Credit, Capital and Crises: A Theory of Counter-Cyclical Macroprudential Policy*

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Abstract

This paper examines the role of macroprudential capital requirements in preventing inefficient credit booms. If banks care about their reputations, unprofitable banks have strong incentives to invest in risky assets and generate inefficient credit booms when macroeconomic fundamentals are good. We show that across-the-system counter-cyclical capital requirements that deter credit booms are constrained optimal when fundamentals are within an intermediate range. We also show that when fundamentals are deteriorating, a public announcement of that fact can itself play a powerful role in preventing inefficient credit booms, providing an additional channel through which macroprudential policies can improve outcomes.

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1 Introduction

One of the key elements of the Basel III framework is the countercyclical capital buffer. According to the Basel Committee on Banking Supervision (BCBS 2010), the primary aim of the countercyclical capital buffer regime is to use a capital cushion to achieve the broader macroprudential goal of protecting the banking sector from periods of excess aggregate credit growth that have often been associated with the build up of system-wide risk. In enhancing the resilience of the banking sector over the credit cycle, the countercyclical capital buffer regime may also help to lean against credit in the build-up phase of the cycle in the first place.

In the United Kingdom, the recent financial crisis has led to the creation of a new macroprudential framework. Under the new framework, the Financial Policy Committee (FPC) within the Bank of England is given the responsibility to operate macroprudential (i.e. 'across the system') policy instruments, in order to moderate credit cycles and enhance banking sector resilience (HMT 2010). Although the range of instruments at the FPC's disposal is yet to be determined, one of the main tools under consideration is counter-cyclical capital adequacy requirements.

This paper considers the role of macroprudential counter-cyclical capital adequacy regulation in moderating credit cycles and enhancing banking sector resilience using a global games model.[1] In our model, banks not only care about returns on their investment, but also their reputations. In particular, banks are assumed to suffer a bigger reputational loss if they fail to make money when macroeconomic fundamentals are good than when they are bad. This is because when fundamentals are good, high ability banks are more likely to earn high profits, such that markets attribute low profits to the low ability of bank managers. The fear of getting a bad market reputation gives low-ability bank managers the incentive to hide low profits and extend excessive credit in a bid to 'gamble for resurrection' when macroeconomic fundamentals are good, thus generating socially inefficient credit booms.

Our analysis suggests that there is a case for counter-cyclical capital adequacy requirements because the presence of the reputational effect means that banks' incentives to gamble are strongest when macroeconomic fundamentals are good. By helping to reduce the

[1] See Morris & Shin (2003) for a discussion of the theory of global games, and Morris & Shin (2000) for applications to macroeconomics.

incidence of inefficient credit booms, which ultimately lead to bank losses, counter-cyclical capital adequacy requirements help to meet the dual objectives of moderating credit cycles and enhancing banking sector resilience.

Higher aggregate capital adequacy requirements come at a cost however, as they also impose higher funding costs for those profitable, high-ability banks that do not have incentives to gamble. When the policymaker cannot observe banks' types *ex ante*, this generates a policy trade-off. In the absence of more targeted instruments, we demonstrate that, given this trade-off, counter-cyclical macroprudential capital adequacy regulation is constrained socially optimal when macroeconomic fundamentals are within an intermediate range, such that a higher capital requirement can deter gambling by some banks without imposing excessive costs on the rest of the banking sector.

Why is this not true over the whole domain of fundamentals? Intuitively, when fundamentals are very weak, most banks will be unprofitable and they have little need to gamble for resurrection in order to preserve their reputations. In this case, the regulator does not need to raise the capital adequacy requirement in response to a *modest* improvement in weak fundamentals as the direct costs outweigh the benefit derived from a small reduction in the probability of gambling. By contrast, when fundamentals are very good, many banks are profitable, and the remaining few unprofitable banks are not easily deterred from gambling by a moderate increase in capital requirements. Since the regulator cannot deter gambling by the minority without imposing a high cost on the rest of the banking sector, an increase in aggregate capital adequacy regulation is not socially optimal when fundamentals are extremely strong. In this case, our analysis suggests that instruments targeted with greater precision are needed.

