Financial Risk Capacity

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Saki Bigio* Adrien d'Avernas†

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Abstract

Financial crises seem particularly severe and lengthy when banks fail to recapitalize after bearing large losses. We present a model that explains the slow recovery of bank capital and economic activity. Banks provide intermediation in markets with informational asymmetries. Large equity losses force banks to reduce intermediation, which exacerbates adverse selection. Adverse selection lowers profit margins for banks, which lowers banks profits and incentives to recapitalize. The model delivers financial crises characterized by persistent low economic growth.

Key Words: Financial Crisis, Adverse Selection, Capacity Constraints

*University of California, Los Angeles
†Stockholm School of Economics

1 Introduction

Financial crises that originate from extreme bank losses are known to be severe in depth and duration(see Cerra and Saxena, 2008; Reinhart and Rogoff, 2009). These episodes suggest that the recapitalization of banks is critical for the recovery of overall economic activity. After the recent financial crisis, the slow recovery of bank equity has been a major concern for policy makers, academics, and practitioners alike.[1] In fact, during his only television interview at the time, the Chairman of the Federal Reserve, Ben Bernanke, was asked when the crisis would be over, to which he answered, "When banks start raising capital on their own."[2] Why banks do struggle to recapitalize after a financial crisis?

One common solution in macroeconomic theory is to introduce frictions that prevent existing banks from raising equity or barriers to entry. However, the answer must also rely on low profit margins from intermediation after banks suffer equity losses. Otherwise, high profit margins should translate into rapid revenue retention and accelerate the recovery of inside equity. Recent macroeconomic theories of financial intermediation cannot explain declines in bank profit margins because frictions impede exclusively on the amount of funds banks can raise—limits to raise debt and equity.[3] Classic analysis suggests that financial intermediation profits should rise, not fall, in the aftermath of a crisis as marginal profits rise when supply is limited. Thus, those models predict accelerated recoveries in bank equity, and immediate in absence of funding frictions.

In this paper, we present a model that explains the slow recovery of bank capital and economic activity. We show that asymmetric information can explain persistent low economic growth after financial crises even though bankers have the funds to

[1]The slow recovery of intermediary capital is the subject of Darrell Duffie's 2010 Presidential Address to the American Finance Association (see Duffie, 2010) and a centerpiece of Bagehot (1873).

[2]See "The Chairman," *60 Minutes*, CBS News, March 15, 2009.

[3]In most macroeconomic models of intermediation developed after the crisis, banks cannot raise equity because bankers are fully invested specialists who face agency frictions. See below for a review of the literature.

recapitalize their banks.

One natural role for banks is to deal with asymmetric information between borrowers and lenders. Banks can diversify transaction risks caused by asymmetric information because they can exploit their scale to pool assets.[4] Yet, banks are not immune to large losses. When banks lose their financial risk capacity, they must scale down their operations. The decline in intermediation volumes exacerbates adverse selection. In turn, heightened adverse selection lowers profit margins for banks and incentives to recapitalize. This mechanism delivers financial crises characterized by persistent low economic growth.

We do not provide an ultimate theory of financial crises, but rather study a mechanism that delivers long-lasting recessions after a banking crisis with a minimal set of ingredients: (i) reallocation of capital across sectors fuels growth to link financial and real activity; (ii) banks face limited liability to tie financial activity to bank equity; (iv) intermediation is risky such that bank equity can suffer losses; and (iv) financial intermediation is subject to asymmetric information which lowers profitability when bank financial risk capacity is low. This simple framework can be enriched to incorporate other important features. Our theory attributes the lack of entry to the decline in profitability. We argue that low profit margins would exacerbate other explanations of slow moving equity. For example, low profits reduce the value for outside investors, worsen debt-overhang problems (Myers, 1977), and add stress to agency frictions such as moral hazard (Holmstrom and Tirole, 1997), limited enforcement (Hart and Moore, 1994), or asymmetric information (Myers and Majluf, 1984).

The paper is related to two branches of financial macroeconomics. The first branch links the net worth of the financial sector to the amount of financial intermediation through agency frictions. This literature builds on earlier work by Bernanke and Gertler (1989) that focused on financial factors affecting firms.[5] Since the onset of

[4]This view is rooted in classic banking theory: for example, Freixas and Rochet (2008), Leland and Pyle (1977), Diamond (1984), or Boyd and Prescott (1986).

[5]Fire-sale phenomena were first described by Shleifer and Vishny (1992). A feedback between

the Great Recession, several papers have incorporated similar intermediaries into state-of-the-art business cycle models. Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) study the business cycle effects after intermediaries suffer equity losses. This paper is closer to the continuous-time models of He and Krishnamurthy (2012) (henceforth HK) and Brunnermeier and Sannikov (2014) (henceforth BS) because those papers also stress the non-linear nature of intermediation dynamics. In HK, equity shocks are amplified through a substitution of equity financing for debt. In BS amplification operates through fire sales. This paper differs from the literature in some important aspects. First, intermediaries do not operate production; they reallocate capital. Second, they issue liabilities that become means of payment. Third, frictions do not limit the ability to raise equity. These three elements bring the model closer to institutional details of banking. Yet, non-linear effects still emerge from the interplay among low bank capital, asymmetric information, and low profitability.

The second branch investigates the effects of asymmetric information in financial market intermediation. Stiglitz and Weiss (1981) investigates asymmetric information on the side of borrowers. This paper relates closely to Eisfeldt (2004) who studies an asset market with asymmetric information. There, adverse selection induces a cost to insure against investment risks. Bigio (2015) and **?** study models where assets are also sold under asymmetric information, but to fund production. The novelty here is the interaction between intermediary capital and asymmetric information. This interaction is important because those models lack a strong internal propagation: the persistence of adverse selection corresponds exactly to the persistence of exogenous shocks. Here, low bank equity leads to a persistent aggravation of adverse selection.[6] This feature connects to the business cycle decompositions in Christiano, Motto, and Rostagno (2012) and Ajello (2012) that find a prevalence of

losses in intermediary capital and reductions in asset values is also a theme in Gromb and Vayanos (2002) and Brunnermeier and Pedersen (2009). Maggiori (2011) extends this framework to a two-country setup to study current account dynamics. Diamond and Rajan (2011) study strategic behavior by banks to exploit fire sales by their competitors. **?** introduce asymmetric information into a related setup.

[6]Other models that study lemons markets, such as Hendel and Lizzeri (1999), Guerrieri and Shimer (2011), Plantin (2009), or Daley and Green (2011) obtain persistence through learning.

exogenous shocks that exacerbate asymmetric information. Although those models lack intermediaries, their filtering exercises find that dates associated with stronger adverse selection coincide with dates where financial institutions were in distress. Stiglitz and Greenwald (2003) argue that credit quality deteriorates when banks provide little intermediation, and regards this as being essential to understanding cycles, monetary policy, and the evolution of bank equity and profits after crises. Gennaioli, Shleifer, and Vishny (2013) study an environment where intermediaries increase leverage when they can mutually insure against idiosyncratic credit risk. However, their higher leverage increases aggregate credit risk. In Martinez-Miera and Suarez (2011) and Begenau (2014), banks can choose the risk of their assets directly. As an outcome, those models deliver procyclical credit risk, but they cannot explain declines in margins in crises. In this paper, credit risk and returns are endogenous. Finally, the mechanism here relates to the mechanisms in Gorton and Ordoez (2014) and Dang, Gorton, Holmstrom, and Ordoez (2015). In those models, the equity of constrained agents determines their incentives to acquire information. Thus, equity losses may trigger adverse selection because the economy swings from states where information is symmetric and assets are liquid to states where information is asymmetric and assets illiquid. Here, what triggers adverse selection is that low bank equity induces low volumes of intermediation.

