteristics including legal origin, government type etc.

Even though, the fixed effects model appears as the natural choice for our sample, I still estimate the model using pooled OLS regression (with clustered standard errors) for comparison. The results are presented in the next section. Although not reported, I also performed

a random effects estimation. The random effect estimation is inconsistent if regressors are correlated with country fixed effects. I use Hausman test to check the validity of this assumption. The null hypothesis is that regrossors are uncorrelated with unobserved country level heterogeneity. Under the null, the random effects model is consistent and it is the efficient estimator. Hausman test strongly rejects the null hypothesis indicating that the random effects coefficients are inconsistent in our sample. In other words, Hausman test adds a fourth justification to the choice of the fixed effects model as the main estimation strategy in this study.

2.5 Results

Table 2.3 presents the estimation of the model given by Equation (2.1). The first and second columns are the pooled OLS estimation where errors are clustered over countries to account for possible within country serial correlation in the combined error term $\alpha_i + \epsilon_{it}$. The second column includes country legal origin dummies to control for the institutional background of the economy.

The focus of this study is on the fixed effects model given by column three as discussed in the previous section, but still I present the pooled OLS estimations for comparison. The fixed effect models predict a strongly significant and negative effect of all three variables on the stringency of bank capital regulations.[10] The negative coefficient on the GDP growth variable provides empirical support to the theoretical result in Kara (2013). He shows that high return countries choose less stringent bank capital regulations because higher returns allow a country to take on more risk through less stringent regulations. The fixed effects model estimates that one percentage point increase in the GDP growth rate reduces the stringency of capital regulation by 8.3% standard deviation. This coefficient is not only statistically highly significant, but it is also economically meaningful. The following exercise helps us to see the economic significance of the coefficient: what would be the necessary change in the GDP growth rate for an emerging country to have the capital stringency level of an advanced country? The mean of the standardized index is 0.18 for the advanced countries, and it is

[10]The legal origin dummies disappear in the fixed effects estimation, because any time invariant variable is eliminated due to the within transformation.

-0.07 for the emerging countries. Therefore, the difference between the two means is equal to 0.25 standard deviation and a *t-test* shows that it is statistically greater than zero. The coefficient on the GDP growth variable implies that, everything else constant, if emerging countries had 3 percentage points lower GDP growth rate, they would choose the same level of bank capital stringency as the developed countries ($0.25/0.083 \simeq 3$). A larger and economically more significant effect is obtained when a dynamic model is estimated in the next section.

Table 2.3: Results for the Statics Model

VARIABLES	(1) Pooled OLS	(2) Pooled OLS	(3) Fixed Effects
GDP growth	-0.067***	-0.069***	-0.083***
	(0.004)	(0.004)	(0.000)
Government-owned banks	-0.004	-0.003	-0.020***
	(0.334)	(0.388)	(0.002)
Concentration ratio	-0.003	-0.003	-0.019**
	(0.424)	(0.414)	(0.013)
Legal origin UK		-0.046	
		(0.912)	
Legal origin FR		-0.221	
		(0.568)	
Legal origin GE		-0.157	
		(0.690)	
Constant	0.419*	0.584	1.657***
	(0.097)	(0.268)	(0.000)
Observations	246	245	246
R-squared	0.058	0.066	0.171
Number of code			81

[1] The dependent variable is the standardized value of the capital stringency index. The range of the standardized index is $[-2.25, 1.22]$. For the pooled OLS regressions, standard errors are clustered at the country level to take into account the highly likely within country correlation in error terms.

[2] GDP growth, government-owned banks and concentration ratio are expressed in percentages. For example, three percent real GDP growth rate is expressed as 3.0 in our data.

[3] GDP growth is 3 year average growth rate for years t, $t-1$ and $t-2$ whereas the capital stringency index represents the state of the capital regulation the end of year t.

[4] Legal origin variables are dummies that do not change over time, and hence they are dropped in the fixed effect regressions as a result of the within transformation.

[5] p-values in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The negative coefficient on government-owned banks supports the theoretical prediction in Dell'Ariccia and Marquez (2006). They show that if a regulator is more concerned about the

banking sector profits as opposed to the financial stability, it will choose less stringent capital regulations. I use government ownership of banks as a proxy for the weight on bank profits in a regulator's objective function. The fixed effects results show that one percentage point increase in government ownership of banks ratio leads to 2% standard deviation decrease in the stringency of bank capital regulations. Using the same exercise from the previous paragraph, the coefficient implies that, everything else constant, if emerging countries had 12.5 percentage points lower government-owned bank ratios, they would choose the same level of bank capital stringency as the developed countries ($0.25/0.02 \simeq 12.5$). Since government ownership of banks varies between 0% and 80% in our sample, the estimated effect is economically reasonable in addition to being statistically highly significant.

Lastly, the negative coefficient on concentration ratio shows that regulators relax stringency of bank capital regulations as the banking sector becomes more concentrated. This could happen if the regulators tend to associate higher concentration ratio with less incentives for excessive risk taking in the banking sector. Therefore, the result supports the "concentration-stability" hypothesis in the long theoretical and empirical divide about the effect of concentration in the banking sector on financial stability. The fixed effects result shows that one percentage point increase in the concentration ratio reduces the stringency of capital regulations by 1.9% standard deviations. Again let us ask: what would be the necessary change in concentration ratio for an emerging country to have the capital stringency level of an advanced country? The coefficient implies that, everything else constant, if emerging countries had 13 percentage points lower concentration ratio, they would choose the same level of bank capital stringency as the developed countries. ($0.25/0.019 \simeq 13$). This effect is also economically meaningful given that the concentration ratio varies between 15% and 100% in our sample.

Estimating a pooled OLS model increases standard errors significantly: government-owned banks and concentration ratio become insignificant whereas the p-value of GDP growth rises from 0.000 to 0.004. However, the pooled OLS results are inconsistent if the independent variables are correlated with fixed country effects, which is quite likely in this setup. I provide them here only for comparative reasons. Also, the second column in Table 2.3 shows that none of the legal origin dummies have a significant effect on the stringency of capital regulations.

2.6 Dynamic Model

It could very well be argued that regulatory choices contain some degree of inertia. Regulators may not want to make large changes in the stringency of capital regulations at once in order to not to cause a large and uncontrollable reaction in markets. They may also face political pressure or difficulties as they try to change regulation levels. Even more, they may not know how to best react to changing economy dynamics and choose simply to do nothing. Actually, Figure B.2 shows that in each survey a large fraction of countries keep the stringency of capital regulations the same compared to the last survey. In order to capture this highly possible inertia in capital regulations I introduce the following dynamic model:

$$CS_{it} = \beta_0 CR_{i,t-1} + \beta_1 \bar{R}_{it} + \beta_2 GB_{it} + \beta_3 Con_{it} + \gamma X_{it} + \alpha_i + \epsilon_{it} \tag{2.2}$$

where $\epsilon_{it} \sim IID(0, \sigma_\epsilon^2)$.

The only difference of the dynamic model from the static model given by Equation (2.1) is the introduction of the lagged dependent variable, $CS_{i,t-1}$, on the right hand side as an explanatory variable. However, this seemingly small change requires a significant alteration of the estimation technique. The within transformation or taking the first difference will not eliminate the endogeneity issue, and hence fixed effect model will yield inconsistent parameter estimates for the dynamic model. In order to see that, consider the equation in the first-difference form below

$$\Delta CS_{it} = \beta_0 \Delta CS_{i,t-1} + \beta_1 \Delta \bar{R}_{it} + \beta_2 \Delta GB_{it} + \beta_3 \Delta Con_{it} + \gamma \Delta X_{it} + \Delta \epsilon_{it} \tag{2.3}$$

Here the error term $\Delta\epsilon_{it}$ is correlated with $\Delta CS_{i,t-1}$ among the right hand side variables because $\epsilon_{i,t-1}$ in $\Delta\epsilon_{it}$ is correlated with $CS_{i,t-1}$ in $\Delta CS_{i,t-1}$. Therefore, Equation (2.3) can only be consistently estimated with appropriate set of instruments that are correlated with the endogenous regressor $\Delta CS_{i,t-1}$, but not correlated with the error term, $\Delta\epsilon_{it}$. Arellano and Bond (1991) show that $CS_{i,t-s}$ for $s \geq 2$ are uncorrelated with $\Delta\epsilon_{it}$ and can be used as instruments. Similarly, if there is any other endogenous variable among regressors, second and higher order lags of that variable can be included in the instrument set. When a regressor is

predetermined but not strictly exogenous, its lagged values of order one or higher are valid instruments. If the regressor is strictly exogenous, then current and all lagged values are valid instruments. This estimation technique is also called the Difference GMM estimation.

Arellano and Bover (1995) argue that efficiency of dynamic panel data estimation by the Difference GMM method can significantly be improved if the equation in levels (given by 2.2) is estimated along side with the equation in first difference (given by 2.3). They show that the lags of the difference variables can be used as instruments for the level equation. This augmented estimator is called the System-GMM estimator.

Estimation of the dynamic model is given by Table 2.4. The first two columns are the Difference GMM estimator and the last two column are estimated using the System GMM. All four specifications are estimated using a two-step procedure where the first step results used to calculate the optimal weighting matrix for the second step estimation. Windmeijer (2005) corrected robust standard errors for the two-step GMM estimation is used in all four specifications.

The first and third columns are estimated under the assumption that all three regressors are strictly exogenous with respect to the time varying heterogeneity (ϵ_{it}), and the second and fourth columns are estimated under the assumption that GDP growth and concentration ratio are predetermined variables, i.e that the error term ϵ_{it} is uncorrelated with the current and lagged values of these regressors, but ϵ_{it} can be correlated with future values of the regressors. In other words, estimations in columns two and four allow time varying shocks to regulatory standards to effect future GDP growth rates, and concentration ratios but not government-owned banks. I believe that this is a more reasonable assumption than treating these variables strictly exogenous. It is a well known fact the regulatory choices might affect future GDP growth rates. There is also a large literature examining the effects of capital regulations on the banking sector performance and riskiness, which could eventually impact the concentration in the sector. Note that all specifications still allow regressors to be correlated with country specific time-unvarying heterogeneity captured by α_i terms which are eliminated by the first difference transformation.

I use the standardized value of the capital stringency index as in the static model estimations presented in the previous section. Treating GDP growth and government-owned banks

Table 2.4: Results for the Dynamic Model

	Difference GMM		System GMM	
	(1)	(2)	(3)	(4)
L.Capital stringency	0.351	0.298	0.075	0.090
	(0.468)	(0.365)	(0.741)	(0.616)
GDP growth	-0.146***	-0.194***	-0.141***	-0.184***
	(0.002)	(0.000)	(0.000)	(0.000)
Government-owned banks	-0.016	-0.023	-0.019	-0.021
	(0.367)	(0.159)	(0.289)	(0.191)
Concentration ratio	-0.007	0.008	-0.010	-0.011
	(0.647)	(0.706)	(0.394)	(0.396)
Constant	1.333	0.705	1.538*	1.764**
	(0.196)	(0.565)	(0.094)	(0.037)
Observations	86	86	161	161
Number of code	52	52	72	72

[1] The dependent variable is the standardized value of the capital stringency index. The range of the standardized index is $[-2.25, 1.22]$.

[2] Column (1): Two-step GMM estimation where all three right-hand side variables are treated as strictly exogenous with respect to time-varying heterogeneity ϵ_{it}. Column (2): Two-step GMM estimation where GDP growth and concentration ratio are treated as predetermined variables with respect to time-varying heterogeneity ϵ_{it}. Columns (3)-(4) repeat the estimations in Column (1) and (2) with Two-Step System GMM where levels Equation (2.2) is estimated along side with the first difference model given by Equation (2.3).

[3] GDP growth, government-owned banks and concentration ratio are expressed in percentages.

[4] GDP growth is 3 year average growth rate for years t, $t-1$ and $t-2$ whereas the capital stringency index represents the state of the capital regulation the end of year t.

[5] Standard errors are Windmeijer corrected robust. p values in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

as predetermined variables as opposed to strictly exogenous variables significantly reduces the standard errors for all coefficients and increases the estimated magnitudes of the coefficients. This suggests that columns two and four are better specifications for the model of this study as expected. Therefore I focus on the results in these columns.

Estimation with dynamic panel data models conserve the signs obtained with the static fixed effects model for GDP growth and government-owned banks. The coefficient of GDP growth is estimated even with a higher precision than static models. It is significant at 1% level in all four specifications. The coefficient of concentration ratio becomes positive in the System GMM estimations given in the last two columns, however it is not statistically different from zero in any dynamic model estimation. The coefficient of government-owned banks also turns

out to be insignificant in these dynamic model estimations. However, when we use the levels of the index instead of the standardized values, this coefficient becomes quite significant when GDP growth and concentration ratio are treated as predetermined variables (as in columns two and four in Table 2.4). The first difference and System GMM estimations using the levels of the index, which are not reported here, provides p-values of 1.2% and 9.8%, respectively for the government-owned banks variable.

Accounting for the potential inertia in the capital regulation index significantly increases the magnitude of the coefficient for *GDP growth* compared to the static fixed effects model presented in Table 2.3. I repeat the exercise that was performed in the previous section in order to gauge the economic significance of the estimated coefficient. The dynamic model estimates that if the emerging countries had only 1.3 percentage points less average GDP growth rate (as opposed to 3 percentage points in the static model), they would choose the same level of bank capital stringency as the developed countries ($0.25/0.189 \simeq 1.3$) where 0.25 is the difference between the means of the standardized index for these two country groups.[11] Therefore, the results with the dynamic model show a stronger economic impact of GDP growth rate on the choice of the stringency of capital regulations than the static models.

The magnitude of the coefficient on government-owned banks does not change significantly compared to the static model. The exercise shows that, under the dynamic model, if emerging countries had 11.3 percentage points lower government ownership of banks ratio, they would choose the same level of bank capital stringency as the developed countries ($0.25/0.022 \simeq 11.3$). This number was 12.5 percentage points in the static model, which is quite close. The effect of government-owned banks on the capital regulation stringency is economically meaningful, but this effect is not statistically as strong as the effect of the GDP growth variable: coefficient of government-owned banks is only significant under the fixed effects estimations, or when we use the levels of the index in the dynamic model.