We are also able to separate two effects of counter-cyclical capital requirements on banks' risk-taking incentives, namely (i) the direct effect of raising the cost of risk taking, and (ii) the indirect effect of making information about the state of macroeconomic fundamentals public. We demonstrate that the latter can have a powerful effect in reducing banks' risk-taking incentives when fundamentals are rapidly deteriorating. The publicly announced results of stress tests that look 'through the cycle' can therefore also help to achieve macroprudential policy objectives.

Our paper is related to a number of existing papers which analyse the impact of strategic interdependence on banks' risk-taking incentives, including Acharya (2009), Acharya & Yorulmazer (2008), and Aikman, Haldane & Nelson (2010). Our main contribution to this theoretical literature is to model credit and the role of capital adequacy regulation explicitly, so that we can characterize optimal counter-cyclical capital adequacy regulation. In our model, the rationale for counter-cyclical capital regulation arises because of a cross-sectional externality (reputational concerns) that means banks' risk-taking incentives rise during macroeconomic upswings. In this respect, the underlying distortion we model is close in spirit to that of Rajan (1994) in particular, but see also Gorton & He (2008), Scharfstein & Stein (1990), Froot, Scharfstein & Stein (1992), and Thakor (2006). This rationale is related to but distinct from those articulated by Bianchi (2010) and Lorenzoni (2008), who suggest that counter-cyclical capital requirements – or higher capital requirements on assets with higher correlation with macroeconomic shocks – could be desirable if private agents' failure to internalise the pecuniary cost of increasing leverage on *ex post* asset prices and others' collateral constraints leads to *ex ante* over-borrowing. It is also distinct from macroeconomic rationales that emphasise the hedging benefits derived from the issuance of outside equity by banks in general equilibrium, as in Gertler, Kiyotaki & Queralto (2011).

Our theory also offers empirical implications. For instance, our analysis predicts cross-sectional convergence of bank profits during credit booms as low ability banks' attempt to hide their low returns in order to mimic the high ability banks. Similarly, the finding by Drehmann, Borio, Gambacorta, Jiménez & Trucharte (2010) that credit-to-GDP ratio is a good leading indicator of banking crises can be explained by our theory that suggests that inefficient credit booms preceding banking crises are associated with gambling by those banks trying to mimic profitable banks.

This paper is organized as follows. Section 2 provides the most basic set up of the model, in which banks receive noisy signals about the macroeconomic fundamentals in deciding whether to gamble for resurrection or not. The analytical solution in this section helps us to illustrate how capital adequacy requirement affects banks' incentives to gamble and hence the credit cycles. We also discuss the empirical implications of our analysis. Section 3 explicitly analyzes the optimal counter-cyclical capital adequacy regulation, using a model in which banks receive both public and private signals about macroeconomic fundamentals. Section 4 discusses the policy implications of our analysis. Section 5 considers the effect of public announcement of the macroeconomic fundamentals – or 'moral suasion' – on banks' risk-taking incentives. Section 6 concludes.

2 The Model

We first set up a simple global games model in which those banks receiving low returns in the interim decide whether to gamble for resurrection in order to preserve their reputations, based on a private signal they receive about the macroeconomic fundamentals. This simple set up helps to illustrate the impact of the reputational considerations on banks' incentives to gamble, and how capital adequacy requirement affects these. We will characterize the optimal counter-cyclical capital adequacy requirement in Section 3.

2.1 Set up

The model consists of three dates, $t = 0, 1, 2$, and there is a continuum of *ex ante* identical banks. Each bank invests 1 at $t = 0$ in a risky project. A fraction k of the investment is funded by equity, while fraction $1 - k$ is funded by debt. We normalize the cost of debt to zero. The cost of employing equity financing is $c > 0$, such that the unit investment costs ck to fund.[2] The cost of equity is taken as given by the bank, and for the moment, we assume that k is exogenous. As we will illustrate in the next section, k can be used as a policy tool to prevent inefficient credit booms.