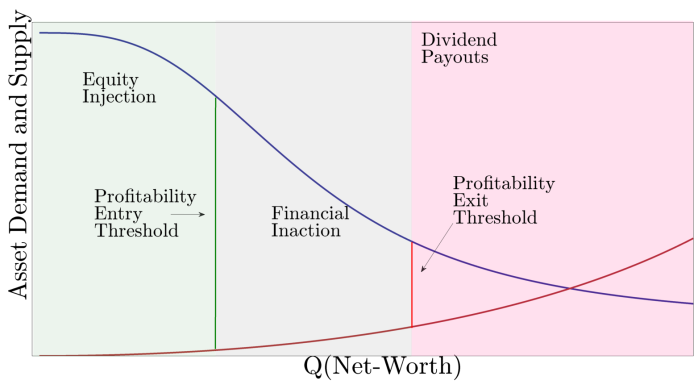
The next section provides an intuitive description of the mechanics of the model. That model is laid out in Section 3 and characterized in Section 4. Section 5 studies two simple policy experiments. Section 6 concludes.

2 The Mechanisms in a Nutshell

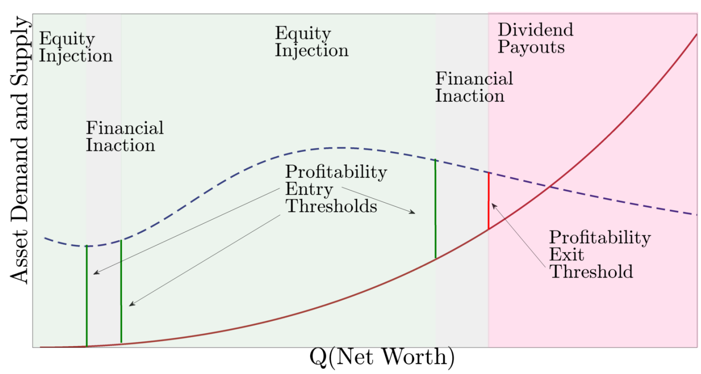
In his celebrated Debt Deflation Theory, Irving Fisher compares financial crises to the capsizing of a boat that "under ordinary conditions, is always near a stable equilibrium but which, after being tipped beyond a certain angle, has no longer this tendency to return to equilibrium...". Eighty years ago, in the aftermath of the

Great Depression, Fisher was providing us with a rudimentary description of the non-linear nature of financial crises. The main insight of this paper is that asymmetric information can induce these "rocking boat" dynamics.

The underlying mechanism can be explained in a nutshell in Figure 1. Panel (1a) illustrates how profitability is a stabilizing force behind financial markets and Panel (1b) how asymmetric information breaks the tendency to return to equilibrium. Figure 1 will be our guide throughout the paper.



(a) Financial Intermediation under Symmetric Information



(b) Financial Intermediation under Asymmetric Information

Figure 1: Financial Intermediation With and Without Asymmetric Information

Let me first discuss Panel (1a). The two curves represent aggregate demand and supply schedules for an asset. In any intermediated market, intermediaries buy assets from suppliers and resell assets to final buyers. For a given aggregate volume of trade Q, the intermediaries' marginal profits —financial arbitrage — are the distance between the price at the supply schedule to the price at the demand schedule, at that Q. If some friction imposes a limit on the volume of intermediation, there is a positive arbitrage. In models with financial frictions, the net worth of intermediaries caps Q. Thus, volumes of intermediation are increasing in the financial sector's net worth, which is why Q is labelled as a function of net worth in the figure.

The shapes of the demand and supply schedules govern the behavior of marginal profits. In the case of Panel (1a), marginal profits are decreasing in Q —and thus also in net worth. Conversely, the evolution of net worth is influenced by marginal profits in two ways: directly, by affecting retained earnings, and, indirectly, by attracting outside equity injections or dividends.

To understand this relation, suppose that there is a level of marginal profits below which dividends are paid out. This threshold is the length of the vertical line indicated as the profitability *exit* threshold. Similarly, suppose there is another profitability threshold above which equity injections are attracted. This is the vertical line indicated as the profitability *entry* threshold. Whenever net worth is above the level that induces exit-threshold profits, dividends are paid out. The opposite occurs whenever net worth is below the level that induces entry-threshold profits —injections replenish net worth. Because the entry and exit profit levels are not the same, there is also an intermediate inaction region where intermediaries neither pay dividends nor raise equity. Within that region, equity has a tendency to increase, but only through retained earnings. This simple graph describes an economic force that brings forth financial stability. If anything reduces net worth below (above) the equity entry (exit) point, intermediaries raise (decrease) equity. In that world, intermediation, equity, and profits live in a bounded region.

Asymmetric information alters this stabilization force. This situation is represented in Panel (1b). That figure emerges from an environment where intermediaries buy individual assets under asymmetric information and resell them as a pool of homogeneous quality. When intermediaries purchase capital under asymmetric information, both the quantity and the quality of assets increase with the purchase price. This is why the supply schedule is also increasing in that figure. However, what has changed in Panel (1b) is that the demand faced by the intermediary has a backward-bending portion. Standard consumer theory dictates that, on the margin, the value of a unit of any normal good —savings instruments included— is lower than the marginal value of the previous unit, provided that all units are homogeneous. When qualities improve with quantities, the marginal valuation may actually rise with quantities —if qualities improve sufficiently fast. The result is an "effective" demand curve that can be backward bending, as in Panel (1b). A direct consequence of this backward-bending demand is that marginal profits are no longer necessarily decreasing, as in Panel (1a). Instead, marginal profits are potentially hump-shaped. In the case of Panel (1b), the hump-shape in marginal profits generates two inaction regions instead of the single region found in Panel (1a).

Let's return to the point of interest: the stability of financial intermediation. Let's assume that net worth is in the inaction region at the right of Panel (1b). In that region, the dynamics of equity and intermediation depend on the size of intermediation losses, as in Fisher's rocking-boat analogy. A shock that produces equity losses, but only sends the economy to the neighboring injection region to the left, will be counterbalanced by quick equity injections. As a result, small shocks are stabilized, just as in Panel (1a). However, if losses are large enough to send the economy to the inaction region at the left, the economy loses the tendency to return to equilibrium. Because profits are low in that other region, intermediaries lack the individual incentives to inject equity. Unless they coordinate an entry, equity remains low for a while. All in all, large shocks can capsize this economy. Eventually, this economy will recover, but slowly as intermediaries retain earnings.

3 Model of Financial Risk Capcity

In this section, we provide a static economy in which a competitive financial sector provides risky financial intermediation and faces limited liability constraints. The purpose of this exercise is to study the equilibrium size of the financial system's when financial intermediaries face a trade-off between the paying-off today dividends and keeping capital to relax their limited liability constraints.