On the other hand, concentration ratio has no significant effect on the stringency of capital regulation under the dynamic model whether we use the levels or the standardized value of the index. In other words, the significant and negative coefficient for concentration ratio obtained

[11] I used the average of the estimated coefficients in columns two and four: $(0.194 + 0.184)/2 = 0.189$.

in the static model is not robust to more reasonable specifications that come with dynamic models. This is not very surprising given that the effect of concentration ratio on the stringency of capital regulations can work both ways from a theoretical perspective.

2.7 Robustness

2.7.1 Principal Component Analysis

In the main section, I used the standardized value of the capital stringency index as the dependent variable. Therefore, I implicitly assumed that all questions that enter into the calculation of the index have equal waits in determining the stringency of bank capital regulation. However, some of the regulation dimensions measured by the index can more easily be adopted by regulators and vary less across countries, whereas implementation of some other components could be more challenging for regulators, and hence vary to a larger extent across countries. For example, on average 99% of countries answered Question 3.1.1 ("Is the minimum capital ratio risk weighted in line with the Basle guidelines?") in Table 2.1 as "Yes", whereas only 46% of them did so for Question 3.3 ("Does the minimum ratio vary as a function of market risk?").

In that regard, one may prefer an index that attaches greater weights to components of regulation that vary more across countries, and smaller weights to components vary less across countries. Principal Component Analysis (PCA) exactly does that. Principal component analysis is an orthogonal transformation of (possibly) correlated variables, the index components here, into a number of linearly uncorrelated variables, called *principal components*. This transformation is defined in such a way that the first principal component is the "most informative", which means, it accounts for as much of the variability in the data as possible. The first principal component in this case explains about 42% of the variation in the index data. I estimate both the static and dynamic models using the first principal component of the capital stringency index as the dependent variable. The results of the static model is presented in Table 2.5. Again, my focus in on the fixed effects regression, but the pooled OLS estimation results are presented for comparison. The results do not change qualitatively compared to the results in Table 2.3 where the standardized value of the index is used. The fixed effects model

Table 2.5: Results for the Statics Model with Principal Component Analysis

VARIABLES	(1) Pooled OLS	(2) Pooled OLS	(3) Fixed Effects
GDP growth	-0.072*	-0.076**	-0.091**
	(0.058)	(0.048)	(0.012)
Government-owned banks	-0.006	-0.005	-0.029***
	(0.413)	(0.463)	(0.008)
Concentration ratio	-0.003	-0.004	-0.031***
	(0.545)	(0.452)	(0.009)
Legal origin UK		-0.149	
		(0.830)	
Legal origin FR		-0.377	
		(0.565)	
Legal origin GE		-0.231	
		(0.727)	
Constant	0.643	0.972	2.719***
	(0.107)	(0.257)	(0.000)
Observations	245	244	245
R-squared	0.030	0.038	0.130
Number of code			81

[1] The dependent variable is the first principal component of the capital stringency index. The range of the principal component is $[-2.52, 1.78]$. For the pooled OLS regressions, standard errors are clustered at the country level to take into account the highly likely within country correlation in error terms.

[2] GDP growth, government-owned banks and concentration ratio are expressed in percentages.

[3] GDP growth is 3 year average growth rate for years t, $t-1$ and $t-2$ whereas the capital stringency index represents the state of the capital regulation the end of year t.

[4] Legal origin variables are dummies that do not change over time, and hence they are dropped in the fixed effect regressions as a result of the within transformation.

[5] Robust p values in parentheses. *** p<0.01, ** p<0.05, * p<0.1

estimates negative and significant effect of all three variables on the stringency of capital regulations. Given that the range of the principal component is $[-2.52, 1.78]$ with mean 0.16 and standard deviation 1.57, the economic magnitude of the coefficients are similar to the those obtained in Table 2.3.

Table 2.6 presents the results of dynamic panel data models using Principal Component Analysis. Similar to Table 2.4, the first and third columns are estimated under the assumption that all three regressors are strictly exogenous with respect to the time varying heterogeneity (ϵ_{it}), and the second and fourth columns are estimated under the assumption that GDP growth and concentration ratio are predetermined variables, i.e that the error term ϵ_{it} is uncorrelated

Table 2.6: Results for the Dynamic Model with Principal Component Analysis

	Difference GMM		System GMM	
	(1)	(2)	(3)	(4)
L.capital stringency_pc	0.122	0.140	0.021	0.109
	(0.705)	(0.512)	(0.925)	(0.503)
GDP growth	-0.221***	-0.268***	-0.209***	-0.260***
	(0.000)	(0.000)	(0.000)	(0.000)
Government-owned banks	-0.018	-0.027	-0.022	-0.023
	(0.498)	(0.293)	(0.461)	(0.393)
Concentration ratio	-0.015	0.014	-0.016	-0.014
	(0.452)	(0.675)	(0.424)	(0.567)
Constant	2.254	0.833	2.341	2.389
	(0.121)	(0.674)	(0.117)	(0.136)
Observations	86	86	161	161
Number of code	52	52	72	72

[1] The dependent variable is the principal component of the capital stringency index. The range of the principal component is $[-2.52, 1.78]$ with mean 0.16 and standard deviation 1.57.

[2] Column (1): Two-step GMM estimation where all three right-hand side variables are treated as strictly exogenous with respect to time-varying heterogeneity ϵ_{it}. Column (2): Two-step GMM estimation where GDP growth and concentration ratio are treated as predetermined variables with respect to time-varying heterogeneity ϵ_{it}. Columns (3) and (4) repeat the estimations in Column (1) and (2) with Two-Step System GMM where levels Equation (2.2) is estimated along side with the first difference model given by Equation (2.3).

[3] GDP growth, government-owned banks and concentration ratio are expressed in percentages.

[4] GDP growth is 3 year average growth rate for years t, $t-1$ and $t-2$ whereas the capital stringency index represents the state of the capital regulation the end of year t.

[5] Standard errors are Windmeijer corrected robust. Robust p values in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

with the current and lagged values of these regressors, but ϵ_{it} can be correlated with future values of these regressors.

The coefficient of GDP Growth is highly significant across all specifications, and it is at least twice as large as the coefficients estimated by static models. Coefficients of the two other explanatory variables (government-owned banks and concentration ratio) and the lagged dependent variable are not significantly different from zero. Those results are qualitatively the same as the results obtained with the standardized value of the index in Table 2.4. Furthermore, the quantitative effects of the coefficients also do not change significantly when the first principal component of the index is used.

In summary, the combined results in this section and the previous one show an economically

meaningful and statistically highly significant negative effect of GDP growth rate on the stringency of bank capital regulations. Government-owned banks has a significant negative effect in static fixed effects models, but under more reasonable dynamic models, it is significant only if the levels of the stringency index is used as the dependent variable. Statistical significance of this coefficient is not robust to using the standardized value or the first principal component of the capital stringency index. Lastly, concentration ratio has a significant negative effect on the stringency of capital regulations in static models, but never has a significant effect in dynamic models.

2.7.2 Controlling for Financial and Institutional Development

There are significant differences in the financial development level, and the institutional structure of the countries in our sample. Those difference might affect the design of capital regulations and the way the regulations change over time. In this section, I control for financial structure and institutional background variables. Most of the variables that measure structure, size, depth and openness of financial sectors are obtained from the extensive panel data set created by Thorsten Beck, Asli Demirguc-Kunt and Ross Levine, the so-called the Financial Structure Database (Beck et al., 2009). I make use of the Polity IV and Worldwide Governance Indicators databases to gather information on the political and institutional structures. The variable definitions in this section are also taken from the corresponding databases.

Controlling for the Financial Structure

I start by controlling for the size, depth and efficiency of financial markets. I perform only fixed effects regressions in this section. The results are presented in Table 2.7. I add one control at a time. The results in the main section do not change at all when we include controls for the financial structure. However, most of the control variables have insignificant coefficients in these regressions. In the first column I control for *Liquid Liabilities to GDP* which is a traditional indicator of financial depth. It equals currency plus demand and interest-bearing liabilities of banks and other financial intermediaries divided by GDP. This is the broadest available indicator of financial intermediation, since it includes all banks, bank-like and non-bank financial institutions. Liquid Liabilities to GDP has a positive but insignificant coefficient.

Table 2.7: Fixed Effects with Financial Structure Controls

	(1)	(2)	(3)	(4)	(5)
GDP growth	-0.082***	-0.081***	-0.067**	-0.119***	-0.082***
	(0.002)	(0.001)	(0.011)	(0.000)	(0.000)
Government-owned banks	-0.022***	-0.020***	-0.026***	-0.024***	-0.020***
	(0.002)	(0.004)	(0.000)	(0.001)	(0.004)
Concentration ratio	-0.018**	-0.015*	-0.022***	-0.019**	-0.018**
	(0.030)	(0.077)	(0.004)	(0.014)	(0.014)
Liquid liabilities / GDP	0.007				
	(0.233)				
Bank credit / Bank deposits		0.004**			
		(0.010)			
Structure-size			-0.188		
			(0.127)		
Capital controls				0.001	
				(0.985)	
Financial openness					-0.005
					(0.961)
Constant	1.181*	0.897	2.040***	1.844***	1.659***
	(0.079)	(0.113)	(0.000)	(0.000)	(0.001)
Observations	224	233	215	225	245

[1] The dependent variable is the standardized value of the capital stringency index. The range of the standardized index is $[-2.25, 1.22]$.
[2] GDP growth, government-owned banks and concentration ratio are expressed in percentages. For example, three percent real GDP growth rate is expressed as 3.0 in our data.
[3] GDP growth is 3 year average growth rate for years t, $t-1$ and $t-2$ whereas the capital stringency index represents the state of the capital regulation the end of year t.
[4] p values in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Theoretical studies on bank capital regulations generally assume that the savings of the economy is turned into socially profitable investments through the intermediation of the financial sector. In particular, studies from which some of the main explanatory variables are derived, namely Kara (2013), Dell'Ariccia and Marquez (2006), Acharya (2001) consider such models. In practice, there are large cross-country differences in the efficiency of banking sectors in turning society's savings into profitable investments as documented by Beck et al. (2009).

I use *Bank Credit to Bank Deposits* to control for the differences in the banking sector efficiency. This variable is equal to the claims on the private sector to deposits in deposit money banks. It measures the extent to which banks intermediate society's savings into private sector credits. Beck et al. (2009) show that financially less developed countries attract relatively less

deposits into banks and they turn a smaller share of these deposits into private sector credits. This ratio can essentially take values above one to indicate that private sector lending is funded also with non-deposit sources. The ratio does indeed take values greater than one for about a half of our sample. Results in the second column show that bank capital regulations become stricter as the Bank Credits to Bank Deposits ratio increases. In other words, the stringency of capital regulation is higher in countries with more efficient banking sectors.

In the third column I control for the financial structure using *Structure-Size* which equals the Stock Market Capitalization to GDP divided by Bank Credit to GDP. Structure-Size compares the total shares outstanding in the economy's stock exchanges to the size of the banking system. Thus, higher values of the indicator corresponds to more market based systems as opposed bank based systems. The variable has a negative coefficient which would indicate that more market based systems tend to have less stringent capital regulations, however this coefficient is not statistically different from zero at conventional significance levels.

In the last two columns I control for the degree of financial openness. Financially open countries have larger exposures to shocks coming from other countries, therefore they may have stronger incentives to set strict capital regulations. I use two indicators of financial openness. *Capital Controls* is obtained from the Economic Freedom of the World database. The index is calculated based on the 13 types of international capital controls included the International Monetary Fund's Annual Report on Exchange Arrangements and Exchange Restrictions. The zero-to-ten rating is the percentage of capital controls not levied as a share of the total number of capital controls listed multiplied by 10. Therefore, higher values of this index corresponds to less controls on capital and hence to a greater degree of financial openness. The second indicator, *Financial Openness*, is also called the Chinn-Ito index (KAOPEN) (Chinn and Ito, 2006). This index is again based on the same IMF report, but it has a relatively more complex construction that focuses more on financial openness than controls. The index takes higher values the more open the country to cross-border capital transactions. The coefficient of these two different measures of financial openness turn out to be the opposite in the regressions, however neither of them is statistically different than zero. Therefore, I do not find evidence that financially more open countries impose stricter capital regulations.

To sum, the results in Table 2.7 show that the findings in the main section are robust to

controlling for differences in financial structure. In general, I find that the size of the banking system relative to the size of the economy is positively associated with the stringency of capital regulations although that relationship is not statistically significant. Second, the stringency of capital regulation is higher in countries with more efficient banking sectors. Third, the stock market capitalization and its relative size to the banking sector is negatively associated with the stringency of capital regulations while the relationship is again insignificant. Lastly, the degree of financial openness has no statistically significant effect on the stringency of capital regulations.

Controlling for the Institutional and Political Background

Barth et al. (2006) show that international differences in institutional and political structure influence the choice of bank regulatory and supervisory policies such as activity restrictions for banks, entry requirements to the banking sector, the strength of private monitoring, and the powers of the official banking supervisors. They do not bring forward any theoretical argument or empirical evidence about the influence of political and institutional structure on bank capital regulations in particular. Still, in this section, I control for political and institutional structure variables for their potential effect on the stringency of bank capital regulations. I mainly use the same institutional control variables that are used by Barth et al. (2006) in their regressions in addition to few other indicators from commonly used databases. These indicators measure the degree to which the political system is an open, competitive democracy that is accountable to the broad population as opposed to being an autocratic regime that is only responsible to a small group of leaders.

Four of the five institutional control variables are taken from the Polity IV Database. These controls are Executive Constraints, Executive Competition, Executive Openness and Polity. The first three are used by Barth et al. (2006) as well. *Executive Constraints* measures "the extent to which institutionalized constraints on the decision making powers of chief executives, whether individuals or collectivities". The index varies from 1 to 7, where large values correspond to greater constraints on executive power. *Executive Competition* refers to "the extent that prevailing modes of advancement give subordinates equal opportunities to become superordinates." It varies from 0 to 3, where higher values imply greater competition for the

executive position. *Executive Openness* captures if "the recruitment of the chief executive is 'open' to the extent that all the politically active population has an opportunity, in principle, to attain the position through a regularized process." This index takes values between 0 and 4, where higher values indicate greater openness. *Polity* measures the extent to which the political system is democratic. It ranges from +10 (strongly democratic) to -10 (strongly autocratic).