At $t = 1$, banks privately observe the return from an initial investment made in $t = 0$. A fraction α of banks are high ability and observe high returns R_H with probability $f(\theta)$, such that in the population as a whole, a fraction $\alpha f(\theta)$ of banks observe R_H. The remaining fraction of high ability banks observe low returns $R_L < R_H$. The parameter θ indexes macroeconomic fundamentals, which determine the fraction of high ability banks that observe high returns in the first period. We assume that $f'(\theta) > 0$, such that the fraction of high ability banks receiving high return increases as the macroeconomic fundamental, θ, increases. High ability banks observing R_H publicly announce these returns, raise new finance, and invest 1 unit for another period, at cost ck. Banks that have observed R_H from their $t = 0$ investments can be sure that their $t = 1$ investments will return R_H at $t = 2$.

[2] The cost of equity $c > 0$ could reflect the foregone tax advantage of debt. There could be other deadweight costs associated with equity issuance as opposed to debt issuance where the latter provides a monitoring advantage, e.g. Calomiris & Kahn (1991).

The fraction $1 - \alpha$ of low ability banks, together with the 'unlucky' fraction of high ability $\alpha [1 - f(\theta)]$ banks observe $R_L < R_H$ at $t = 1$, such that in the population as a whole, a fraction $1 - \alpha f(\theta)$ of all banks observe R_L. If a bank chooses to announce the true profit of R_L, it is unable to raise new finance to invest at $t = 1$. But given that interim returns are observed privately, banks observing R_L can mimic lucky high ability types by announcing R_H, too. They can then raise new finance at cost ck, and invest 1 unit: this investment constitutes 'gambling for resurrection'. In particular, having observed low returns, investing in a subsequent project yields a $t = 2$ return of $2R_H - R_L$ with probability $b \in [0, 1]$, such that at $t = 2$, total announced profits are $2(R_H - ck)$, which are exactly the same as those of the lucky high ability banks. But the gamble could fail. With probability $1 - b$, banks lose all of their $t = 1$ profits, such that they have to announce zero profits in $t = 2$. We assume that the probability of the $t = 1$ gamble being successful is independent of a bank's ability, whereas the probability of the $t = 0$ investment being successful depends on a bank's ability. We think of the gambling option as a highly risky short-run strategy whose return distribution is invariant to the characteristics of those who execute it. Because following such a strategy requires that the bank raises finance and invests twice over, we also think of this as implying 'rapid balance sheet expansion'.

Banks that fail to announce a final profit of $2(R_H - ck)$ at $t = 2$ suffer reputational damage $p(\theta, l)$, where $l \in [0, 1]$ is the proportion of banks that take the risky gamble having observed initial returns of R_L. A banker's reputation is assessed by the market, which cannot observe ability or fundamentals. Reputational damage has the following properties: (a) $\partial p(\theta, l)/\partial\theta > 0$, so that as fundamentals improve, the reputational cost for announcing low returns increases; and (b) $\partial p(\theta, l)/\partial l > 0$, so that as the proportion of banks taking the risky gamble increases, the reputational damage of announcing low returns increases. Property (a) follows from the observation that as θ rises, high ability types are more likely to receive high initial returns. In the extreme case where $f(\theta) = 1$, all high types always announce high returns; so announcing low returns is a sure signal that ability is low. Property (b) follows from the fact that as the proportion of banks announcing interim low returns for sure decreases, the reputational penalty to any remaining bank doing so increases, as this signals low ability for sure. It could also follow from explicit 'peer benchmarking' in employment contracts.[3] Foster & Young (2010), for example, argue that there is no compensation contract that can separate high ability managers from low ability managers when managers' strategies and positions are not transparent.