Timing, shock and population. There are two periods. The first period is devided into two stage. Between these stages, a random aggregate shock, $\phi \in \{\phi_G, \phi_B\}$ is realized. ϕ affects the conditions of the capital markets. I use the subscripts G and B for good and bad states. The probability of the good state is given by ε. There is a unit measure of entrepreneurs and a unit measure of financial intermidiaries.

Goods, Production Technology and Entrepreneurs. There are is a capital good and perishible consumption good (the numeraire). There are two linear production techonologies, one that transforms one unit of consumption into a unit of capital and the other that transforms one unit of capital to R units of consumption. Entrepreneurs enter start-out with a capital stock. In the first period, they are randomly segmented into two groups. An entrepreneur becomes a capital producer (i-entrepreneur) with probability π and has access to the investment technology only. With probability $(1-\pi)$, he becomes a goods producer (p-entrepeneur) and has acces to the production technology only. Their utility function is given by $c_1 + \frac{\beta}{1-\beta} c_2$.

During the first stage of the first period, i-entrepreneurs sell a fraction ω of their capital at a price $p(\omega)$ to the financial intermediaries. Therefore, ω is also interpreted as the aggregate volume of financial intermediation. Between stages, ϕ is realized this determines the depreciation of the investing entrepreneur's capital. The market conditions are characterized by the function λ which is the fraction of capital that remains undepreiated after the shock is realized. I assume the following: $\lambda(\phi_B) = \lambda_B < \lambda(\phi_G) = \lambda_G$. After the shock is realized, financial firms resell the purchased capital to p-entrepreneurs, so λ has an effect on the equilibrium price of the capital held by financial institutions. This amount is denoted by $q(\phi,\omega)$ and, thus, the total value of the volume of purchases, ω, is $q(\phi,\omega)\lambda(\phi)$, in state ϕ.

Producer's Problem. The producer's problem consists on solving a simple consumption saving's decision.

The producer's problem is,

$$W^P(k,\phi,\omega) = \max_{\Delta k} U(c_1) + \frac{\beta}{(1-\beta)} U(c_2)$$

subject to

$$\begin{aligned} c_1 + q(\phi,\omega)\Delta k &= Rk \\ c_2 &= (R-1)(\lambda k + \Delta k) \end{aligned}$$

Thsi problem yields the demand for capital during the second stage.

Second Stage - Investor's Problem. After trade in the first stage is carried out, investing entrepreneurs enter the period with an amount $p\omega k$ of consumption goods they obtain by selling the fraction ω of their capital stock, k, at a price p. Thus, the investor's problem consists on solving a simple consumption saving's decision. The producer's problem is,

$$W^I(k,\phi,\omega;p) = \max_{i} U(c_1) + \frac{\beta}{(1-\beta)} U(c_2)$$

subject to

$$\begin{aligned} c_1 + i &= p\omega k \\ c_2 &= (R-1)(\lambda(\phi)(1-\omega)k + i) \end{aligned}$$

This problem yields the amount of investment carried in this economy.

First Stage - Investor's Problem. During the first stage, the investing entrepreneur chooses ω, in order to maximize his expected utility. The investor's problem is:

$$\max_{\omega} E\left[W^I\left(k,\phi,\omega;p\right)\right]$$

The solution to this problem yields a supply schedule for capital sold to the financial sector.

Finacial intermediaries. Financial intermediaries risk neutral and identified by some $j\in[0,1]$. Each intermediary owns a financial firm and maximizes the expected discounted value of their consumption: $E\left[\frac{\sum_{t=1,2}\left(\beta^f\right)^{t-1}c_t}{(1+\tau_e)}\right]$ where $(1+\tau_e)$ is a normalization constant. At the beginning of the period, banker's are endowed with an exogenous large amount endowment of consumption goods $\bar{e}$, and an amount of consumption goods in their finacial firms $b(j)$. $b(j)$ is interpreted as the the financial firm's net-worth and there is an initial distribution of these across financial firms.

At the beginning of the first stage of the first period bankers can inject an amount of e of their endowment into their firm's balance sheets or do the opposite by paying out dividends. Consumption during the first stage is given by $c_1=\bar{e}-e+(1-\tau_d)\,d$ where $(1-\tau_d)$ is the tax on dividends. It is convenient to express these decisions by normalizing them in terms of their firm's balance sheet. Thus, let $e\left(j\right)$ and $d\left(j\right)$ be the equity injections and dividend pay-offs per unit of net-worth in a financial firm j. After adjusting for the capital injections and dividend payoffs, the capital within the intermediaries firm is $b\prime\left(j\right)=\left(1+e\left(j\right)-d\left(j\right)\right)b\left(j\right)$. After dividends and capital injections, the aggregate net-worth of the financial system is $\int b\prime\left(j\right)dj=B$.

During the first stage, but once the capital adjustments have taken place, financial firms buy capital from investors which they resell during in the second stage to producers. I denote by Q the amount of capital purchases per unit of net-worth. Financial firms obtain profits depending on the difference between value of a unit of capital in the second the second stage and its purchase price in the first stage. Thus,

$q(\omega,\phi)\,\lambda(\phi) - p(\omega)$, are the profits per unit of transaction. Total profits or losses for a single firm are given by $(q(\omega,\phi)\,\lambda(\phi) - p(\omega))\,Qb$.

The surprise in ϕ can cause losses from financial intermediation depending on the volume of intermediation. Losses are financed by resorting to the financial firms own net-worth. At the end of the second period, financial firms are liquidated and pay-out dividends equivalent to the firms net-worth after the realization of profits/losses. The key assumption in the model is that financial losses may not exceed the financial firm's net-worth. This assumption reflects the real life feature that stock-owners of banks are not liable. Given the limited liability constraint, the firm chooses Q such that:

$$\underbrace{-\left[q(\phi,\omega)\,\lambda(\phi) - p(\omega)\right]}_{\text{losses per unit of intermediation}} \cdot \underbrace{Qb}_{\text{volume of intermediation}} \leq \underbrace{(1+e(j)-d(j))\,b(j)}_{\text{financial firm's balance sheet}},\ \forall\phi$$

The constraint implies that the total amount of losses than can be born by a financial institution cannot exceed the financial firm's net-worth. Thus, $(1+e-d)\,b$ represents the firm's capacity to bear losses or, in other words, its financial risk capacity. Another way to interpret this condition is in terms of a leverage condition. When, $[q(\phi,\omega)\,\lambda(\phi) - p(\omega)]$ is negative under the worst case shock, one obtains the following expression,

$$\frac{\overbrace{Q}^{\text{Traded Assets}}}{\underbrace{(1+e-d)}_{\text{Net-worth}}} \leq \underbrace{\frac{1}{-\left[q(\phi,\omega)\,\lambda(\phi) - p(\omega)\right]}}_{\text{Leverage Rate}},\ \forall\phi.$$

This condition is simply a cap on the leverage rate that depends on the ω, the voluom of intermediation in capital markets.