Table 2.8: Fixed Effects Estimation with Institutional and Political Structure Controls

	(1)	(2)	(3)	(4)	(5)
	xconst	xrcomp	xropen	polity	rlest
VARIABLES	ocns	ocns	ocns	ocns	ocn
GDP growth	-0.080***	-0.080***	-0.080***	-0.080***	-0.141***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)
Government-owned banks	-0.019**	-0.019**	-0.019**	-0.019**	-0.034***
	(0.013)	(0.013)	(0.013)	(0.011)	(0.003)
Concentration ratio	-0.016**	-0.016**	-0.016**	-0.016**	-0.032**
	(0.035)	(0.035)	(0.035)	(0.035)	(0.014)
Executive constraints	0.005				
	(0.677)				
Executive competition		0.005			
		(0.677)			
Executive openness			0.005		
			(0.644)		
Polity				0.001	
				(0.916)	
Rule of law					0.175
					(0.831)
Constant	1.465***	1.479***	1.472***	1.482***	6.645***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.000)
Observations	240	240	240	240	246
R-squared	0.147	0.147	0.147	0.146	0.170
Number of code	79	79	79	79	81

[1] The dependent variable is the standardized value of the capital stringency index. The range of the standardized index is $[-2.25, 1.22]$.
[2] GDP growth, government-owned banks and concentration ratio are expressed in percentages. For example, three percent real GDP growth rate is expressed as 3.0 in our data.
[3] GDP growth is 3 year average growth rate for years t, $t-1$ and $t-2$ whereas the capital stringency index represents the state of the capital regulation the end of year t.
[4] p values in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The last indicator, *Rule of Law* is taken from the World Governance Indicators Database. Rule of Law "captures perceptions of the extent to which agents have confidence in and abide

by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence." In our sample, Rule of Law ranges from a low of -1.63 to a high of 1.99. The mean is 0.47 with a standard deviation of 0.97. Based on data in 2011, some countries have political systems characterized by having very low levels of rule of law such as Iraq, Nigeria and Venezuela. On the other hand, rule of law applies strongly in many countries including the US, UK, Iceland, New Zealand and Singapore.

Barth et al. (2006) argue that open, competitive and democratic political systems will support banking regulations that maximize the welfare of society at large. However, when it comes to bank capital regulations in particular, the level of stringency that maximize the welfare may not be the most stringent regulations at all times for all countries. For example, Kara (2013) shows that high return countries optimally choose less stringent capital regulations. Therefore, the theory does not necessarily predicts a positive relationship between more democratic political systems and the stringency of capital regulations. I obtain positive coefficients for all of the political system indicators in the regressions presented in Table 2.8. However, none of the coefficients for these controls is significantly different from zero confirming the lack of direct influence of the political structure on the design of bank capital regulations.

2.8 Extensions

2.8.1 Logit Regressions for Individual Index Questions

In previous sections I used an aggregate index to measure the stringency of capital regulations. The index is aggregated either by summing the values of individual questions, which implicitly attached the same weight to all questions, or by using the principal component analysis, which attaches greater weights to questions that vary more across countries and over time. In this section, I analyze how the individual questions that make up the aggregate index changes with the main independent variables. This analysis helps us go into the 'black box' of the aggregate index and see which questions mainly differentiate across countries and drive the results that were obtained in the previous sections.

The dependent variables in this section are the individual index questions that are presented

in Table 2.1. Since the dependent variables are binary (take values either 0 or 1), I use logistic regressions (logit) in this section. The unobserved country-specific heterogeneity is still highly likely to be correlated with the explanatory variables. The consistent estimator in this case is the conditional fixed effects logit model. Population averaged logit and pooled logit regressions are performed for comparison. These two model results should be viewed with caution because under the presence of fixed effects they are inconsistent.

The results are presented in Table B.4. The top panel presents the results of the conditional fixed effects logit model, the middle panel presents population averaged logit and the last panel presents the pooled logit model results. I will focus on the results in the top panel. The conditional fixed effects logit model is identified through within (over time) variation. Therefore, the estimation technique drops the countries from the sample for which the index answers do not change over time.

There is so little over-time variation for the first question ("Is the minimum capital ratio risk weighted in line with the Basle guidelines?") for the majority of the countries. 78 countries are dropped from the sample for the conditional fixed effects estimation of this question, and hence observations from only 3 countries are used. The result in column one shows that the coefficients of all three independent variables are negative but they are not statistically different from zero. The result is quite expected. The independent variables do not cause any significant effect in differentiating the answers to this question because there is not enough variation in the answers to differentiate.

There is sufficient variation in the remaining five questions which can be seen from the fact that they are estimated using the majority of the countries in the sample. The "number of code" row shows how many countries were used to estimate the coefficients for each regression. The coefficient of GDP growth is negative for all remaining five questions, but is is only significantly different than zero for the second, third and fourth questions. It is actually barely significant at 10% for the fourth question ("Does the market value of loan losses not realized in accounting books deducted from the book value of capital before minimum capital adequacy is determined?"), whereas it is significant even at 1% level for the second and third questions. Therefore, the fixed effects logit regression shows that the negative and significant coefficient of GDP growth in the aggregated index regressions in the previous sections is mainly driven by

these two questions which concern if the minimum capital adequacy ratio varies as a function of an individual bank's credit risk and market risk.

The coefficient of concentration ratio is also negative for all six questions, but it is significant only for the last three questions that deal with the determination of capital. The result indicates that the negative and significant sign of concentration ratio in the aggregated index fixed effects regressions is driven by the variation in answers to these last three questions. Countries with more concentrated banking sectors are more lenient in the way banks are allowed to calculate the equity capital (the numerator of the capital ratio).

The third main explanatory variable, government-owned banks, negatively effects the probability of a country answering 'yes' to any of the six questions as well. The coefficient of this variable is significant only for the second, third and fourth questions similar to the GDP growth variable. Higher government ownership of banks significantly reduces the proabilty that a country allows the minimum capital adequacy ratio to vary with individual bank's credit risk and market risk, and the probability that the country requires loan losses not realized in accounting books to be deducted from the book value of capital before minimum capital adequacy is determined.

Population averaged and pooled logit models results are quite similar to each other. They estimate negative and significant effect of GDP growth on the first question as well in addition to the second, third and fourth questions. However, these two methods do not find any significant effect of concentration ratio and government-owned banks on the probability that countries answer 'yes' to any of the six questions. These results have to viewed by caution as they are inconsistent under the presence of country fixed effects, which are very likely in this setup.

2.8.2 Estimation of Different Slopes for Advanced and Emerging Countries

The regressions above assumed that the coefficients for the three explanatory variables are the same across advanced and emerging countries. In this section, I estimate the fixed effect model with interaction terms between the explanatory variables and a dummy for advanced countries (dummy variable is equal to one for advanced countries and zero for emerging countries). The results of this estimation is given in Table B.5. First, the fixed effects model is estimated by

adding an interaction term and one of the right hand side variables once at a time. The column four adds interaction terms between all right hand side variables and the advanced dummy.

The interaction terms allows estimating different slopes for advanced and emerging countries. The first three rows present the estimated coefficient of GDP growth, government-owned banks and concentration ratio for emerging countries (that is when the dummy *adv=0*). The signs are the same as the fixed effects estimation results in Table 2.3, but they are larger in magnitude. Rows four to six show the coefficients of the interaction terms. Interaction terms for GDP growth and government-owned banks are negative whereas the interaction terms for concentration ratio is positive in all four specifications. However, none of the interaction terms is statistically significant which means that the slopes for advanced and emerging countries are not statistically different than each other.

The implied slopes for the advanced country group can be calculated by adding the interaction terms to the estimated slopes for the emerging country group given by the first three rows. The resulting coefficients along with the p-values are presented in rows nine to eleven. Slopes for GDP growth and government-owned Banks are larger in absolute value than the slopes for emerging countries indicating that capital regulation in advanced countries are more sensitive to changes in these independent variables than they are in emerging countries. Those coefficients for advanced economies are statistically significant with p-values less than 2% on their own. This result is reasonable because advanced countries have much lower growth rates and government ownership of banks, and hence one percentage point change in these ratios imply a larger change in terms of percentages of the original values compared to the emerging countries.

The coefficient of concentration ratio is smaller in absolute value for advanced economies, indicating that the capital regulation in advanced economies is responding less to changes in concentration ratio. This could suggest that advanced country regulators expect smaller changes in bank risk behavior as a result of changes in banking sector concentration. However, neither the coefficient nor the difference between the estimates for the two country groups is statistically different from zero for concentration ratio.

2.9 Conclusion

Despite the extensive attention that the Basel capital adequacy standards received internationally, there exists significant variation in the implementation of these standards across countries. Furthermore, a significant number of countries increase or decrease stringency of capital regulations over time. In this chapter, I have investigated the empirical determinants of the variation that is seen in the data based on the theories of bank capital regulation.

This study measures the stringency of capital regulations using an index created from responses to the World Bank surveys on bank regulations. The capital stringency index shows whether the capital requirement reflects certain risk elements and deducts certain market value losses from capital before minimum capital adequacy is determined. The sample of this study includes 83 major developed and developing countries. I have estimated static and dynamic panel data models, and performed robustness tests using Principal Component Analysis.

The study provides strong evidence that countries with high average returns to investment choose less stringent capital regulation standards. It also finds some evidence that capital regulations are less stringent in countries with higher ratio of government ownership of banks: government ownership of banks has a significant negative effect on the stringency of capital regulations in the static fixed effects model, but under more reasonable dynamic models, it is significant only if the levels of the capital stringency index is used as the dependent variable. Statistical significance of this coefficient is not robust to using the standardized value or the first principal component of the capital stringency index. Government ownership of banks is used as a proxy for the regulatory capture: the degree to which regulators are captured by the financial institutions under their control. Therefore, this result implies that the stringency of capital regulations decrease in the regulatory capture. Lastly, the results provide somewhat weaker evidence that countries with higher concentration in banking sectors impose less strict capital standards: concentration ratio has a significant negative effect on the stringency of capital regulations in static models, but never has a significant effect in dynamic models. A negative relationship between the stringency of capital regulations and concentration ratio would be obtained if regulators expect the banking sector to become more stable as it becomes more concentrated.

Appendix A

Examples and Proofs for Chapter 1

A.1 Functional Form Examples

Example 1 $F(y) = R\ln(1+y)$

For this return function we obtain the (inverse) demand function as

$$P = F'(y) = \frac{R}{1+y} \text{ and hence } y = F'^{-1}(P) = \frac{R-P}{P} \equiv D(P) \tag{A.1.1}$$

This demand function is clearly downward slopping and convex as seen below

$$D'(P) = -\frac{R}{P^2} < 0 \text{ and } D''(P) = \frac{2R}{P^3} > 0$$

$F(\cdot)$ satisfies Assumption *CONCAVITY* since

$$F''(y) = -\frac{R}{(1+y)^2} < 0 \text{ and since } F'(0) = R$$

Let's check whether this functional form satisfies the conditions given by *Assumption ELASTICITY and Assumption REGULARITY,* respectively.

$$F'(y) + yF''(y) = \frac{R}{1+y} - y\frac{R}{(1+y)^2} = \frac{Ra}{(1+y)^2} > 0$$

Clearly *Assumption ELASTICITY* is satisfied. Below we see that this function satisfies *Assumption REGULARITY* as well:

$$F'(y)F'''(y) - 2F''(y)^2 = \frac{R}{(1+y)}\frac{2R}{(1+y)^3} - 2\left(\frac{R}{(1+y)^2}\right)^2 = 0$$

From above we can also see that this return function induces a log-convex demand function since we will have $F'(y)F'''(y) - F''(y)^2 > 0$

Example 2 $F(y) = \sqrt{y + a^2}$

For this example the demand function will be obtained as

$$P = F'(y) = \frac{1}{2\sqrt{y + a^2}} \text{ and hence } y = F'^{-1}(P) = \frac{1}{4P^2} - a^2 \equiv D(P)$$

This demand function is also downward slopping and convex as seen below

$$D'(P) = -\frac{1}{2P^3} < 0 \text{ and } D''(P) = \frac{3}{2P^4} > 0$$

Assumption CONCAVITY is satisfied since

$$F''(y) = -\frac{1}{4\left(y + a\right)^{3/2}} < 0 \text{ and } F'(0) = R \text{ implies that } \frac{1}{2a} = R \text{ or } a = \frac{1}{2R}$$

We can easily show that *Assumption ELASTICITY* is satisfied:

$$F'(y) + yF''(y) = \frac{1}{2\left(y + a\right)^{\frac{1}{2}}} - y\frac{1}{4\left(y + a\right)^{\frac{3}{2}}} = \frac{y + 2a}{4\left(y + a\right)^{\frac{3}{2}}} > 0$$

Likewise we can show that this function satisfies *Assumption REGULARITY* as well:

$$\begin{aligned} F'(y)F'''(y) - 2F''(y)^2 &= \frac{1}{2\left(y + a\right)^{\frac{1}{2}}}\frac{3}{8\left(y + a\right)^{\frac{5}{2}}} - 2\left(\frac{1}{4\left(y + a\right)^{\frac{3}{2}}}\right)^2 \\ &= \frac{-1}{16\left(y + a\right)^3} < 0 \end{aligned}$$

Note that in contrast to the first example this functional form induces a log-concave demand function since we can show that $F'(y)F'''(y) - F''(y)^2 < 0$

A.2 Symmetric Countries: An example

In this section, I obtain closed form solutions for non-cooperative equilibrium regulation levels and regulation levels under cooperative benchmark for the particular functional form choice for the global investors' technology given by Example 1 above.