In making a decision about whether to gamble for resurrection, banks have to make an assessment of whether other banks will also gamble, as their reputational cost of announcing low returns will depend on what others will do. In making this decision, each bank $i \in [0, 1]$ receives a noisy private signal x_i about fundamentals at $t = 1$:

$$x_i = \theta + \sigma\varepsilon_i, \quad \sigma > 0,$$

where the noise terms are distributed with density $g(.)$ with support on the real line. Given this set up, a bank's expected payoff from gambling at $t = 1$ is:

$$b[2(R_H - ck)] + (1 - b)[-2ck - p(\theta, l)],$$

whereas the payoff to playing safe is

$$R_L - ck - p(\theta, l).$$

From a social perspective, gambling for resurrection is inefficient if

$$b < \frac{R_L + ck}{2R_H}, \tag{1}$$

i.e. if the gamble is sufficiently risky. We assume condition (1) holds throughout our analysis. Taken together, the game gives a banker's marginal payoff to gambling $\pi(\theta, l)$ as

$$\pi(\theta, l) = b[2R_H + p(\theta, l)] - R_L - ck. \tag{2}$$

Figure 1 summarizes the timing and the payoffs of the game. Note that in our set up, reputational considerations generate a source of strategic interdependence between banks' actions: each banker has a stronger incentive to gamble when (s)he believes that others are

[3] In the appendix A.6, we discuss a small change to the model set up under which $p(\cdot)$ can be thought of as the probability assigned by the market of the banker being low ability conditional on failing to achieve high returns. In our main analysis, we prefer to keep the functional form for $p(\cdot)$ general, such that it can be interpreted flexibly to account for different types of 'relative return' friction.

doing the same. So the reputational consideration is the friction which induces banks to take the socially inefficient action of gambling for resurrection and generates inefficient credit booms: in its absence, banks will never choose to gamble, as $\pi(\theta, l)$ will always be negative by equation 1.

'Reputation' should be interpreted as a metaphor, which is designed to capture bankers' aversion to admitting to bad results when everyone else is doing well. There are several reasons why bankers may behave in this way. First, their compensation, promotion and dismissal – as well as their ability to secure another job – may be implicitly or explicitly linked to their performance relative to others in the industry: indeed, a banker's performance relative to others in the industry is a good signal of their ability when the banking industry is subject to a common shock.[4] Murphy (1999), updating Gibbons & Murphy (1990), finds that CEO pay in financial services is likely to be evaluated relative to market and industry returns among S&P500 financial services companies. Explicit relative performance evaluation is used by 57% of the financial services firms in Murphy's (1999) survey.[5] Second, policymakers' inclination to bail out banks when they fail together than when they fail in isolation – due to their concerns about systemic risk associated with multiple bank failures – may also give bankers the incentive to avoid failure by gambling when other banks are doing well.[6]

Our story also relies on imperfect information about fundamentals and ability. Empirically, Slovin, Sushka & Polonchek (1992) find that market participants take individual bank stock issuance as signals of value for other banking firms. In particular, commercial bank equity issues are associated with a significant negative valuation effect of -0.6% on rival commercial banking firms. Slovin et al. (1992) interpret this as evidence that an individual bank's issuance conveys not just institution-specific information to the market, but industry-wide information regarding fundamentals too. That is, information released by one bank conveys information to the market about industry value, which triggers a re-appraisal of other banks' market values. Rajan (1994) also finds evidence in favour of cross-bank informational effects.[7] When benchmarking in compensation ties individual incentives to relative

[4]Holmstrom (1982) argues that relative performance evaluation is useful if agents face some common uncertainty, such that other agents' performance reveals information about an agent's unobservable choices that cannot be inferred from his or her own measured performance.

[5]See Table 9, p. 2538.

[6]See, for example, Acharya & Yorulmazer (2008).