Financial Firm's Accounting. Some accounting is useful. During the first stage, financial firms enter the period with net-worth equivalent to $(1+e-d)$. After trading at the first stage, the balance sheet of a financial institution is modified to account for the purchases of capital:

Assets	**Liability**
$(1+e-d)$	
	<u>Net-worth</u>
	$(1+e-d)$

Pre-trade Balance Sheet

Assets	**Liability**
$(1+e-d)$	$p(\omega)Q$
$p(\omega)Q$	**<u>Net-worth</u>**
	$(1+e-d)$

Post-trade Balance Sheet

After ϕ is realized, the value of the assets in the balance sheet of financial firms adjusts to account for the effects of the shock to the value of its assets:

Assets	**Liability**
$(1+e-d)$	$p(\omega)Q$
$q(\phi,\omega)\lambda(\phi)Q$	**<u>Net-worth</u>**
	$(1+e-d)+[q(\phi,\omega)\lambda(\phi)-p(\omega)]Q$

Post-shock Balance Sheet

Net-worth is affected by the losses or gains in the value of the assets that are bought for intermediation: $[q(\phi,\omega)\lambda(\phi)-p(\omega)]Q$.

Financial Intermediaries Problem: The financial intermediaries take the other firm's actions and prices as given and solve:

Problem 1 (Static Problem)**.**

$$\begin{aligned} V(b;X) &= \frac{1}{(1+\tau_e)}\max_{e\geq 0,d\geq 0,Q\geq 0}(\bar{e}-e)+(1-\tau_d)d... \\ &\quad +(1-\tau_d)\beta^F\left[\mathbb{E}\left[q(\phi,\omega)\lambda-p(\omega)\right]Q+(e-d)\right]b \end{aligned}$$

subject to

$$-\left[q(\phi,\omega)\lambda-p(\omega)\right]Qb\leq(1+e-d)b,\forall\phi$$

and $e\in[0,\bar{e}]\,,d\in[0,b]\,,Q\geq 0$.

The problem is homogeneous in the firm's balance sheet. One can re-write the value of the problem as:

$$V(b,\kappa) = V(\kappa)\, b$$

where

$$V(\kappa) = \max_{e\geq 0, d\geq 0, Q\geq 0} (1-\tau_d)\, d - (1+\tau_\varepsilon)\, e + (1-\tau_d)\, \beta^F \mathbb{E}\left[\left[q(\phi,\omega)\,\lambda - p(\omega)\right] Q + e - d\right]$$

and

$$-\left[q(\phi,\omega)\,\lambda - p(\omega)\right] Q \leq (1+e-d), \forall\phi \tag{1}$$

Market Clearing Conditions: There are two market clearing conditions, one for each state. During the first stage, the total supply of capital for used capital must clear, $\omega\pi \int k(i)\, di = Q \int b\prime(j)\, dj$, at the price $p(\omega)$. During the second stage, the amount of capital supplied by financial firms must equal the amount in demand by producers, $\lambda(\phi)\, Q \int b\prime(j)\, dj = \int s(i)\, di$, at price $q(\phi,\lambda)$.

Equilibria: An equilibrium consists of the following objects.

Definition 1 (Static Equilibrium)**.** *Given an initial distribution over net-worth $b(j)$ and capital holdigns $k(i)$, a static equilibrium with financial risk capacity are financial intermediaries policy functions, e,d and Q, and entrepreneur policy functions such such that:*

1. *e,d and Q are solutions to the financial firms problem taking $p(\omega), q(\omega,\phi)$ as given,*
2. *ω,s and i are solutions to the corresponding entrepreneur problems.*
3. *Market clears during the first stage:*
4. *Market clears during the first stage:$\omega = Q \int b(j)dj = \frac{Q\kappa}{(1+e-d)}$.*

Equilibria can be characterized by first finding the second stage market price for capital, $q(\omega, \phi)$ and $p(\omega)$. **Proposition:** Formula's p is increasing in ω and $q(\omega, \phi)$ decreasing in ω and ϕ.

An immediate inspection of this function reveals that the value per unit is decreasing in ω and is lower in the bad state. Since intermediaries don't keep any of the assets after the second period, the market (in the second period) must clear at $q(\omega, \phi)$. Thus, from the perspective of the first stage, $q(\phi, \omega)\lambda$ can be seen as a random value a unit of capital, when the aggregate volume is ω.

When deciding over equity and dividend policies e, d, financial firms affect the feasible set of transactions Q. In equilibrium, the aggregate volume of intermediation is taken as given. The aggregate volume of intermediation ω determines the profitability per trade because it affects the price margins. The first thing to note is that it is never profitable to pay dividends and inject equity simultaneously. Thus, if $e > 0$ then $d = 0$, and conversely if $d > 0$ then $e = 0$. Second, in equilibrium, $\mathbb{E}[q(\phi, \omega)\lambda(\phi) - p(\omega)] > 0$. If this condition is not true, then the firm is better-off by paying dividends since future dividends are discounted. Because expected profits are greater than 0, in equilibrium, the limited liability constraint (1) is always binding. This insights are used to pin-down the equilibrium quantities.

Proposition 2. *Equilibria are given by the set of ω such that:*

$$\left[\frac{\mathbb{E}[q(\phi, \omega)\lambda(\phi) - p(\omega)]}{-[q(\phi_B, \omega)\lambda(\phi_B) - p(\omega)]} + 1\right] \in \left(\beta^F\right)^{-1}\left[1, \frac{1+\tau_\varepsilon}{1-\tau_d}\right]$$

The equilibrium set of ω is a unique interval $[\underline{\omega}, \overline{\omega}]$. In addition, (1) always binds and the equilibrium value for κ is also an interval $[\underline{\kappa}, \overline{\kappa}]$. Dividend and equity policies are indeterminate at the individual level and,

$$e > 0 \text{ only if } \mathbb{E}[q(\phi, \omega)\lambda(\phi) - p(\omega)] \geq -\left[\frac{1}{\beta^F}\left[\frac{1+\tau_\varepsilon}{(1-\tau_d)}\right] - 1\right][q(\phi_B, \omega)\lambda_B - p(\omega)]$$

and

$$d > 0 \text{ only if } \mathbb{E}[q(\phi, \omega)\lambda(\phi) - p(\omega)] \leq -\left[\frac{1}{\beta^F} - 1\right][q(\phi_B, \omega)\lambda_B - p(\omega)]$$

This proposition establishes that the equilibrium aggregate volumes of intermediation, ω, must belong to a given interval. In essence, in equilibrium, the capacity constraint (1), is always binding. The conditions in the proposition correspond to aggregate volumes such that, taking these as given, financial firms don't have incentives to recompose their balance sheets. The points at the interior of this interval correspond to volumes of intermediation such that taking prices as given, financial firms don't find it profitable to alter their balance sheet composition. Thus, if the initial size of the financial system is $\int b(j)\, dj \in (\underline{\kappa}, \overline{\kappa})$, no dividends or equity injections should be occur in equilibrium. For the value of the balance sheet, ω is at the interior of its equilibrium set. If in contrast, $\int b(j)\, dj$ falls out of $[\underline{\kappa}, \overline{\kappa}]$, the equity injections and dividend pay-offs will adjust to a point where at κ, firms are indifferent about their financial policies. More precisely, when $\int b(j) dj$, falls under $\underline{\kappa}$, financial firms will inject funds to their balance sheets up to reaching, $\underline{\kappa}$, the point where they are exactly indifferent between injecting more capital or not. A similar logic holds for the choice of dividend pay-offs,: if $\int b(j) dj$ is above the interval, dividends will be payed out up to the point where $\kappa = \overline{\kappa}$

At this point, one can conjecture what happens in a dynamic version of this model. If one were to mechanically repeat this static game letting κ evolve according to the policy functions of the static game simply by adding profits to the firm's balance sheet we should expect several things. First, positive expected profits in equilibrium. Second, for a sufficiently bad sequence, κ should shrink up to the point where capital injections stabilize the financial sector's size. Thus, the possibility of injecting capital to the financial system would place a lower bound on the equilibrium financial risk capacity, at $\underline{\kappa}$. Below that value, the financial system would become less competitive and, hence, attract capital. In a dynamic model with these features, $[\underline{\kappa}, \overline{\kappa}]$ are reflecting barriers that stabilize the financial system's size.