For analytical convenience suppose that the technology of global investors is given by the

following logarithmic function as investigated by Example 1 above

$$F(y) = A\ln(a+y) \tag{A.2.1}$$

where the amount of assets the global investors optimally buy satisfies the following first order conditions

$$F'(y) = \frac{A}{a+y} = P \tag{A.2.2}$$

which will induce a downward slopping demand function

$$y = F'(P)^{-1} = \frac{A-aP}{P} \equiv D(P) \tag{A.2.3}$$

Imposing *Assumption CONCAVITY* on this functional form gives

$$F'(0) = R \Rightarrow \frac{A}{a} = R \quad \text{or} \quad A = aR \tag{A.2.4}$$

It is shown in the previous section that this functional form satisfies the conditions given by *Assumptions ELASTICITY and REGULARITY.* Since this functional form satisfies all sufficient conditions, we can proceed with solving for the equilibrium. We start solving the model backwards as in the previous section. Therefore we first find the equilibrium price at $t = 1$ using the market clearing condition.

$$D(P) = S(P, N_A + N_B) \Rightarrow \frac{A-aP}{P} = \frac{c(N_A+N_B)}{P} \tag{A.2.5}$$

Hence, we get the equilibrium price of assets at $t = 1$ as

$$P^* = \frac{A - c(N_A+N_B)}{a} \tag{A.2.6}$$

which is clearly decreasing in the investment levels in both countries. Note also that equilibrium price is determined only by the total investment level in the two countries. Exact division of the total investment between the countries will not affect P^*. This property of the equilibrium price of assets is very helpful in the analysis of the model.

We can also obtain equilibrium fraction of assets retained by banks after fire-sales as a function of initial investment levels in each country by plugging the equilibrium price given by equation (A.2.6) into equation (1.9) that defines this fraction as a ratio of market price, which will give that

$$\gamma^*(N_A, N_B) = 1 - \frac{c}{P^*(N_A, N_B)} = 1 - \frac{ac}{A - c(N_A + N_B)} \tag{A.2.7}$$

Remember that regulator i's objective function is

$$\max_{N_i \geq 0} W_i(N_i, N_j) = q(R-1)N_i + (1-q)[R\gamma^*(N_i, N_j)N_i - N_i] \tag{A.2.8}$$

Substituting for $\gamma^*(N_i, N_j)$ from (A.2.7) gives

$$\max_{N_i \geq 0} W_i(N_i, N_j) = q(R-1)N_i + (1-q)\left[R\left(1 - \frac{ac}{A - c(N_i + N_j)}\right)N_i - N_i\right] \tag{A.2.9}$$

where FOCs can be obtained as

$$\frac{\partial W_i(N_i, N_j)}{\partial N_i} = qR + (1-q)R\left\{1 - \frac{ac(A - cN_j)}{[A - c(N_i + N_j)]^2}\right\} - 1 = 0 \tag{A.2.10}$$

Solving for N_i gives the best response function of regulator i

$$N_i^*(N_j) = \frac{A - cN_j - \sqrt{\sigma ac(A - cN_j)}}{c} \tag{A.2.11}$$

where we define

$$\sigma \equiv \frac{(1-q)R}{R-1} \tag{A.2.12}$$

We can use the best response functions to solve for the symmetric equilibrium investment level. After some algebra we can obtain that for $i = A, B$

$$\widehat{N}_i = \frac{4A - \sigma ac - \sqrt{8\sigma Aac + (\sigma ac)^2}}{8c} \tag{A.2.13}$$

Note that by Assumption *CONCAVITY* we impose that $A = aR$. Substituting for A using this identity gives

$$\widehat{N}_i = \frac{4R - \sigma c - \sqrt{8R\sigma c + (\sigma c)^2}}{8c} \tag{A.2.14}$$

A.2.1 Central Regulation

Let's consider the central regulator's problem where the central regulator chooses the total investment level in both countries.

$$\max_{N\geq 0} W(N) = q(R-1)N + (1-q)[R\gamma^*(N)N - N] \tag{A.2.15}$$

Denote the solution to this global problem by $\overline{N}$. Central regulator will impose maximum investment level in each country as $\widetilde{N}_i = \overline{N}/2$ as discussed before. $\overline{N}$ will be characterized by the FOCs of the problem above which we could derive as

$$\frac{\partial W(N)}{\partial N} = qR + (1-q)R\left\{1 - \frac{acA}{(A-c\overline{N})^2}\right\} - 1 = 0 \tag{A.2.16}$$

Solving for $\overline{N}$ and substituting $\widetilde{N}_i = \overline{N}/2$ gives the globally regulated investment level in each country as

$$\widetilde{N}_i = \frac{A - \sqrt{\sigma Aac}}{2c} \tag{A.2.17}$$

A.3 Proofs Omitted in the Text

A.3.1 Proofs for the Symmetric Countries Case

Lemma 1. *$P^*(n_i, n_j)$ is decreasing in n_i for $i = A, B$ under Assumptions CONCAVITY and ELASTICITY.*

Proof. Applying the IFT on the MC condition gives

$$\frac{dP^*}{dn_i} = -\frac{\partial E(\cdot)/\partial n_i}{\partial E(\cdot)/\partial P} = \frac{\partial S(P^*, n_i, n_j)/\partial n_i}{D'(P^*) - \partial S(P^*, n_i, n_j)/\partial P} \tag{A.3.1}$$

First, note that using the expression for the total supply function given by (1.13) we obtain

$$\frac{\partial S(\cdot)}{\partial n_i} = \frac{c}{P} > 0 \tag{A.3.2}$$

Hence, we can write the derivative in (A.3.1) as

$$\frac{dP^*}{dn_i} = \frac{c}{P^* D'(P^*) - P^* \left[\partial S(P^*, n_i, n_j)/\partial P\right]} \tag{A.3.3}$$

The following equivalence will help us to write this derivative using only return function of global investors' return function, $F(\cdot)$, and its derivatives

$$P^* \frac{\partial S(P^*, n_i, n_j)}{\partial P} = P^* \frac{-c(n_i + n_j)}{P^{*2}} = \frac{-c(n_i + n_j)}{P^*} = -S(P^*, n_i, n_j) \tag{A.3.4}$$

Using this equivalence we can express the derivative given by (A.3.3) as

$$\frac{dP^*}{dn_i} = \frac{c}{P^* D'(P^*) + S(P^*, n_i, n_j)} \tag{A.3.5}$$

Let $y^* \equiv S(P^*, n_i, n_j)$ denote the total volume of equilibrium fire-sales. In equilibrium we will have $P^* = F'(y^*)$ from the demand curve. Therefore we can obtain

$$D'(P^*) = \frac{1}{F''(y^*)} \tag{A.3.6}$$

where we make use of the fact that $D'(P) \equiv F'(P)^{-1}$ as given by (1.3). Hence, we can rewrite the denominator of the expression (A.3.5) above as

$$P^* D'(P^*) + S(P^*, n_i, n_j) = \frac{F'(y^*)}{F''(y^*)} + y^* \tag{A.3.7}$$

which we can write equivalently as

$$P^* D'(P^*) + S(P^*, n_i, n_j) = \frac{F'(y^*) + y^* F''(y^*)}{F''(y^*)} < 0 \tag{A.3.8}$$

This expression is negative since $F''(y) < 0$ by Assumption *CONCAVITY* and

$$F'(y) + yF''(y) > 0 \tag{A.3.9}$$

by Assumption *ELASTICITY*. Therefore we conclude that $dP^*/dn_i < 0$. □

Lemma 2. *Equilibrium fraction of assets sold in each country,* $1-\gamma^*(n_i, n_j)$*, is increasing in* n_i *for* $i = A, B$ *under Assumptions CONCAVITY and ELASTICITY.*

Proof. Using (1.9) we can write banks' asset sales in equilibrium as

$$1-\gamma^*(n_i, n_j) = \frac{c}{P^*(n_i, n_j)} \tag{A.3.10}$$

Note that

$$\frac{\partial \gamma^*}{\partial n_i} = \frac{\partial \gamma^*}{\partial P^*}\frac{dP^*}{dn_i} < 0 \tag{A.3.11}$$

since $\delta\gamma/\delta P = c/P^2 > 0$ from (1.9) and by Lemma 1 we have that $dP^*/dn_i < 0$ for $i = A, B$. Therefore, equilibrium fraction of assets rescued after fire-sales (γ^*) is decreasing in n_i for $i = A, B$.

Since equilibrium fraction of assets sold in each country is given by $1-\gamma^*(n_i, n_j)$, we obtain that this fraction is increasing in n_i for $i = A, B$. □

Lemma 3. *Under Assumptions CONCAVITY, ELASTICITY and REGULARITY, each regulator's best response is unique valued.*

Proof. For this proof I refer to the conditions given by Assumptions *CONCAVITY*, *ELASTICITY* and *REGULARITY*. I show that if the global investors' return function, $F(\cdot)$ satisfies these conditions, then the objective functions of independent regulators are concave. This also tells us that first order conditions of the regulators problem, which also implicitly defines their best response functions, is monotone and decreasing. Therefore, there is a unique solution to these first order conditions or in other words best response of each regulator is unique valued.

Let's reproduce regulators' objective function here for convenience

$$\max_{N_i \geq 0} \; W_i(N_i, N_j) = \max_{N_i \geq 0} \; q(R-1)N_i + (1-q)[R\gamma^*(N_i, N_j)N_i - N_i] \tag{A.3.12}$$

FOCs for regulator of country i's problem will be given by

$$\frac{\partial W_i(N_i, N_j)}{\partial N_i} = qR + (1-q)R\left\{\frac{\partial \gamma^*(N_i, N_j)}{\partial N_i}N_i + \gamma^*(N_i, N_j)\right\} - 1 \tag{A.3.13}$$

Let's define the following function for convenience

$$v^i(N_i, N_j) \equiv \frac{\partial \gamma^*(N_i, N_j)}{\partial N_i} N_i + \gamma^*(N_i, N_j) \tag{A.3.14}$$

Hence, we can write the FOCs simply as

$$\frac{\partial W_i(N_i, N_j)}{\partial N_i} = qR + (1-q)Rv^i(N_i, N_j) - 1 \tag{A.3.15}$$

We will show that Under Assumptions *CONCAVITY*, *ELASTICITY* and *REGULARITY* we have $v_1^i(N_i, N_j) < 0$, hence the objective function is concave. This also means that the best response functions are unique-valued. Note that in Lemma 1 we have obtained

$$\frac{dP^*}{dN_i} = \frac{c}{P^* D'(P^*) + S(P^*, N_i, N_j)} \tag{A.3.16}$$

which is negative as we have shown there. Since $D(P^*) = S(P^*, N_i, N_j)$ by the market clearing condition, we can also express this derivative as

$$\frac{dP^*}{dN_i} = \frac{c}{P^* D'(P^*) + D(P^*)} \tag{A.3.17}$$

We will use this expression in the derivative of γ^* with respect to N_i below

$$\begin{aligned} \frac{\partial \gamma^*(N_i, N_j)}{\partial N_i} &= \frac{\partial \gamma^*(N_i, N_j)}{\partial P^*} \frac{dP^*}{dN_i} \\ &= \left(\frac{c}{P^*}\right)^2 \frac{1}{D(P^*) + P^* D'(P^*)} < 0 \end{aligned} \tag{A.3.18}$$

Hence we can obtain the second derivative as

$$\frac{\partial^2 \gamma^*(N_i, N_j)}{\partial N_i^2} = -\left(\frac{c}{P^*}\right)^2 G(P^*) \frac{dP^*}{dN_i} \tag{A.3.19}$$

where we define

$$G(P^*) \equiv \frac{2D(P^*) + 4P^* D'(P^*) + P^{*2} D''(P^*)}{P^*[D(P^*) + P^* D'(P^*)]^2} \tag{A.3.20}$$

Note that the derivative of $v^i(\cdot)$, which was defined by (A.3.14), with respect to the first

argument is equal to

$$v_1^i(N_i, N_j) \equiv \frac{\partial v^i(N_i, N_j)}{\partial N_i} = \frac{\partial^2 \gamma^*(N_i, N_j)}{\partial N_i^2} N_i + 2\frac{\partial \gamma^*(N_i, N_j)}{\partial N_i} \tag{A.3.21}$$

Put the findings above together to get this derivative as

$$v_1^i(\cdot) = -\left(\frac{c}{P^*}\right)^2 \left[G(P^*)N_i - \frac{2}{c}\right] \frac{dP^*}{dN_i} \tag{A.3.22}$$

again where $G(P^*)$ is as defined by (A.3.20) above.We will show that $G(P^*)$ is negative under Assumptions *CONCAVITY*, *ELASTICITY* and *REGULARITY*, and hence $v_1^i(\cdot) < 0$.

Note that using $D(P) \equiv F'(P)^{-1}$ and $P = F'(y)$ we can obtain

$$(i)\ D(P) = y, \quad (ii)\ D'(P) = \frac{1}{F''(y)} \quad \text{and} \quad (iii)\ D''(P) = -\frac{F'''(y)}{F''(y)^3} \tag{A.3.23}$$

Hence, we can write the expression in the numerator of $G(P^*)$ as

$$2D(P^*) + 4P^*D'(P^*) + P^{*2}D''(P^*) = 2y^* + \frac{4F'(y^*)}{F''(y^*)} - \frac{F'(y^*)^2F'''(y^*)}{F''(y^*)^3} \tag{A.3.24}$$

Re-arranging the RHS of (A.3.24), we obtain

$$\frac{2y^*F''(y^*)^3 + 4F'(y^*)F''(y^*)^2 - F'(y^*)^2F'''(y^*)}{F''(y^*)^3} \tag{A.3.25}$$

Note that the denominator of the last expression is negative by *Assumption CONCAVITY*. Re-arrange the numerator to write it as

$$2F''(y^*)^2 \underbrace{\left[y^*F''(y^*) + F'(y^*)\right]}_{(+)\ by\ ELASTICITY} - F'(y^*) \underbrace{\left[F'(y^*)F'''(y^*) - 2F''(y^*)^2\right]}_{(-)\ by\ REGULARITY} > 0 \tag{A.3.26}$$

The expression in (A.3.26) is positive under Assumption *ELASTICITY* and *REGULARITY* as shown above. This implies that

$$2D(P^*) + 4P^*D'(P^*) + P^{*2}D''(P^*) < 0 \tag{A.3.27}$$

i.e. the numerator of $G(P^*)$ which was given by (A.3.24) is negative. Putting these results together we obtain that $v_1^i(N_i, N_j) < 0$.