[7]Rajan examines the cross-bank effects resulting from Bank of New England Corp.'s announcement that, prompted by the regulator, it would boost loan loss reserves in response to growing losses in 1989. Banks with headquarters in one state in New England suffered disproportionate cumulative abnormal returns of -8%.

performance, these informational externalities generate strong incentives to herd.

2.2 The symmetric switching equilibrium

We analyze the problem faced by a bank who has observed low initial returns. At this juncture, it has to choose an action {gamble, safe} to maximize its expected payoff. Suppose that a bank that has received R_L and signal x_i at $t = 1$ uses the following switching strategy:

$$s(\bar{\theta}) = \{\text{gamble if } x_i \geqslant \theta^*, \text{ don't if } x_i < \theta^*\}.$$

Using equation 2 and the results in Morris and Shin (2003), we can prove the following:

Proposition 1 *The unique symmetric switching equilibrium value of fundamentals θ^* above which banks coordinate on gambling following low initial returns is given implicitly by:*

$$\int_0^1 p(\theta^*, l)dl = \frac{R_L + ck - 2bR_H}{b}.$$

Proof. See Annex A.1. ■

Consider a simple example, in which $p(\theta, l) = \theta + l - 1$. Then θ^* is given by

$$\theta^* = \frac{1}{2} + \frac{R_L + ck}{b} - 2R_H. \tag{3}$$

Note that the gambling threshold θ^* is increasing in k, the capital held by banks. This is very intuitive: a bank has a weaker incentive to gamble if it has to finance a higher proportion of the new lending by costly capital, as it diminishes the expected return from gambling relative to playing safe. Thus, a bank with a higher level of capital tends to play safe even if their private signal points to relatively strong fundamentals. Were the gamble to pay off with a higher probability (i.e. b is high), this effect would be mitigated: banks would then choose to gamble even if their private signal suggests fundamentals are low, as they are more likely to be able to avoid a reputational penalty; thus, θ^* would fall. Note that our model assumes unlimited liability, so the mechanism via which higher capital reduces risk taking in our model is different from that in Furlong & Keeley (1989) and Tanaka & Hoggarth (2006), in

Using data on real estate firms, Rajan argues that the announcement conveyed information to the market about the state of the New England real estate sector in general, rather than conveying only institution-specific information in particular.

which banks' risk-taking incentives arises from the implicit subsidy from (mis-priced) deposit insurance or limited liability.

These results are quite general for $p(\cdot)$ with the properties we described above. Therefore, we write $\theta^* = \theta^*(k)$, in which:

$$\frac{\partial \theta^*(k)}{\partial k} > 0,$$

such that higher bank capital raises the threshold level of the private signal above which banks take the gambling option.

2.3 Empirical implications

This simple private signals model has a number of empirical implications. We focus on two. First, reputational incentives drive low ability banks to gamble when macro fundamentals are sufficiently high. This generates an inefficient credit boom in the model, which is followed by the realization of large scale losses. In other words, credit booms should precede crises, and even small changes in fundamentals can have a large impact on the path for credit. Work by Drehmann et al (2010) supports this view, arguing that the ratio of credit to GDP can be a useful indicator of subsequent distress. In Figure 2, we plot the ratio of credit to GDP for the UK, since 1963. The series have been filtered using a band-pass filter, which isolates variation in the ratio over a particular frequency range. Consistent with Drehmann et al (2010) and Aikman et al (2010), we show variation in the ratio of credit to GDP over the 1-20 year frequency range.[8] Shaded regions indicate periods of banking distress, namely, the 1973-5 secondary banking crisis, the 1990-4 small banks crisis[9], and the recent episode. The figure illustrates that a medium-term build up in the ratio of credit to GDP has tended to lead crisis periods.

Second, on the microeconomic level, the efforts of low ability banks to mimic their high ability counterparts implies a compression in the distribution of announced profits during credit booms. It is during these periods that standing out from the crowd is most damaging to reputation. Figure 3 plots the cross-sectional dispersion of equity returns for major UK

[8]This is equivalent to passing a relatively 'smooth' trend through the series. An HP filter with a high value of the smoothing parameter would achieve this. We use a band pass filter because it allows us to be more precise about the band of the frequency domain over which the filter returns cyclical variation.