Figure 2 provides a graphical explanation of an equilibrium to gain further insight. The upper-left panel describes 4 curves. The increasing function is the aggregate supply function $p(\omega)$. The top and bottom downward-slopping curves correspond to the market value of a volume ω for high and low realizations of ϕ respectively. The curve in the middle corresponds to the expected value per unit of intermediation when the volume is ω. Like in standard demand-supply analysis, the difference between the green and black lines is the expected marginal profit from financial intermediation. Total expected profits for the system correspond to the rectangle of length ω and height $\mathbb{E}[q(\phi,\omega)\lambda(\phi)] - p(\omega)$. This area is plotted at the bottom left panel. The downward-slopping curve in the top right panel plots the expected marginal profit (expected markup-up) of a financial transaction given for given volumes, ω. The red and green upward sloping curves, correspond to the marginal costs of injecting equity and the marginal benefit of dividend pay-offs. Once financial firms choose e and d, the equilibrium ω must be such that financial firms no longer have the incentives to alter their balance-sheet composition. Thus, the equilibrium set of ω is characterized by the points in which the black curve is above the green line (it is not profitable to pay dividends) but under the red curve (it is neither profitable to inject more equity into the financial system).

The bottom right panel shows a constructive way to pin-down the equilibrium range for κ. Given the equilibrium set obtained for ω, the panel plots the maximal losses corresponding to the realization of ϕ_L. For the equilibrium set ω, it must be the case that κ is sufficiently large to support losses in the worst realization. In equilibrium, e and d adjust to make the system's balance-sheet fall in this interval. Let me summarize the key insights of this section.

Discussion: The two-stage model described in this section provides some lessons:

1. Financial intermediation is characterized by an interval $[\underline{\kappa}, \overline{\kappa}]$ for the aggregate net-worth of the financial system, κ.

2. κ represents the financial system's capacity to bear financial risk.

3. The expected return to capital in the financial system is decreasing κ: the volume of intermediation is larger and expected premia are lower. Thus, one can interpret a financial system with a larger κ as a more competitive financial system.

4. Equity injections and dividend pay-offs are stabilizing forces in the financial system. If the balance sheet $\int b(j)dj$ of financial firms is sufficiently low, the financial sector attracts capital as expected returns are higher. Dividends act in the opposing direction. The financial system reduces its capacity if $\int b(j)dj$ is sufficiently large.

5. In a dynamic economy, we should expected the size of the financial sector to fluctuate between similar bounds.

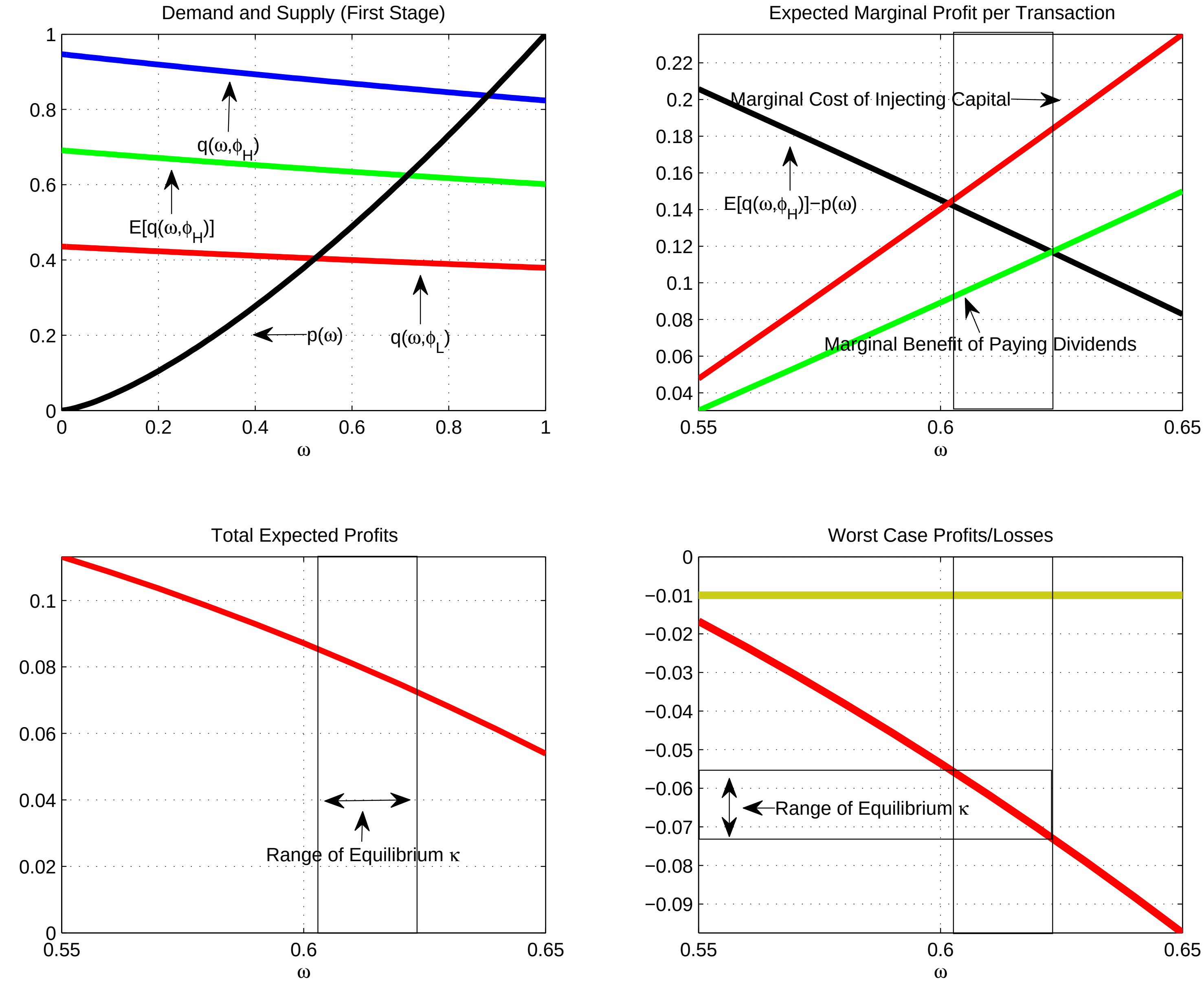


Figure 2: Equilibrium objects in Static Model. The figure is constructed by setting parameters to: $\pi = 0.1$, $\beta = 0.97$, $\beta^f = 0.99$, $\tau_e = 0.1$, $\tau_d = 0.3$, $\epsilon = 0.5$, $\lambda(\phi_G) = 2$ and $\lambda(\phi_B) = 0.5$.