The analysis above shows that FOCs of each regulator is monotone and decreasing. Therefore, we conclude that their best response functions are unique valued as desired. □

Proposition 1. *Under Assumptions CONCAVITY, ELASTICITY and REGULARITY, optimal regulatory standards in the two countries are strategic substitutes.*

Proof. Optimal regulatory standards in the two countries are strategic substitutes if and only if the best response functions of regulators are downward slopping. We can apply the Implicit Function Theorem (IFT) on the first order conditions to obtain the sign of the slope of best response functions. This sign is shown to be equal to the sign of the cross derivative of the objective function due to the results in Proposition 1. In order to show that the sign of the cross derivative of the objective function is negative, I again refer to the technical conditions given by Assumptions *CONCAVITY*, *ELASTICITY* and *REGULARITY*. I show that for any (induced) demand function that satisfies Assumptions *CONCAVITY* to *REGULARITY*, this sign is negative and hence optimal investment levels are strategic substitutes.

If N_i and N_j are strategic substitutes we must have $\partial^2 W_i(N_i, N_j)/\partial N_i \partial N_j < 0$. Remember that

$$\frac{\partial W_i(N_i, N_j)}{\partial N_i} = qR + (1-q)Rv^i(N_i, N_j) - 1 \tag{A.3.28}$$

where

$$v^i(N_i, N_j) \equiv \frac{\partial \gamma^*(N_i, N_j)}{\partial N_i} N_i + \gamma^*(N_i, N_j) \tag{A.3.29}$$

hence

$$\begin{aligned} \frac{\partial^2 W_i(N_i, N_j)}{\partial N_i \partial N_j} &= (1-q)R\frac{\partial v^i(N_i, N_j)}{\partial N_j} \\ &= (1-q)R\left\{\frac{\partial^2 \gamma^*(N_i, N_j)}{\partial N_i \partial N_j} N_i + \frac{\partial \gamma^*(N_i, N_j)}{\partial N_j}\right\} < 0 \end{aligned} \tag{A.3.30}$$

The sing of equation (A.3.30) is negative since

(i) $\frac{\partial \gamma^*(N_i, N_j)}{\partial N_j} < 0$ as shown by eq (A.3.18) and

(ii) for the cross derivative of $\gamma^*(N_i, N_j)$ we know that

$$\frac{\partial^2 \gamma^*(N_i, N_j)}{\partial N_i \partial N_j} = \frac{\partial^2 \gamma^*(N_i, N_j)}{\partial N_i^2} \tag{A.3.31}$$

since $\gamma^*(N_i, N_j)$ is determined only by the sum of the two investment levels, not by their individual values. Therefore we get an equation similar to the one obtained in the proof of Lemma 3

$$v_2^i(\cdot) \equiv \frac{\partial v^i(N_i, N_j)}{\partial N_j} = -\left(\frac{c}{P^*}\right)^2 \left[G(P^*)N_i - \frac{1}{c}\right] \frac{dP^*}{dN_i} \tag{A.3.32}$$

which is negative under Assumptions 1 to 3 as shown in the proof of Lemma 3. Hence, the best response functions are downward slopping which implies that N_i and N_j are strategic substitutes. □

Lemma 4. *The best responses of each country satisfy* $0 < N_i^* < \infty$ *for* $i = A, B$ *if Assumption RANGE holds, i.e. if* $1 + c(1-q) < R \leq 1/q$.

Proof. **Part 1** If $R \leq 1/q$ then $N_i^* < \infty$.

Let's first define $M = N_A + N_B$ such that

$$P^*(M) = c \tag{A.3.33}$$

Fix some N_j and consider two exhaustive cases:

Case 1 $N_j < M$.

Define

$$\overline{N}_i = M - N_j \tag{A.3.34}$$

Consider regulators objective function as $N_i \to \overline{N}_i$

$$\lim_{Ni \to \overline{N}_i} W_i(N_i, N_j) = \lim_{Ni \to \overline{N}_i} q(R-1)N_i + (1-q)[R\gamma^*(N_i, N_j)N_i - N_i] \tag{A.3.35}$$

Now note that

$$\lim_{Ni \to \overline{N}_i} \gamma^*(N_i, N_j) = \lim_{Ni \to \overline{N}_i} \left(1 - \frac{c}{P^*(N_i, N_j)}\right) = 0 \tag{A.3.36}$$

since $\lim_{Ni,N_j \to M} P^*(N_i, N_j) = c$ by definition in (A.3.33). Therefore

$$\lim_{Ni \to \overline{N}_i} W_i(N_i, N_j) = \lim_{Ni \to \overline{N}_i} (qR - 1)N_i \leq 0 \tag{A.3.37}$$

since $qR \leq 1$ by Assumption *RANGE*. Hence, it is never optimal to choose $N_i^* \geq \overline{N}_i$ in this case.

Case 2 $N_j \geq M$.

By definition of M this implies that $P^*(N_i, N_j) < c$ for any $N_i > 0$. In this case banks optimally discard all capital at $t = 1$, i.e. $\chi^* = 0$ which implies that $\gamma^*(N_i, N_j) = 0$. Hence social welfare in country i will be given by

$$W_i(N_i, N_j) = (qR - 1)N_i \leq 0 \tag{A.3.38}$$

since $qR \leq 1$ by Assumption *RANGE*. Hence, $N_i^* = 0$ in this case. Therefore we conclude proof of Part 1 by showing that $N_i^* < \infty$ for $i = A, B$ as long as $qR \leq 1$.

Part 2 For the second part of the proof I will show that welfare in country i is always decreasing in N_i when $R < 1 + c(1 - q)$, and hence the best responses will be given by $N_i^* = N_j^* = 0$. Remember

$$W_i(N_i, N_j) = q(R - 1)N_i + (1 - q)[R\gamma^*(N_i, N_j)N_i - N_i] \tag{A.3.39}$$

Note that the highest value of $\gamma^*(N_i, N_j)$ will be obtained as $N_i, N_j \to 0$. Therefore

$$\text{If } W_i(0, 0) < 0 \text{ then } W_i(N_i, N_j) < 0 \text{ for all } N_i, N_j > 0 \tag{A.3.40}$$

Consider first

$$\lim_{Ni,N_j \to 0} \gamma^*(N_i, N_j) = \lim_{Ni,N_j \to 0} \left(1 - \frac{c}{P^*(N_i, N_j)}\right) = 1 - \frac{c}{R} \tag{A.3.41}$$

since $\lim_{Ni,N_j \to 0} P^*(N_i, N_j) = R$. Using this we can write

$$\lim_{Ni,N_j \to 0} W_i(N_i, N_j) = \left\{q(R - 1) + (1 - q)[R\left(1 - \frac{c}{R}\right) - 1]\right\} N_i \tag{A.3.42}$$

from which we can obtain $\lim_{Ni,N_j \to 0} W_i(N_i, N_j) < 0$ as long as

$$q(R-1) + (1-q)[R\left(1 - \frac{c}{R}\right) - 1] < 0 \tag{A.3.43}$$

Re-arranging this inequality gives

$$qR + (1-q)R + (1-q)c - 1 < 0 \tag{A.3.44}$$

where further simplification implies $R < 1 + c(1-q)$.

Hence, we conclude that $N_i^*(N_j) = 0$ for $i = A, B$ as long as $R < 1 + c(1-q)$. □

Proposition 2. *Under Assumptions CONCAVITY, ELASTICITY, REGULARITY and RANGE, at least one pure strategy Nash Equilibrium exists in the game between two financial regulator at $t = 0$. Moreover there exists at least one symmetric pure strategy NE.*

Proof. For this proof, I make use of a theorem due to Debreu (1952) which states that *"Suppose that for each player the strategy space is compact and convex and the payoff function is continuous and quasi-concave with respect to each player's own strategy. Then there exists at least one pure strategy NE in the game."*

I establish below that this game satisfies all three conditions stated in this theorem.

(i) Following Lemma 4 we can restrict strategy space for each regulator to $[0, M]$ which is compact and convex.

(ii) Continuity of the objective function is obvious.

(iii) For concavity we evaluate the second derivative of the objective function with respect to the own action:

$$\frac{\partial^2 W_i(N_i, N_j)}{\partial N_i^2} = (1-q)R\frac{\partial v^i(N_i, N_j)}{\partial N_i} < 0 \tag{A.3.45}$$

as shown by Lemma 3 above. Hence Nash Equilibria equilibria exist. Existence of a symmetric Nash Equilibrium equilibrium is implied by the symmetry of the game. □

Proposition 3. *Under Assumptions CONCAVITY, ELASTICITY, REGULARITY and RANGE, there exists a unique symmetric NE of the game between the regulators at $t = 0$.*

Proof. I will make use of the theorem that states: *"If the best response mapping is a contraction on the entire strategy space, there is a unique Nash Equilibrium in the game."*

In two-player games best response functions are contraction everywhere if the absolute value of their slopes are less than one everywhere. In order to show this, I make use of the nice feature of equilibrium price function that it is determined only by the sum of the investment levels in the two countries.

$$\left|\frac{\partial N_i^*(N_j)}{\partial N_j}\right| = \left|-\frac{\frac{\partial^2 W_i(N_i,N_j)}{\partial N_i \partial N_j}}{\frac{\partial^2 W_i(N_i,N_j)}{\partial N_i^2}}\right| < 1 \tag{A.3.46}$$

which can be equivalently stated as

$$\left|\frac{\partial^2 W_i(N_i,N_j)}{\partial N_i \partial N_j}\right| < \left|\frac{\partial^2 W_i(N_i,N_j)}{\partial N_i^2}\right| \tag{A.3.47}$$

Using the expressions for these derivatives given before this corresponds to

$$\left|\frac{\partial^2 \gamma^*(N_i,N_j)}{\partial N_i \partial N_j} N_i + \frac{\partial \gamma^*(N_i,N_j)}{\partial N_j}\right| < \left|\frac{\partial^2 \gamma^*(N_i,N_j)}{\partial N_i^2} N_i + 2\frac{\partial \gamma^*(N_i,N_j)}{\partial N_i}\right| \tag{A.3.48}$$

Note that derivative on the right hand side is negative by Lemma 3 and the derivative on the left hand side is negative by Proposition 1. Moreover, $\gamma^*(N_i, N_j)$ and its derivatives are determined only by the sum of the two investment levels, not by their individual values. This implies that

$$\frac{\partial^2 \gamma^*(N_i,N_j)}{\partial N_j \partial N_i} = \frac{\partial^2 \gamma^*(N_i,N_j)}{\partial N_i^2} \text{ and } \frac{\partial \gamma^*(N_i,N_j)}{\partial N_j} = \frac{\partial \gamma^*(N_i,N_j)}{\partial N_i} \tag{A.3.49}$$

which implies that $|LHS| < |RHS|$ in (A.3.48) and hence the slope of best response functions is less than one everywhere on the domain. □

Proposition 4. *Non-cooperative symmetric equilibrium investment levels are increasing in q and R.*

Proof. Using Cramer's rule on FOCs we get

$$\frac{\partial \widehat{N}_i}{\partial \alpha} = -\frac{\frac{\partial^2 W_i}{\partial N_i \partial \alpha}\frac{\partial^2 W_j}{\partial N_j^2} - \frac{\partial^2 W_i}{\partial N_i \partial N_j}\frac{\partial^2 W_j}{\partial N_j \partial \alpha}}{\frac{\partial^2 W_i}{\partial N_i^2}\frac{\partial^2 W_j}{\partial N_j^2} - \frac{\partial^2 W_i}{\partial N_i \partial N_j}\frac{\partial^2 W_j}{\partial N_j \partial N_i}} \tag{A.3.50}$$

where $\alpha \in \{q, R, c\}$ is a parameter of the model. First note that

$$\frac{\partial^2 W_i}{\partial N_i^2} < 0, \text{ and } \frac{\partial^2 W_j}{\partial N_j \partial N_i} < 0 \text{ for } i = A, B \tag{A.3.51}$$

by Lemma 3 and Proposition 1. Moreover in the proof of Proposition 3 we have shown that

$$\left|\frac{\partial^2 W_i(N_i, N_j)}{\partial N_i \partial N_j}\right| < \left|\frac{\partial^2 W_i(N_i, N_j)}{\partial N_i^2}\right| \tag{A.3.52}$$

which implies that the sign of the denominator above is positive. Moreover, in a symmetric equilibrium we will have

$$\frac{\partial^2 W_i}{\partial N_i \partial \alpha} = \frac{\partial^2 W_j}{\partial N_j \partial \alpha} \quad \text{and} \quad \frac{\partial^2 W_j}{\partial N_j^2} = \frac{\partial^2 W_i}{\partial N_i^2} \tag{A.3.53}$$

which allows us to write the derivative as

$$\frac{\partial \widehat{N}_i}{\partial \alpha} = -\frac{\frac{\partial^2 W_i}{\partial N_i \partial \alpha}\overbrace{\left[\frac{\partial^2 W_i}{\partial N_i^2} - \frac{\partial^2 W_i}{\partial N_i \partial N_j}\right]}^{(-)}}{\underbrace{\frac{\partial^2 W_i}{\partial N_i^2}\frac{\partial^2 W_j}{\partial N_j^2} - \frac{\partial^2 W_i}{\partial N_i \partial N_j}\frac{\partial^2 W_j}{\partial N_j \partial N_i}}_{(+)}} \tag{A.3.54}$$

the term inside the brackets in the numerator is again negative by the inequality (A.3.52). Therefore the sing of the derivative above will be equal to the sign of $\partial^2 W_i / \partial N_i \partial \alpha$. To obtain this sign consider the FOCs of regulators' problem

$$\frac{\partial W_i(N_i, N_j)}{\partial N_i} = qR + (1-q)Rv^i(N_i, N_j) - 1 \tag{A.3.55}$$

which will imply that in equilibrium

$$v^i(\widehat{N}_i, \widehat{N}_j) = \frac{1 - qR}{(1-q)R} \tag{A.3.56}$$

Therefore we can obtain that

$$\begin{aligned} \frac{\partial W_i(N_i, N_j)}{\partial N_i \partial R} &= q + (1-q)v^i(N_i, N_j) \\ &= q + \frac{1-qR}{R} = \frac{1}{R} > 0 \end{aligned} \tag{A.3.57}$$

in equilibrium, using equation (A.3.15). Hence we conclude that $\partial \widehat{N}_i / \partial R > 0$.