[9]In the early 1990s, the Bank of England provided liquidity support to a few small banks in order to prevent a widespread loss of confidence in the banking system. 25 banks failed or closed during this period. The emergency liquidity assisstance provided by the Bank is regarded as having safeguarded the system as a whole, which was vulnerable to a tightening in wholesale markets. See Logan (2000) for discussion.

banks and the top 100 UK private non-financial corporations (PNFCs) for 1997-2009. It is striking that the cross sectional dispersion tended to be lower for banks versus PNFCs for much of the period, despite banks operating at much higher levels of leverage. Further, this compression reached its nadir in the boom years of 2004-7. This phase maps our model, which says that standing out from the crowd is worst for reputation in a boom, to the micro data. A similar story is told in Figure 4, which shows the cross-sectional dispersion in the return on equity (ROE) for major UK banks versus PNFCs.

We turn next to an examination of what policy actions might contribute to mitigating the inefficient credit booms that the model predicts. To do that, we extend our model to include a policymaker explicitly.

3 Capital adequacy regulation

3.1 Game with public and private signals

Let us now consider how a regulator may set k, which can be interpreted as the regulatory capital adequacy requirement. To do that, the regulator needs to know the distribution of θ, such that (s)he can estimate what proportion of banks would receive low returns and hence would potentially have incentives to gamble at time $t = 1$. So suppose now that $\theta \sim N(y, \tau^2)$, and that all agents in the model (including the regulator) observe this distribution. The distribution of fundamentals is therefore a public signal. The regulator sets the capital adequacy requirement, k^*, at $t = 0$, which applies to investments made at both $t = 0$ and $t = 1$, so as to maximize social welfare. The rest of the game's set up is as before, as illustrated in Figure 5.

We solve the model backwards, first working out banks' strategies at $t = 1$ given that they now observe a public signal about $\theta \sim N(y, \tau^2)$ (namely, its distribution) in addition to the private signal, which we now assume follows the process $x_i = \theta + \varepsilon_i$, where $\varepsilon_i \sim N(0, \sigma^2)$. Given these two signals, a bank's posterior belief of θ conditional on the two signals will be normal with a mean of:

$$\bar{\theta} = \frac{\sigma^2 y + \tau^2 x}{\sigma^2 + \tau^2}, \tag{4}$$

and standard deviation

$$\sqrt{\frac{\sigma^2 \tau^2}{\sigma^2 + \tau^2}}.$$

Suppose banks that have received R_L at $t = 1$ use the following switching strategy:

$$s(\bar{\theta}) = \left\{\text{gamble if } \bar{\theta} \geqslant \theta^*, \text{ don't if } \bar{\theta} < \theta^*\right\}. \tag{5}$$

To solve for the equilibrium, assume a simple functional form for bank reputation, $p(\theta, l) = \theta + l - 1$. Following the solution method used by Morris and Shin (2003), we can prove the following:

Proposition 2 *There exists a unique symmetric switching equilibrium with cut-off* θ^**, where* θ^* *solves the equation:*

$$\theta^*(k, y) = \Phi\left\{\sqrt{\gamma}\left[\theta^*(k, y) - y\right]\right\} + \frac{R_L + ck}{b} - 2R_H, \tag{6}$$

in which $\Phi(\cdot)$ *is the normal cdf, as long as* $\gamma \equiv \frac{\sigma^2}{\tau^4}\left(\frac{\sigma^2+\tau^2}{\sigma^2+2\tau^2}\right) \leq 2\pi$.