3.1 Asymmetric Information

We introduce asymmetric information in the quality of capital to the environment described in the previous section. Again, $\omega \in [0, 1]$ denotes an index for the volume of intermediation but now volumes are associated to an average quality for the capital stock in the model. Thus, every ω is mapped into a quality through a monotone increasing function $\lambda(\omega)$. $\lambda(\omega)$ can be thought of as random depreciation or efficiency units that will remain from that capital unit. In the dynamic model, qualities have a direct interpretation but for now, once should just consider them as a scale factor. As in other models with asymmetric information, I assume that the worst qualities are sold first. Thus, ω represents a quantity of capital and also an ordering over qualities. λ is the quality the ω-percentile. So when $\omega = 0.5$, 50% of capital is being sold, but prices incorporate the average quality of assets traded at that volume.

Because λ is a deterministic increasing function, ϕ affects the supply and demand for capital in a different way now. In particular, ϕ now determines the realization of a density function $f_\phi(\omega)$. During the second stage, instead of scaling capital by a multiplicative shock λ, purchases are scaled by the factor: $\mathbb{E}_\phi[\lambda(\omega)|\omega < \bar{\omega}]$, where $\mathbb{E}_\phi$ represents the expectation operator with respect to the density. That is, the effective supply of capital by financial firms in the second stage is $\mathbb{E}_\phi[\lambda(\omega)|\omega < \bar{\omega}]\bar{\omega}$, given that it purchased $\bar{\omega}$. Thus, the decreasing relationship between the marginal expected value of capital and the volume of intermediation no longer holds. It may be the case that given a realization for ϕ. In particular, for particular volumes of intermediation, the positive effect of the increase in quality may more than compensate the negative effect of greater supply.

We assume that $\mathbb{E}_\phi[\lambda(\omega)] = \bar{\lambda}$, for any of the two values of ϕ, so that for any realization of the shock the average quality is the same. On the other hand, $\mathbb{E}_{\phi_B}\left[\lambda\left(\omega\right)|\omega < \bar{\omega}\right] < \mathbb{E}_{\phi_G}\left[\lambda\left(\omega\right)|\omega < \bar{\omega}\right]$ for any level $\bar{\omega}$. The interpretation of this assumption is that for any quantity purchased by financial firms, the effective quality is worse in the bad state ϕ_b.

Again, there is an initial distribution of $b(j)$ and supply in the first stage is given by $p(\omega)$ with the same properties as before. Demand during the second stage takes a different form but is also derived from the same problem corresponding to that will studied in the subsequent section.

$$q\left(\phi,\omega\right) \equiv \frac{\beta[R+\lambda](1-\pi))}{\lambda(1-\pi)+\pi\mathbb{E}_{\phi}[\lambda(\omega)|\omega<\bar{\omega}]}$$

Financial firm's now face the following problem,

Problem 2 (Static Problem)**.** *Financial firms solve:*

$$\begin{aligned} V\left(b,\kappa\right) &= \max_{e\geq 0,d\geq 0,Q\geq 0}\left(1-\tau_{d}\right)db-\left(1+\tau_{\varepsilon}\right)eb... \\ &\quad +\left(1-\tau_{d}\right)\beta^{F}\mathbb{E}\left[\left[q\left(\phi,\bar{\omega}\right)\mathbb{E}_{\phi}\left[\lambda\left(\omega\right)|\omega<\bar{\omega}\right]-p(\bar{\omega})\right]Q+\left(e-d\right)\right]b \end{aligned}$$

subject to

$$-\left[q\left(\phi,\bar{\omega}\right)\mathbb{E}_{\phi}\left[\lambda\left(\omega\right)|\omega<\bar{\omega}\right]-p(\bar{\omega})\right]Qb\leq\left(1+e-d\right)b,\forall\phi \qquad (2)$$

The definition of equilibrium is the same as before. The only difference is in the definition of the value of the financial firm's purchases which are now $q\left(\phi,\bar{\omega}\right)\mathbb{E}_{\phi}\left[\lambda\left(\omega\right)|\omega<\bar{\omega}\right]$. Now, for the same level of capacity, κ, there may be two prices and volumes for which the capacity constraint just binds. Price multiplicity is a common to other models with asymmetric information. When there are multiple equilibrium prices for the same amount of capacity, I will select the equilibrium with the largest price.

There is an analog to Proposition 2:

Proposition 3. *Any equilibrium is characterized by any ω such that:*

$$\left[\frac{\mathbb{E}\left[q\left(\phi,\omega\right)\lambda-p(\omega)\right]}{-\left[q\left(\phi_{B},\omega\right)\mathbb{E}_{\phi_{B}}\left[\lambda\left(\omega\right)|\omega<\bar{\omega}\right]-p(\omega)\right]}+1\right]\in\left(\beta^{F}\right)^{-1}\left[1,\frac{1+\tau_{\varepsilon}}{1-\tau_{d}}\right]$$

The equilibrium set of ω is given by unconnected intervals. In addition, (2) always *binds and the equilibrium value for κ is also given by unconnected intervals. Dividend and equity policies are indeterminate and the individual level and satisfy,*

$$e > 0 \text{ only if } \left[\frac{\mathbb{E}\left[q\left(\phi,\omega\right)\mathbb{E}_{\phi_G}\left[\lambda\left(\omega\right)|\omega<\bar{\omega}\right]-p(\omega)\right]}{-\left[q\left(\phi_B,\omega\right)\mathbb{E}_{\phi_B}\left[\lambda\left(\omega\right)|\omega<\bar{\omega}\right]-p(\omega)\right]}+1\right] = \frac{1+\tau_{\varepsilon}}{\beta^F\left(1-\tau_d\right)}$$

and

$$d > 0 \text{ only if } \left[\frac{\mathbb{E}\left[q\left(\phi,\omega\right)\mathbb{E}_{\phi_G}\left[\lambda\left(\omega\right)|\omega<\bar{\omega}\right]-p(\omega)\right]}{-\left[q\left(\phi_B,\omega\right)\mathbb{E}_{\phi_B}\left[\lambda\left(\omega\right)|\omega<\bar{\omega}\right]-p(\omega)\right]}+1\right] = \left(\beta^F\right)^{-1}.$$

The difference between propositions 2 and 3 is that the equilibrium size for the financial sector is no longer characterized by a unique interval. The reason behind this potential multiplicity responds to the non-monotonic behavior of the expected return to an additional unit of capital in the financial sector.

Figure **??** explains the equilibrium in presence of asymmetric information. As in 2, the upper-left panel describes 4 curves. The increasing function is the aggregate supply of function $p(\omega)$. The zigzagging curves are the market value of the capital purchases. The top and bottom curves correspond to the market value of purchases of capital ω given high and low realizations of ϕ respectively. This curves are no longer downward sloping in the volume of purchases because the average quality improve with the volume of intermediation.

Total expected profits for the financial system are also plotted in the bottom left panel. This curve is no longer downward sloping either. What's going on? With asymmetric information, financial firms are better-off with more intermediation from other firms because the quality of capital sold by financial firms is increasing in the volume. The increase in the average quality of units that are intermediated causes an increase the expected profits of financial firms.