For comparative statics with respect to q consider

$$\frac{\partial W_i(N_i, N_j)}{\partial N_i \partial q} = R - Rv^i(N_i, N_j) \tag{A.3.58}$$

which in equilibrium, using equation (A.3.15) we can write as

$$\frac{\partial W_i(\widehat{N}_i, \widehat{N}_j)}{\partial N_i \partial q} = R\left[1 - \frac{1-qR}{(1-q)R}\right] \tag{A.3.59}$$

$$= \frac{R-1}{1-q} > 0 \tag{A.3.60}$$

hence we can also conclude that

$$\frac{\partial \widehat{N}_i}{\partial q} > 0 \text{ for } i = A, B$$

i.e. equilibrium investment levels in both countries are increasing as the probability of good state rises. □

Lemma 5. *Under Assumptions CONCAVITY, ELASTICITY, REGULARITY and RANGE, equilibrium price of assets satisfy $P^* > c$.*

Proof. By Proposition 4 we have established that equilibrium investment levels are increasing in both q and R. Since Assumption *RANGE* restricts $qR \leq 1$, for a given set of other parameters we will obtain the highest investment in equilibrium if $qR = 1$. Consider the FOCs of regulators'

problem evaluated at equilibrium regulation standards for $qR = 1$

$$\begin{aligned}\frac{\partial W_i(N_i, N_j)}{\partial N_i} &= qR + (1-q)R\left\{\frac{\partial \gamma^*(\widehat{N}_i, \widehat{N}_j)}{\partial N_i}\widehat{N}_i + \gamma^*(\widehat{N}_i, \widehat{N}_j)\right\} - 1 = 0 \\ &= (R-1)\left\{\frac{\partial \gamma^*(\widehat{N}_i, \widehat{N}_j)}{\partial N_i}\widehat{N}_i + \gamma^*(\widehat{N}_i, \widehat{N}_j)\right\} = 0\end{aligned}$$

which implies that

$$\frac{\partial \gamma^*(\widehat{N}_i, \widehat{N}_j)}{\partial N_i}\widehat{N}_i + \gamma^*(\widehat{N}_i, \widehat{N}_j) = 0$$

Lemma 3 has shown that

$$\frac{\partial \gamma^*(N_i, N_j)}{\partial N_i} < 0$$

Therefore for the FOCs above to hold we need

$$\gamma^*(\widehat{N}_i, \widehat{N}_j) = 1 - \frac{c}{P^*(\widehat{N}_i, \widehat{N}_j)} > 0 \tag{A.3.61}$$

which implies that $P^*(\widehat{N}_i, \widehat{N}_j) > c$ as needed. □

Proposition 5. $\widetilde{N} < \widehat{N}$, *i.e. independent national regulators choose a higher investment in equilibrium compared to the cooperative benchmark.*

Proof. For this proof I use the alternative formulation of central regulator's problem which I reproduce here for convenience

$$\max_{N \geq 0} W(N) = q(R-1)N + (1-q)[R\widetilde{\gamma}^*(N)N - N] \tag{A.3.62}$$

The FOCs for this problem will be given by

$$\left.\frac{\partial W(\cdot)}{\partial N}\right|_{\overline{N}} = qR + (1-q)R\widetilde{v}(\overline{N}) - 1 = 0 \tag{A.3.63}$$

where $\overline{N}$ is the optimal total investment level in the two countries. Rearranging the FOCs gives that

$$\widetilde{v}(\overline{N}) \equiv \widetilde{\gamma}^{*\prime}(\overline{N})\overline{N} + \widetilde{\gamma}^*(\overline{N}) = \frac{1-qR}{(1-q)R} \tag{A.3.64}$$

where $\widetilde{v}(\cdot)$ is similar to the function $v^i(N_i, N_j)$ except that it is defined over the total investment

level in the two countries. The same is true for the function $\widetilde{\gamma}^*(\cdot)$. Now using the fact that globally optimal investment level in each country will satisfy $\widetilde{N} = \overline{N}/2$ we can write

$$\widetilde{v}(\overline{N}) = \widetilde{v}(2\widetilde{N}) = \gamma'(2\widetilde{N})(2\widetilde{N}) + \gamma(2\widetilde{N}) \tag{A.3.65}$$

Note that equilibrium fraction of rescued assets, $\widetilde{\gamma}^*(\cdot)$, is determined by the sum of the investment levels in the two countries. In other words, exact division of global investment between the two countries do not affect $\widetilde{\gamma}^*(\cdot)$ and hence its derivatives. This property allows us to write $\widetilde{v}(\overline{N})$ as (with a slight abuse of notation)

$$\begin{aligned}\widetilde{v}(\overline{N}) = \widetilde{v}(2\widetilde{N}) &= \widetilde{\gamma}^{*\prime}(2\widetilde{N})(2\widetilde{N}) + \widetilde{\gamma}^*(2\widetilde{N}) \\ &= 2\gamma_1^*(\widetilde{N},\widetilde{N})\widetilde{N} + \gamma^*(\widetilde{N},\widetilde{N}) \\ &= v(\widetilde{N},\widetilde{N}) + \gamma_1^*(\widetilde{N},\widetilde{N})\widetilde{N}\end{aligned} \tag{A.3.66}$$

On the other hand, remember that each independent regulator's FOCs will give us

$$\left.\frac{\partial W_i(\cdot)}{\partial N_i}\right|_{(\widehat{N}_i,\widehat{N}_j)} = qR + (1-q)Rv^i(\widehat{N}_i,\widehat{N}_j) - 1 = 0 \tag{A.3.67}$$

from which we get that in equilibrium

$$v^i(\widehat{N}_i,\widehat{N}_j) = \frac{1-qR}{(1-q)R} \tag{A.3.68}$$

Comparing (A.3.68) and (A.3.64) we see that $\widetilde{v}(\overline{N}) = v^i(\widehat{N},\widehat{N})$ where $(\widehat{N},\widehat{N})$ are the symmetric Nash equilibrium investment levels. Using this together with equality (A.3.66) we can write

$$\begin{aligned}v(\widetilde{N},\widetilde{N}) &= \widetilde{v}(\overline{N}) - \gamma_1(\widetilde{N},\widetilde{N})\widetilde{N} \\ &= v^i(\widehat{N},\widehat{N}) - \gamma_1(\widetilde{N},\widetilde{N})\widetilde{N}\end{aligned} \tag{A.3.69}$$

we have previously shown that $\gamma'(N_i,N_j) < 0$ which implies that $v(\widetilde{N},\widetilde{N}) > v(\widehat{N},\widehat{N})$. Lemma 3 has shown that $v^i(N_i,N_j)$ is decreasing in N_i, and Proposition 1 has shown that $v^i(N_i,N_j)$

is decreasing in N_j. Since $v^i(N_i, N_j)$ is decreasing in both arguments, we can conclude that $\widetilde{N} < \widehat{N}$. □

Proposition 6. *If the countries are symmetric then both regulators prefer to deliver their authority to a central systemic risk regulator, i.e.* $W_i(\widetilde{N}_i, \widetilde{N}_j) \geq W_i(\widehat{N}_i, \widehat{N}_j)$ *holds for* $i = A, B$.

Proof. First, let's define $\widetilde{W}_i \equiv W_i(\widetilde{N}_i, \widetilde{N}_j)$ as the welfare of country $i = A, B$ under central regulation and $\widehat{W}_i \equiv W_i(\widehat{N}_i, \widehat{N}_j)$ as the welfare of country $i = A, B$ under the symmetric non-cooperative equilibrium. Note that by symmetry we have

$$\widetilde{W}_A = \widetilde{W}_B \text{ and } \widehat{W}_A = \widehat{W}_B$$

Since central regulation levels, $(\widetilde{N}_A, \widetilde{N}_B)$, maximize the total welfare of the two countries, $W_A + W_B$, by definition we know that

$$\widetilde{W}_A + \widetilde{W}_B \geq \widehat{W}_A + \widehat{W}_B$$

which implies that $\widetilde{W}_i \geq \widehat{W}_i$ for $i = A, B$. □

A.3.2 Proofs for the Asymmetric Countries Case

Proposition 7. *If* $R_A > R_B$*, then* $\widehat{N}_A > \widehat{N}_B$ *in non-cooperative equilibrium.*

Proof. Remember the FOCs of regulator's problem

$$\frac{\partial W_i(N_i, N_j)}{\partial N_i} = qR + (1-q)Rv^i(N_i, N_j) - 1 \tag{A.3.70}$$

which will imply that in equilibrium we have

$$v^i(N_i, N_j) = \frac{1 - qR_i}{(1-q)R_i} \equiv \beta_i \tag{A.3.71}$$

Note that β_i is decreasing in R. Since $R_A > R_B$ by assumption, we will have that $\beta_A < \beta_B$. Remember that by $v^i(N_i, N_j)$ is defined as

$$v^i(N_i, N_j) \equiv \frac{\partial \gamma^*(N_i, N_j)}{\partial N_i} N_i + \gamma^*(N_i, N_j) \tag{A.3.72}$$

$\beta_A < \beta_B$ implies that $v^A(\widehat{N}_A, \widehat{N}_B) < v^B(\widehat{N}_B, \widehat{N}_A)$. Using the expression above this is equivalent to

$$\frac{\partial \gamma^*(N_A, N_B)}{\partial N_A}\bigg|_{\widehat{N}_A, \widehat{N}_B} \widehat{N}_A + \gamma^*(\widehat{N}_A, \widehat{N}_B) < \frac{\partial \gamma^*(N_B, N_A)}{\partial N_B}\bigg|_{\widehat{N}_B, \widehat{N}_A} \widehat{N}_B + \gamma^*(\widehat{N}_B, \widehat{N}_A) \quad \text{(A.3.73)}$$

Since $\gamma^*()$, and its derivatives determined only by the sum of the regulation levels, we will have

$$\gamma^*(\widehat{N}_A, \widehat{N}_B) = \gamma^*(\widehat{N}_B, \widehat{N}_A) \quad \text{(A.3.74)}$$

and

$$\frac{\partial \gamma^*(N_A, N_B)}{\partial N_A}\bigg|_{\widehat{N}_A, \widehat{N}_B} = \frac{\partial \gamma^*(N_B, N_A)}{\partial N_B}\bigg|_{\widehat{N}_B, \widehat{N}_A} \quad \text{(A.3.75)}$$

Using these two equalities in (A.3.73) gives

$$\frac{\partial \gamma^*(N_A, N_B)}{\partial N_A}\bigg|_{\widehat{N}_A, \widehat{N}_B} \left(\widehat{N}_A - \widehat{N}_B\right) < 0 \quad \text{(A.3.76)}$$

From Lemma 3 we know that

$$\frac{\partial \gamma^*(N_A, N_B)}{\partial N_A}\bigg|_{\widehat{N}_A, \widehat{N}_B} < 0 \quad \text{(A.3.77)}$$

Therefore, for inequality (A.3.76) to be true we need to have $\widehat{N}_A - \widehat{N}_B > 0$, or equivalently $\widehat{N}_A > \widehat{N}_B$. □

Proposition 8. *There exists no central regulation level* $N > \min\{\widehat{N}_A, \widehat{N}_B\}$.

Proof. By Envelope Theorem we will have that

$$\frac{dW_i(N_i^*(N_j), N_j)}{dN_j} = \frac{\partial W_i(N_i, N_j)}{\partial N_j}\bigg|_{N_i = N_i^*(N_j)} < 0 \quad \text{(A.3.78)}$$

By assumption we have $\widehat{N}_A > \widehat{N}_B$. Consider a central regulation $N = \widehat{N}_B$. From above we get that $W_B(\widehat{N}_B, \widehat{N}_B) > W_B(\widehat{N}_B, \widehat{N}_A)$. However, by definition $W_A(\widehat{N}_B, \widehat{N}_B) < W_A(\widehat{N}_A, \widehat{N}_B)$, i.e. a central regulation with $N = \widehat{N}_B$ is rejected by Regulator A. Now consider $N > \widehat{N}_B$. By

Envelope Theorem we have that

$$W_A(N_A^*(N), N) < W_A(\widehat{N}_A, \widehat{N}_B) \tag{A.3.79}$$

Moreover, by definition

$$W_A(N, N) < W_A(N_A^*(N), N) \tag{A.3.80}$$

Hence, any common regulation such that $N > \widehat{N}_B$ will also be rejected by regulator A. □

Lemma 6. *For any common regulation level N such that $W_A(N, N) > W_A(\widehat{N}_A, \widehat{N}_B)$ we have $W_B(N, N) > W_B(\widehat{N}_B, \widehat{N}_A)$.*

Proof. Suppose that $W_A(N, N) > W_A(\widehat{N}_A, \widehat{N}_B)$ for some N. From Proposition 8 we know that such N must satisfy $N < N_B$. Note that we can obtain

$$W_A(\widehat{N}_A, \widehat{N}_B) > W_A(N_A^*(\widehat{N}_A), \widehat{N}_A) > W_A(\widehat{N}_B, \widehat{N}_A) \tag{A.3.81}$$

where the first inequality is follows from Envelope Theorem given by (A.3.79), and the second is by definition of optimality. Remember that

$$W_i(N_i, N_j) = qR_iN_i + (1-q)R_i\gamma^*(N_i, N_j)N_i - N_i \tag{A.3.82}$$

Hence, $W_A(N, N) - W_A(\widehat{N}_B, \widehat{N}_A)$ will be given by

$$qR_A[N - \widehat{N}_B] + (1-q)R_A[\gamma^*(N, N)N - \gamma^*(\widehat{N}_B, \widehat{N}_A)\widehat{N}_B] - [N - \widehat{N}_B] > 0 \tag{A.3.83}$$

Which we can re-arrange and write as

$$(1 - qR_A)[\widehat{N}_B - N] + (1-q)R_A[\gamma^*(N, N)N - \gamma^*(\widehat{N}_B, \widehat{N}_A)\widehat{N}_B] \tag{A.3.84}$$