Proof. See Annex A.2. ■

The condition $\gamma \leq 2\pi$ implies that the unique equilibrium exists only when the public signal is quite noisy relative to the private signal; Morris & Shin (2003) show that when this condition is violated, multiple equilibria can arise. Expression (6) defines banks' reaction function to the public signal about the fundamental, y, and the capital adequacy requirement, k. It can be shown that, by totally differentiating equation 6,

$$\frac{d\theta^*(k, y)}{dk} = \frac{c/b}{1 - \phi\left\{\sqrt{\gamma}\left[\theta^*(k, y) - y\right]\right\}\sqrt{\gamma}} > 0, \tag{7}$$

and

$$\frac{d\theta^*(k, y)}{dy} = \frac{-\phi\left\{\sqrt{\gamma}\left[\theta^*(k, y) - y\right]\right\}\sqrt{\gamma}}{1 - \phi\left\{\sqrt{\gamma}\left[\theta^*(k, y) - y\right]\right\}\sqrt{\gamma}} < 0, \tag{8}$$

in which $\phi(\cdot)$ is the normal pdf. Equation 7 says that, as before, a higher capital adequacy requirement increases the threshold of the private signal above which banks start gambling, and hence it helps to reduce the incidence of gambling. In addition, equation 8 says that a higher public signal y reduces the threshold of private signal at which banks start gambling. This is because the higher y, the more likely it is that other banks will also choose to gamble, and since all banks observe y, all banks know this. As such, each bank has an increased incentive to gamble even if his own private signal is low. Thus, a high public signal makes it more likely that banks will coordinate on the gambling equilibrium, all else equal.

3.2 The optimal capital requirement

We now consider how the policymaker might set the *aggregate* capital requirement which applies system-wide, to all banks. In setting the capital requirement, the policymaker faces the following trade-off. On the one hand, raising the capital requirement deters gambling by those banks that have received low profits in the interim, and thus leans against inefficient investments. On the other hand, it also increases the funding cost for all banks and thus reduces their payoffs, including for those which have received high profits in the interim and therefore have no incentive to gamble. Capital requirements set too high will also affect lending: beyond a certain point, raising k makes all payoffs negative, even those of lucky high ability banks.

To examine the optimal capital requirement, suppose that the policymaker chooses k to maximize social welfare, S, consisting of a weighted sum of banks' expected returns given their reaction function defined implicitly in equation 6:[10]

$$\begin{aligned} \max_k S(k,y) &= \alpha f(y) \times 2(R_H - ck) + [1-\alpha f(y)] \times X(k,\theta^*), \qquad (9) \\ \text{s.t. } \theta^* &= \theta^*(k,y), \end{aligned}$$

where

$$X(k,\theta^*) \equiv \Pr(\text{gamble})[b(2R_H - 2ck) + (1-b)(-2ck)] + \Pr(\text{safe})(R_L - ck).$$

The function $X(k,\theta^*)$ is the expected payoff of unprofitable banks, where Pr(safe) defines the probability of unprofitable banks playing the safe strategy, given the public and private signals about fundamentals and the capital requirement, while Pr(gamble) is defined

[10] We could incorporate a degree of policymaker aversion to the outcome of low return banks' decisions by modifying $S(\cdot)$ to be

$$S(k,y) = (1-\delta)\alpha f(y) \times 2(R_H - ck) + \delta[1-\alpha f(y)] \times X(k,\theta^*),$$

where parameter $\delta \in [0,1]$ captures the relative weight (s)he places on the outcome of the gambling game played by low return banks: $\delta = 1/2$ characterizes a risk-neutral policymaker who cares equally about the returns of profitable and unprofitable banks, whereas $\delta = 1$ characterizes a highly risk-averse policymaker who cares only about deterring gambling by unprofitable banks. The main results we discuss would be qualitatively unaffected under this specification.

analogously. We show in the Annex that:

$$\Pr(\text{safe}) = \theta^*(k,y) - \frac{R_L + ck}{b} + 2R_H.$$

Note that the social welfare function in expression 9 is not a weighted sum of banks' utility functions. This is because the reputational effect, $p(\theta, l)$, is a private cost which induces banks to gamble for resurrection, so that the policymaker does not place any weight on it. Thus, the policymaker's objective as formulated in equation 9 can be interpreted as minimizing the banks' expected losses caused by gambling and inefficient credit booms, while avoiding the imposition of excessive funding costs on the entire banking system.