The top right panel, plots the expected marginal profits per transaction given n aggregate amount of intermediation ω. The red and green curves correspond to marginal cost of injecting a unit of capital and the marginal benefit of paying dividends. The black curve again depicts the marginal value of an extra unit of capacity in the financial system. The equilibrium set of ω is again the set of points where the black curve is above the green line (it is not profitable to pay dividends) but under the red curve (it is neither profitable to inject more equity into the financial system). The key distinction between the exercises in this section and the previous one is possibility of multiple crossings for this curves. In the particular calibration of Figure ??, there are three intervals that characterize the equilibrium quantity. The bottom right panel also shows the maximal losses which correspond to he low realization of ϕ_L. The equilibrium set ω is supported by sufficient κ such that those losses are supported. The middle interval induces the same amount of losses in the worse case outcome of the shock ϕ_L. By assumption, this interval is not part of the equilibrium set because there are other choices of prices and quantities the deliver the same amount of losses in the worse draw for ϕ_L. For the same amount of financial capacity, financial firms can afford larger volume of intermediation and more competitive terms.

The interesting case is the set of equilibrium volumes of intermediation are given by the first and third intervals. The bottom right panel shows the corresponding equilibrium levels for κ. Thus, there are two equilibrium sets: a first set with low intermediation, large premia, a bad average of capital quality and a low capitalization of financial intermediaries. The profitability of the sector is low at these levels of intermediation. Therefore, there are no incentives to inject capital to financial firms. The second interval corresponds the good equilibrium. This region is characterized by a greater degree of financial intermediation with better capital and a stronger financial system.

The next section presents the model in a dynamic setup. In a dynamic setup, the financial system's capacity stochastically fluctuates between good and bad equilibrium, which are interpreted as financial crisis.

Lessons: There are some key lessons obtained by comparing the models with and without asymmetric information:

1. The expected return to capital in the financial system may be non-monotone in κ. In particular, there may exist equilibrium κ such that adverse selection effects are dominant.

2. Financial intermediation under asymmetric information is, as before, characterized by set of equilibrium aggregate net-worth, κ. Yet, the equilibrium set is not necessarily a connected interval but rather can be characterized by multiple unconnected sets. Asymmetric information generates non-monotonic expected profits of banks as a function of aggregate volumes of intermediation.

3. The non-monotonicity of expected profits in the financial system prevents the recapitalization of the financial system after large shocks. Large shocks can reduce the financial systems net-worth up to the point in which adverse-selection effects kick-in and the financial market conditions no longer justify the injection of capital on to the system.

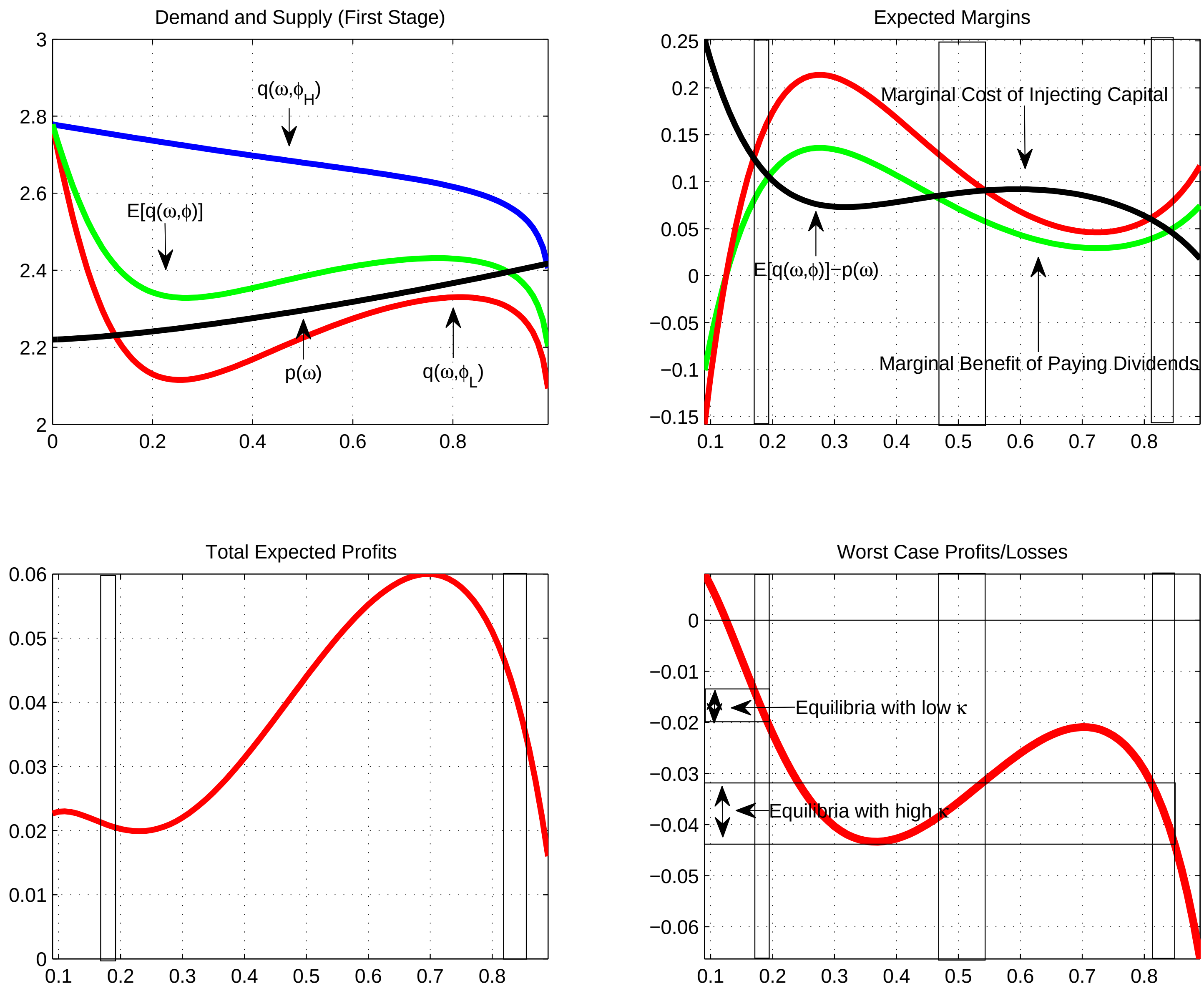


Figure 3: Equilibrium objects in Static Model with asymmetric information. The figure is constructed by setting parameters to: $\pi = 0.1$, $\beta = 0.97$, $\beta^f = 0.99$, $\tau_e = 0.1$, $\tau_d = 0.3$, $\epsilon = 0.5$, and f_ϕ are two exponential distributions with different support and variance and the same unconditional expectation.

4 Equilibrium

TBA

5 Policy

Two Externalities. This section discusses the effects of capital requirements. Two externalities merit their use. First, when bankers purchase capital, they consider risks and rewards, but act as price takers. They fail to internalize that, on aggregate, they affect κ. Although this is also true in frictionless models, here κ affects prices. In turn, prices affect the LLC so there is a pecuniary externality. Hence, a planner that controls Q directly, but is subject to the same constraints and equity/dividend policies, would consider the law of motion of κ in his decision. In particular, the planner may want to limit intermediation to avoid large losses and low prices.

The second externality is produced by the coordination failures. Coordination failures occur only in crises. Although a planner may not control equity injections directly, he may want to limit intermediation to make sure the economy falls to equity injection regions instead of crisis regions.