Now consider $W_B(N, N) - W_B(\widehat{N}_B, \widehat{N}_A)$ which will be equal to

$$(1 - qR_B)[\widehat{N}_B - N] + (1-q)R_B[\gamma^*(N, N)N - \gamma^*(\widehat{N}_B, \widehat{N}_A)\widehat{N}_B] \tag{A.3.85}$$

Now, let's compare (A.3.84) and (A.3.85). First note that the first terms are positive in both of them. $\widehat{N}_B - N > 0$ as argued above and it receives a higher weight in (A.3.85) since $1 - qR_B > 1 - qR_A$ due to our assumption that $R_A > R_B$. Now, if the second terms are also positive, (A.3.85) will be positive and we are done. However, if second terms are negative, we know that this second term receives a higher weight in (A.3.84). Hence, if (A.3.84) is positive in spite of this higher weight on the negative term, (A.3.85) will necessarily be positive, since it carries a lower weight on the negative term. □

Proposition 9. *Suppose that $F'(0) = 1$. Let $s \equiv R_A - R_B > 0$. Then for any R_A, there exists $\widehat{s} \in (0, R_A - 1)$ such that $W_A(N^m, N^m) - W_A(\widehat{N}_A, \widehat{N}_B) \geq 0$ if $s \leq \widehat{s}$, and $W_A(N^m, N^m) - W_A(\widehat{N}_A, \widehat{N}_B) < 0$ otherwise.*

Proof. Let's see how this difference changes with s

$$\frac{d[W_A(N^m, N^m) - W_A(\widehat{N}_A, \widehat{N}_B)]}{ds} \tag{A.3.86}$$

this derivative will be given by

$$W_{A1}\frac{\partial N^m}{\partial s} + W_{A2}\frac{\partial N^m}{\partial s} + \left.\frac{\partial W_A}{\partial s}\right|_{N^m, N^m} - W_{A1}\frac{d\widehat{N}_A}{ds} - W_{A2}\frac{d\widehat{N}_B}{ds} - \left.\frac{\partial W_A}{\partial s}\right|_{\widehat{N}_A, \widehat{N}_B} \tag{A.3.87}$$

Applying envelope theorem reduces this to

$$\left.\frac{\partial W_A}{\partial s}\right|_{N^m, N^m} - W_{A2}\frac{d\widehat{N}_B}{ds} - \left.\frac{\partial W_A}{\partial s}\right|_{\widehat{N}_A, \widehat{N}_B} \tag{A.3.88}$$

Now note that since

$$W_A(N_A, N_B) = q(R_A - 1)N_A + (1 - q)[R_A\gamma^*(N_A, N_B)N_A - N_A] \tag{A.3.89}$$

we will have that

$$\left.\frac{\partial W_A}{\partial s}\right|_{N^m, N^m} = 0 \text{ and } \left.\frac{\partial W_A}{\partial s}\right|_{\widehat{N}_A, \widehat{N}_B} = 0 \tag{A.3.90}$$

Therefore

$$\frac{d[W_A(N^m, N^m) - W_A(\widehat{N}_A, \widehat{N}_B)]}{ds} = -W_{A2}\frac{d\widehat{N}_B}{ds} \tag{A.3.91}$$

First note that

$$W_{A2} \equiv \frac{\partial W_A(N,N)}{\partial N_B} = (1-q)R\frac{\partial \gamma^*(N_A,N_B)}{\partial N_B}N_A < 0 \tag{A.3.92}$$

Moreover, by Proposition 4 we have shown that $\widehat{N}_i$ is decreasing in R for $i = A, B$. This will imply that as s increases (or R_2 decreases), regulator 2 will choose a lower $\widehat{N}_B$ in equilibrium, i.e. $d\widehat{N}_B/ds < 0$.Therefore,

$$\frac{d[W_A(N^m,N^m) - W_A(\widehat{N}_A,\widehat{N}_B)]}{ds} = -W_{A2}\frac{d\widehat{N}_B}{ds} < 0 \tag{A.3.93}$$

Hence, the benefit from cooperating is decreasing in the difference between the two countries. Therefore if $W_A(N^m,N^m) - W_A(\widehat{N}_A,\widehat{N}_B) = 0$ for some $\widehat{s}$ it will be negative for $s \geq \widehat{s}$.

We will show that such an $\widehat{s}$ exists. It is clear that for $s = 0$ we have $W_A(N^m,N^m) - W_A(\widehat{N}_A,\widehat{N}_B) > 0$. On the other hand, as $R_B \to 1 + c(1-q)$, we can argue that $\widehat{N}_B$ will necessarily become zero. From Proposition 11 we know that for central regulation be acceptable by regulator 1, we must have $N^m < \widehat{N}_B$. However, as $\widehat{N}_B \to 0$, it won't be possible to reduce $\widehat{N}_B$ sufficiently to compensate regulator 1. Therefore, we will have $W_A(N^m,N^m) - W_A(\widehat{N}_A,\widehat{N}_B) < 0$ for sufficiently large s. By continuity an $\widehat{s}$ such that $W_A(N^m,N^m) - W_A(\widehat{N}_A,\widehat{N}_B) = 0$ must exist. □

A.3.3 Proof of the Systemic Failure Exercise

Proposition 10. *Let $F(y) = R\ln(1+y)$. If $1 + c < R < \widehat{R}$ then there exists a $\widehat{q} \in (0, 1/R)$ such that for all $q \geq \widehat{q}$ we have that $\widehat{N}(q) \geq N^c$.In other words, if the probability of the good state is higher than $\widehat{q}$, banks fail in the bad state in non-competitive equilibrium. If $R \leq 1 + c$ then banks always fail in the bad state, and if $R \geq \widehat{R}$ then banks never fail in the bad state where $\widehat{R}$ is given by*

$$\widehat{R} \equiv \frac{1}{2}\left(2 + c + \sqrt{c}\sqrt{8+c}\right) \tag{A.3.94}$$

Proof. By Proposition 4 we have already shown that equilibrium investment level is increasing in q and R. Fix some R. Note that, if $\widehat{N}(R, 1/R, c) < N^c$, then $\widehat{N}(R,q,c) < \widehat{N}^c$ for all $q \in [0, 1/R]$ since $\widehat{N}$ is increasing in q.

I will first show that when $q = 1/R$, the difference $N^c - \widehat{N}$ is monotonically increasing in

R. Moreover, it is negative when R is small and positive for sufficiently high R. Therefore, we will establish using Intermediate Value Theorem that there exists some $\widehat{R}$ such that $N^c(\widehat{R}, c) - \widehat{N}(\widehat{R}, 1/\widehat{R}, c) = 0$. Using definitions of N^c and $\widehat{N}$ we can write this difference as

$$N^c - \widehat{N} = \frac{aR}{2c}\left(\frac{R-1-c}{R-1}\right) - \frac{a\left(4R - c\sigma - \sqrt{8c\sigma R + (c\sigma)^2}\right)}{8c} \tag{A.3.95}$$

where

$$\sigma = \frac{(1-q)R}{R-1}$$

as defined before. Evaluating this difference at $q = 1/R$ gives that

$$N^c - \widehat{N} = \frac{aR}{2c}\left(\frac{R-1-c}{R-1}\right) - \frac{a\left(4R - c - \sqrt{8cR + c^2}\right)}{8c} \tag{A.3.96}$$

We can determine the behavior of this difference as R changes by looking at the derivative with respect to R which will be given by

$$\frac{\partial\left(N^c - \widehat{N}\right)}{\partial R} = \frac{aR}{2c}\left(\frac{(R-1)^2 + c}{(R-1)^2} - 1 + \frac{\sqrt{8cR + c^2}}{c}\right) > 0 \tag{A.3.97}$$

This derivative is clearly positive, which means that the difference is monotonically increasing in R. Moreover, note that given $q = 1/R$

$$\lim_{R \to 1+c}\left\{N^c(R, c) - \widehat{N}(R, q, c)\right\} < 0 \tag{A.3.98}$$

This follows since $N^c(R, c) \to 0$ as $R \to 1 + c$, which can be clearly seen from the definition of $N^c(R, c)$. We know that $\widehat{N}(R, q, c) > 0$ as $R \to 1+c$ since by Proposition 3 we have established that equilibrium investment levels are positive as long as $R > 1 + c(1 - q)$. To complete the argument, I will show that when $q = 1/R$

$$\lim_{R \to \infty}\left\{N^c(R, c) - \widehat{N}(R, q, c)\right\} > 0 \tag{A.3.99}$$

In order to see this we can expand the difference $N^c - \widehat{N}$ given by (A.3.96) to write it as

$$N^c - \widehat{N} \quad = \frac{aR}{2c}\left(\frac{-c}{R-1} - \frac{c}{4} + \frac{\sqrt{8cR+c^2}}{4}\right) \tag{A.3.100}$$

Now, note that as R becomes large the first term inside the parenthesis goes to zero whereas the last term goes to infinity. Therefore this difference is definitely positive for large R. Now, using the Intermediate Value Theorem we can conclude that there exists some $\widehat{R} > 1 + c$ such that $\widehat{N}(\widehat{R}, 1/\widehat{R}, c) = N^c(\widehat{R}, c)$. Using the definitions of $\widehat{N}$, and N^c from equations (1.22) and (1.22) respectively we can solve for $\widehat{R}$ as follows

$$\widehat{R} = \frac{1}{2}\left(2 + c + \sqrt{c}\sqrt{8+c}\right) \tag{A.3.101}$$

Case 1 $\quad R \geq \widehat{R}$

The analysis above implies that for $R \geq \widehat{R}$ we have that $\widehat{N}(R, 1/R, c) \leq N^c(R, c)$. Moreover, since for any given R, the highest value of $\widehat{N}$ is obtained when $q = 1/R$, we will also have that for $R \geq \widehat{R}$ we have $\widehat{N}(R, q, c) \leq N^c(R, c)$ for all $q \in [0, 1/R]$. In other words, if $R \geq \widehat{R}$, banks never fail in the bad state for any value of $q \in [0, 1/R]$.

Case 2 $\quad 1 + c < R < \widehat{R}$.

In this case we can show that

$$\lim_{q \to 0} \widehat{N}(R, q, c) < N^c < \lim_{q \to 1/R} \widehat{N}(R, q, c) \tag{A.3.102}$$

Hence by the Intermediate Value Theorem we will conclude that there exists $\widehat{q} \in (0, 1/R)$ such that $\widehat{N}(\widehat{q}) = N^c$. Therefore, banks will fail in the bad state if $q \geq \widehat{q}$, and they will survive otherwise. First, I will consider the first part of the inequality in (A.3.102). It will be useful to note that

$$\lim_{q \to 0} \sigma = \frac{R}{R-1} \text{ and } \lim_{q \to 1/R} \sigma = 1 \tag{A.3.103}$$

Therefore let's consider $\widehat{N}$ when $q = 0$ and check whether it is less than N^c

$$\frac{a\left(4R - \frac{cR}{R-1} - \sqrt{8Rc\frac{R}{R-1} + \left(\frac{R}{R-1}\right)^2}\right)}{8c} <^? \frac{aR}{2c}\left(\frac{R-1-c}{R-1}\right) \tag{A.3.104}$$

where left hand side of the inequality is $\widehat{N}$ evaluated when $q = 0$, and right hand side is N^c given by (1.22). Simplifying both sides reduces this comparison to

$$4aR - \frac{acR}{R-1} - a\sqrt{8Rc\frac{R}{R-1} + \left(\frac{R}{R-1}\right)^2} <^? 4aR - \frac{4acR}{R-1} \tag{A.3.105}$$

simplifying further yields

$$\frac{c}{R-1} <^? 1 \tag{A.3.106}$$

which is true as long as $1 + c < R$ as we proposed for this case.

For the second part of the inequality (A.3.102) consider $\widehat{N}$ when $q = 1/R$ and check when it is greater than N^c

$$\frac{a\left(4R - c - \sqrt{8Rc + c^2}\right)}{8c} >^? \frac{aR}{2c}\left(\frac{R-1-c}{R-1}\right) \tag{A.3.107}$$

where the left hand side of the inequality is $\widehat{N}$ evaluated when $q = 1/R$, and right hand side is N^c given by (1.22). Simplifying reduces this comparison to

$$4aR - ac - a\sqrt{8Rc + c^2} >^? 4aR - \frac{4acR}{R-1} \tag{A.3.108}$$

Solving for R yields that this inequality is true as long as

$$R < \frac{1}{2}\left(2 + c + \sqrt{c}\sqrt{8+c}\right) \equiv \widehat{R} \tag{A.3.109}$$

Therefore we can conclude that if $1+c < R < \widehat{R}$,there exists $\widehat{q} \in (0, 1/R)$ such that $\widehat{N}(q) > N^c$ for $q \geq \widehat{q}$. In words, when $1 + c < R < \widehat{R}$ banks fail systemically in the bad state if $q \geq \widehat{q}\,(R)$, and they survive if $q < \widehat{q}\,(R)$.

Case 3 $1 + c(1-q) < R \leq 1 + c$

We know that when $1 + c(1-q) < R \leq 1 + c$ we will have $N^c(R,c) = 0$ by definition and $\widehat{N}(R,q,c) > 0$ from Proposition 3. Therefore, we will have that $\widehat{N}(R,q,c) \geq N^c$ whenever $1 + c(1-q) < R \leq 1 + c$ for all $q \in [0, 1/R]$. Therefore banks always fail in the bad state in this case. □

Lemma 7. *For any given $R < \widehat{R}$, there exists some $\widetilde{q} > \widehat{q}$, where $\widehat{q}$ is as defined in Proposition 10, such that if $q \in (\widehat{q}, \widetilde{q}]$ moving to a central common regulation from the symmetric uncoordinated equilibrium will eliminate the systemic failure in the bad state.*

Proof. We know that systemic crises happen when initial investment levels are high. If initial investment levels are close to the critical borders beyond which systemic crises occur, i.e. $\widehat{N}(\cdot)$ is slightly above $N^c(\cdot)$, then moving to global regulation can reduce investment levels in both countries to $\widetilde{N} < N^c$, and eliminate systemic failures in the bad state.