Effects of Capital Requirements. The impact of capital requirements can be studied through θ. Capital requirements have two effects. The first effect is the direct decrease in intermediation for a given κ by tightening of the LLC. The second is the effect on the dynamics of κ. Both effects show in the marginal value of bank equity, which now is:

$$\underbrace{\tilde{v}\left(X\right)}_{\text{Dynamic Effect}} = \hat{\beta}\left[\mathbb{E}[v_2^f(X')] + \underbrace{(1-\theta)}_{\text{Limit on Leverage}} \max\left\{\frac{\mathbb{E}[v_2^f(X')\Pi\left(X,X'\right)]}{-\min_{\tilde{X}}\Pi\left(X,\tilde{X}\right)},0\right\}\right].$$

In summary, a social planner will trade off the cost of a lower growth rate against the reduction in the probability of a crisis. Furthermore, a planner will also consider the change in the dynamics of κ.

The following two numerical exercises illustrate how these effects balance out and are motivated by ongoing policy debates on the optimal regulation of financial institutions (see Admati et al., 2011).

Invariant Distribution after Tightening of Capital Requirements. This section describes the effects of an increase in θ from 0.08 (Basel-II scenario) to 0.18 (Basel-III scenario).[7] Figure 4 presents the invariant distribution of κ for both scenarios. Table 1 shows the corresponding occupation and exit times obtained from these distributions. The Basel-III distribution has the bimodal shape of Basel-II, although there are some key differences. The distribution under Basel-III has a lower mass concentrated at the bottom because exit times are faster and the likelihood of entering a crisis state is lower. Second, the distribution under Basel-III is wider. The higher average levels of κ under Basel-III result from higher intermediation margins. In competitive inaction regions, a constraint in the quantity generates higher profits. Thus, although leverage is lower, the value of equity can increase due to higher margins and this generates higher average equity values. Through these measures, the economy seems more resilient under Basel-III.

Table 1: Comparison of Moments Under Basel-II and III in the Model.
The table plots some moments corresponding to values of θ equal to 0.08 (Basel-II) and 0.18 (Basel-III).

Variable	**Basel-II**		**Basel-III**	
	Unconditional	**Crisis**	**Unconditional**	**Crisis**
Occupation Time	100%	32.6%	100%	19.77%
Duration (quarters)	-	10.26	-	3.89
Average Growth Rate	4.3%	-10.3%	9.3%	-9.61%
Average κ	0.0659	0.0048	0.100	0.01

[7] Similar exercises are performed in Begenau (2014) and Bianchi (2011) in the context of international capital flows.

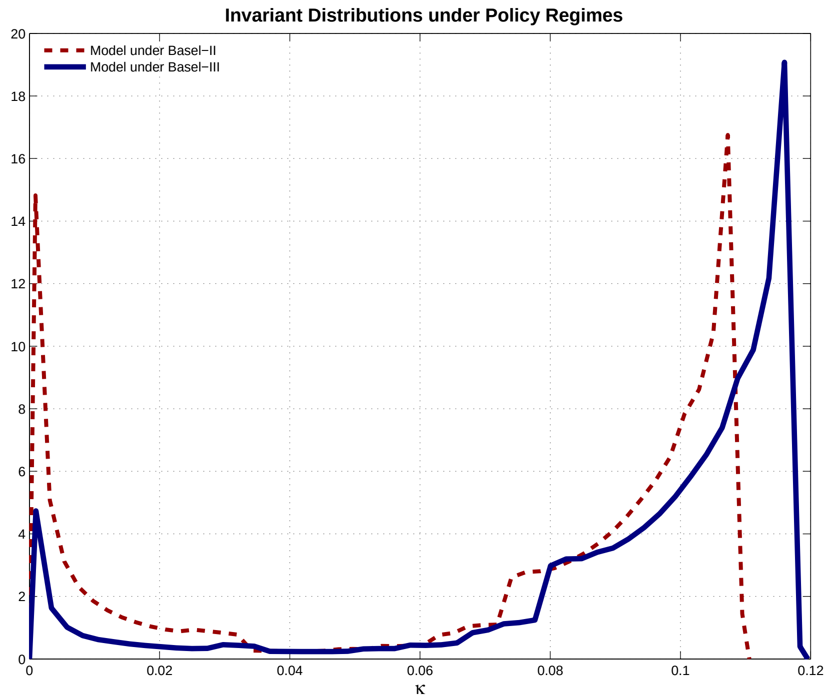


Figure 4: Invariant Distributions under Basel-II and III.

Timing of Capital Requirements. There is another important lesson: the timing of capital requirements matters. I illustrate this through an unexpected increase to Basel-III once the economy is in a typical Basel-II crisis. To show this, in Figure 5 I compare the average growth rate that results from the policy change with the growth rate if the economy remains under Basel-II.

There is a surprising result. The recovery under Basel-II is faster even though exit times are lower under Basel-III. Why? Exit times from the typical Basel-III crisis are shorter because the average Basel-III crisis is less severe. However, if the economy is already in a Basel-II crisis, the policy change only prolongs the decline because capital requirements depress intermediation, exacerbate adverse selection, and hurt growth. The model warns policy makers not to do in bad times what they

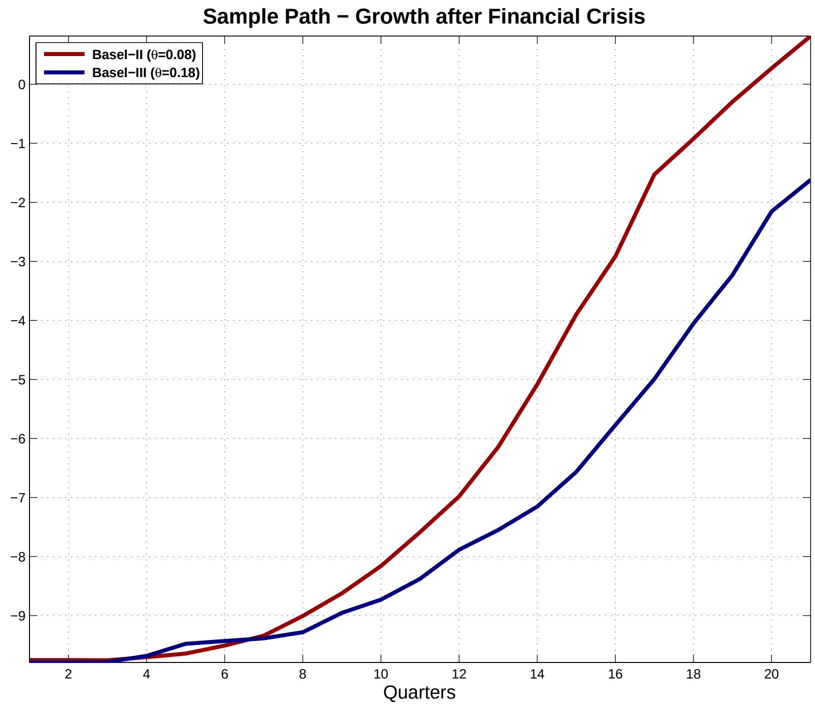


Figure 5: Expected Growth Recovery Path Under Basel-II and -III.

should have done in good times. In turn, this result suggests the use of pro-cyclical requirements, also proposed by Kashyap and Stein (2004).

6 Conclusion

This paper provides a theory about risky financial intermediation under asymmetric information. Financial markets where asymmetric information is a first-order friction are likely to be more unstable than otherwise. The source of instability is low profitability generated when intermediation is low. This force can also lead to coordination failures to recapitalize banks after large losses, even when resources are available. The financial crises that emerge are deep and long-lasting.

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