We can follow the similar lines in the proof of Proposition 10, and show that if $1+c < R < \widetilde{R}$ then there exists a $\widetilde{q} \in (0, 1/R)$ such that for all $q \geq \widetilde{q}$ we have that $\widetilde{N}(q) \geq N^c$. In other words, for such R, if the probability of the good state is higher than $\widetilde{q}$, banks fail in the bad state under common central regulation. If $R \leq 1 + c$ then banks always fail in the bad state, and if $R \geq \widetilde{R}$ then banks never fail in the bad state where

$$\widetilde{R} \equiv \frac{1}{2}\left(2 + c + \sqrt{c}\sqrt{4+c}\right) \tag{A.3.110}$$

It is clear that $\widetilde{R} < \widehat{R} \equiv (1/2)\left(2 + c + \sqrt{c}\sqrt{8+c}\right)$. We can also show that $1/R > \widetilde{q} > \widehat{q}$ which will complete the proof. □

Appendix B

Graphs and Tables for Chapter 2

Figure B.1: Distribution of the Capital Stringency Index for Each Survey

Figure B.2: Distribution of the Change in the Capital Stringency Index

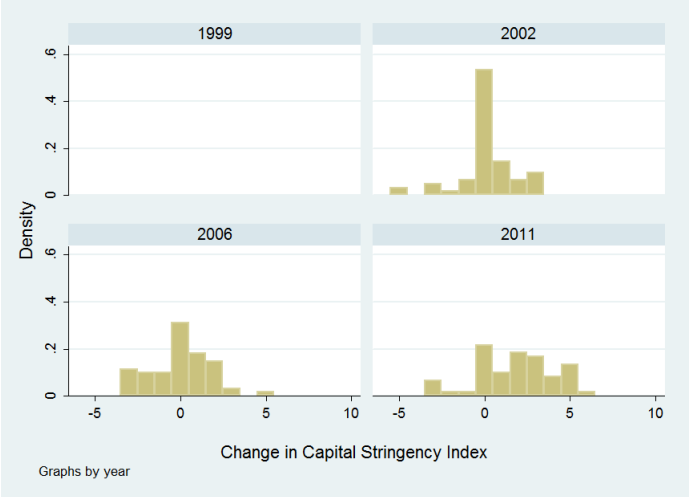

Figure B.3: Average Capital Stringency and World Business Cycle Trend

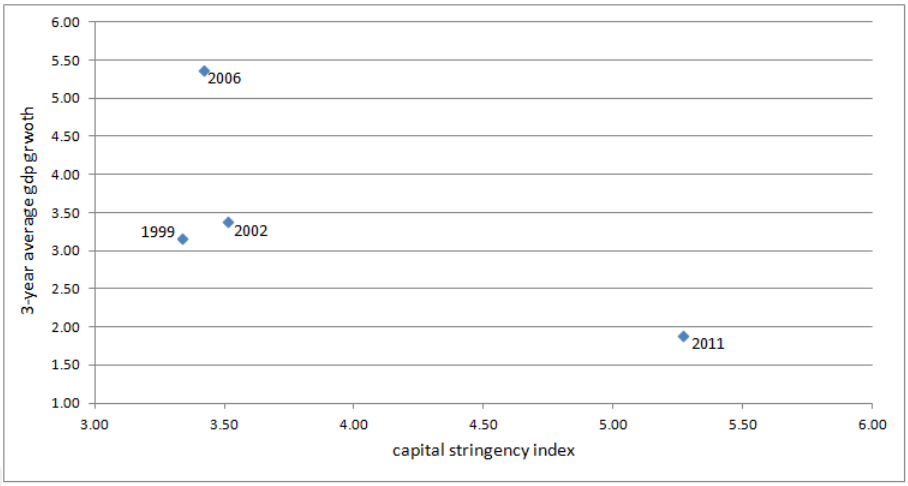

Figure B.4: Average Stringency of Bank Capital Regulations

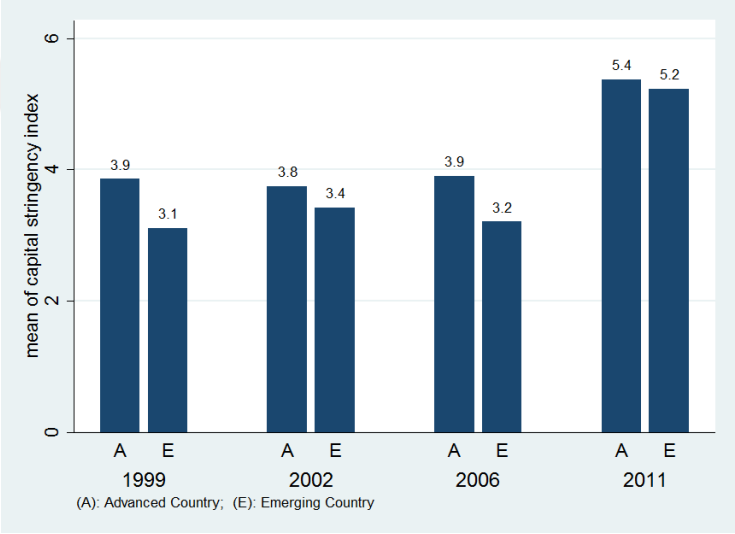

Table B.1: Countries by Income Group and Development Level

	Advanced	**Emerging**
High Income	Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States	Croatia, Cyprus, Czech Republic, Estonia, Hong Kong, China, Hungary, Israel, Korea, Rep., Kuwait, Oman, Poland, Qatar, Saudi Arabia, Singapore, Slovakia, Slovenia, Taiwan, United Arab Emirates
Upper Middle Income		Argentina, Belarus, Bosnia and Herzegovina, Brazil, Bulgaria, Chile, China, Colombia, Dominican Republic, Ecuador, Jamaica, Jordan, Kazakhstan, Latvia, Lebanon, Lihtuania, Macedonia, Malaysia, Mexico, Panama, Peru, Romania, Russia, Serbia, South Africa, Thailand, Tunisia, Turkey, Uruguay, Venezuela
Middle Income		Cote d'Ivoire, Egypt, El Salvador, Georgia, India, Indonesia, Iraq, Morocco, Nigeria, Pakistan, Philippines, Sri Lanka, Ukraine

Table B.2: Panel Data Summary

Variable		Mean	Std. Dev.	Min	Max	Observations
capital_stringency	overall	3.72	1.61	0	6	N = 280
	between		1.01	1	6	n = 83
	within		1.28	0.72	7.72	T-bar = 3.37
gdp_growth	overall	3.45	3.08	-5.36	19.86	N = 275
	between		1.98	-0.25	11.37	n = 82
	within		2.56	-5.28	15.67	T-bar = 3.35
government_banks	overall	16.98	20.53	0	80	N = 253
	between		18.72	0	75.74	n = 82
	within		9.08	-21.05	54.85	T-bar = 3.09
concentration_ratio	overall	58.73	18.46	15.32	100.00	N = 274
	between		16.27	19.16	96.53	n = 82
	within		7.77	31.52	93.98	T-bar = 3.34
legal_origin_uk	overall	0.25	0.44	0	1	N = 279
	between		0.43	0	1	n = 82
	within		0.00	0.25	0.25	T-bar = 3.40
legal_origin_fr	overall	0.45	0.50	0	1	N = 279
	between		0.50	0	1	n = 82
	within		0.00	0.45	0.45	T-bar = 3.40
legal_origin_ge	overall	0.23	0.42	0	1	N = 279
	between		0.42	0	1	n = 82
	within		0	0.23	0.23	T-bar = 3.40

Table B.3: Pairwise Correlations Between Variables

	cs	growth	gbank	con	emg	inc	louk	lofr	loge
cs	1.00								
growth	-0.17	1.00							
	(0.00)								
gbank	-0.10	0.13	1.00						
	(0.10)	(0.04)							
con	-0.03	0.08	-0.10	1.00					
	(0.60)	(0.18)	(0.10)						
emg	-0.11	0.26	0.26	0.04	1.00				
	(0.06)	(0.00)	(0.00)	(0.50)					
inc	-0.07	0.15	0.34	-0.20	0.56	1.00			
	(0.22)	(0.01)	(0.00)	(0.00)	(0.00)				
louk	0.05	0.01	-0.08	-0.11	-0.04	-0.01	1.00		
	(0.41)	(0.82)	(0.19)	(0.08)	(0.47)	(0.81)			
lofr	-0.01	-0.02	0.07	-0.05	0.17	0.35	-0.53	1.00	
	(0.84)	(0.78)	(0.24)	(0.44)	(0.00)	(0.00)	(0.00)		
loge	-0.05	0.04	0.06	0.05	0.07	-0.27	-0.32	-0.50	1.00
	(0.40)	(0.49)	(0.33)	(0.45)	(0.23)	(0.00)	(0.00)	(0.00)	

[1] p values in parentheses.
[2] *cs* is the levels of the capital stringency index. The index takes disrete values between 0 and 6.
[3] *growth* is 3 year average growth rate for years $t,\ t-1$ and $t-2$ whereas the capital_stringency index represents the state of the capital regulation the end of year t.
[4] *gbank* is the percentage of banking system's assets in banks that are 50% or more government owned.
[4] *con* is the two year average $(t,\ t-1)$ of three bank concentration ratio for each country.
[4] *emg* is a dummy that is equal to 1 for emerging countries, and to 0 for advanced countries.
[4] *inc* is equal to 1 if the country is in 'high income' group, 2 if in 'upper-middle income' group, and 3 if in 'middle income' group.
[4] *louk, lofr, loge* are dummy variables that take a value equal to 1 if the legal origin of the country is based on the United Kingdom, France and Germany respectively.

Table B.4: Logit Regressions for Individual Index Questions

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	baselweight (3.1)	creditrisk (3.2)	marketrisk (3.3)	dloanloss (3.9.1)	dlosssecury (3.9.2)	dlossfx (3.9.3)
Fixed Effects						
GDP growth	-0.494	-0.208***	-0.228***	-0.102*	-0.031	-0.048
	(0.440)	(0.002)	(0.001)	(0.100)	(0.559)	(0.372)
Concentration	-0.032	-0.007	-0.025	-0.038*	-0.042*	-0.051**
	(0.453)	(0.755)	(0.314)	(0.065)	(0.069)	(0.012)
Govt. banks	-0.095	-0.042**	-0.041*	-0.036*	-0.020	-0.023
	(0.783)	(0.041)	(0.056)	(0.058)	(0.233)	(0.164)
Observations	12	176	165	155	148	164
Number of code	3	51	48	44	43	48
Pop. Average						
GDP growth	-0.312**	-0.178***	-0.189***	-0.084*	-0.037	-0.037
	(0.032)	(0.000)	(0.000)	(0.098)	(0.459)	(0.459)
Concentration	0.034	-0.007	-0.012	-0.001	-0.001	-0.014
	(0.408)	(0.415)	(0.121)	(0.886)	(0.892)	(0.103)
Govt. banks	0.057	-0.012*	-0.010	-0.007	-0.013	-0.009
	(0.229)	(0.100)	(0.173)	(0.414)	(0.175)	(0.279)
Constant	3.500**	0.903	1.226**	0.832	1.264**	1.858***
	(0.028)	(0.107)	(0.024)	(0.193)	(0.027)	(0.002)
Observations	246	246	246	246	246	246
Number of code	81	81	81	81	81	81
Pooled Logit						
GDP growth	-0.315**	-0.173***	-0.182***	-0.075	-0.035	-0.031
	(0.032)	(0.000)	(0.000)	(0.136)	(0.486)	(0.525)
Concentration	0.033	-0.007	-0.012	0.005	0.004	-0.011
	(0.429)	(0.393)	(0.108)	(0.594)	(0.655)	(0.176)
Govt. banks	0.058	-0.010	-0.007	-0.001	-0.010	-0.007
	(0.239)	(0.151)	(0.298)	(0.911)	(0.305)	(0.411)
Constant	3.550**	0.860	1.158**	0.344	0.920*	1.620***
	(0.032)	(0.105)	(0.026)	(0.550)	(0.094)	(0.004)
Observations	246	246	246	246	246	246

[1] The dependent variables are individual questions that make up the capital stringency index. See Table 2.1 for question definitions.

[2] GDP growth, government-owned banks and concentration ratio are expressed in percentages. For example, three percent real GDP growth rate is expressed as 3.0 in our data.

[3] p values in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table B.5: Fixed Effects Estimation with Interaction Terms

VARIABLES	(1)	(2)	(3)	(4)
GDP growth	-0.125***	-0.144***	-0.144***	-0.124***
	(0.003)	(0.000)	(0.000)	(0.003)
Government-owned banks	-0.036***	-0.028**	-0.035***	-0.027**
	(0.002)	(0.031)	(0.003)	(0.036)
Concentration ratio	-0.029**	-0.032**	-0.036**	-0.038**
	(0.023)	(0.014)	(0.017)	(0.012)
adv*GDP growth	-0.137			-0.186
	(0.236)			(0.121)
adv*Government-owned banks		-0.030		-0.038
		(0.271)		(0.165)
adv*Concentration ratio			0.016	0.031
			(0.556)	(0.275)
Constant	6.648***	6.700***	6.733***	6.587***
	(0.000)	(0.000)	(0.000)	(0.000)
Observations	246	246	246	246
R-squared	0.177	0.176	0.172	0.191
Number of code	81	81	81	81
Calculated Slopes for Advanced Countries				
GDP growth (adv=1)	-0.262**			-0.310***
	(0.016)			(0.006)
Government-owned banks (adv=1)		-0.058**		-0.065***
		(0.015)		(0.007)
Concentration ratio (adv=1)			-0.020	-0.006
			(0.400)	(0.794)

[1] The dependent variable is the standardized value of the capital stringency index. The range of the standardized index is $[-2.25, 1.22]$.

[2] *adv* is a dummy that is equal to 1 for advanced countries, and 0 for emerging countries.

[3] The slopes for advanced countries in the last three rows calculated by adding the corresponding coefficient in the first three rows and the interaction term in the next three rows.

[4] GDP growth, government-owned banks and concentration ratio are expressed in percentages. For example, three percent real GDP growth rate is expressed as 3.0 in our data.

[5] GDP growth is 3 year average growth rate for years t, $t-1$ and $t-2$ whereas the capital stringency index represents the state of the capital regulation the end of year t.

[6] p values in parentheses. *** p<0.01, ** p<0.05, * p<0.1

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