Solving for the policymaker's first order condition, the optimal capital requirement k^* – and hence the regulator's optimal choice of $\theta^*(k^*, y)$ – is given by the solution to the following (see Annex A.4):

$$[1 - \alpha f(y)] \frac{\partial \Pr(\text{safe})}{\partial k} (u^s - u^g) = c\left\{2 - [1 - \alpha f(y)] \Pr(\text{safe})\right\}, \tag{10}$$

where $u^g \equiv b(2R_H - 2ck) + (1-b)(-2ck)$ and $u^s \equiv R_L - ck$ are banks' returns from gambling and safe options, respectively, and:

$$\begin{aligned} \frac{\partial \Pr(\text{safe})}{\partial k} &= \frac{d\theta^*(k,y)}{dk} - \frac{c}{b} > 0, \\ u^s - u^g &= R_L - 2bR_H + ck > 0. \end{aligned}$$

The first order condition equates the marginal cost of increasing the capital requirement with the marginal benefit. The marginal cost of raising k is linear in c for all bank types across all states of the world. Since finance is raised twice by high return banks and gamblers, a 2 appears on the right hand side of equation 10, adjusted by the fraction $1-\alpha f(y)$ of low return banks that are expected to play it safe. The marginal benefit of higher capital requirements on in the left hand side of equation 10 captures the marginal social gain associated with reduced gambling by the $1-\alpha f(y)$ low return banks. In the Annex, we show that the second order condition is negative – and an interior solution exists – only when γ is sufficiently close to 2π, and k^*, which solves the first order condition, above gives rise to $\theta^*(k^*, y) > y$. Otherwise, we will have a corner solution, as we will illustrate later using simulations.

Is the optimal capital adequacy requirement counter-cyclical? We show that indeed it is, as long as macroeconomic fundamentals are within a certain range:

Proposition 3 *When the public signal about the macroeconomic fundamentals, y, is within a range, $y \in [\underline{y}, \bar{y}]$, and the public signal is neither too noisy nor too informative, $\gamma \in (\underline{\gamma}, 2\pi]$, the policymaker's optimal capital requirement k^* is procyclical, such that $\frac{dk^*}{dy} > 0$.*

Proof. See Annex A.5. ■

This is the core result of our paper. We turn next to an explanation of why it arises.

3.3 Simulations

We now show our results graphically in order to illustrate the intuition behind them. Figure 6 plots aggregate credit supply (expected at $t = 0$ for different values of y) under our baseline calibration[11]: this illustrates how a higher capital adequacy requirement can mitigate inefficient credit booms. The green dotted line in Figure 6 represents the efficient, 'no gambling' level of credit supply, given by $\alpha f(y) \times 2 + [1 - \alpha f(y)] \times 1$, which rises gently with y. The blue and the red lines show the aggregate credit supply with gambling, $\alpha f(y) \times 2 + [1 - \alpha f(y)] \times \{\Pr(\text{safe}) \times 1 + [1 - \Pr(\text{safe})] \times 2\}$, for different levels of capital requirements, $k = 10\%$ and $k = 20\%$, respectively. As the blue and the red lines show, banks' gambling incentives generate inefficient credit booms when fundamentals are high; and a higher capital requirement mitigates inefficient credit booms by increasing the range of fundamentals in which banks choose not to gamble, and by reducing gambling for any given level of fundamentals.

Our analysis points to a particular view of the 'transmission mechanism' of capital regulation. The model suggests that risky gambling requires fast balance sheet expansion: low initial return banks must raise funds twice over in order to finance their gambling for resurrection.[12] That rapid balance sheet expansion is an indicator of potential future stress in our model is reminiscent of the recent experience. In this context, a capital requirement

[11] We use $\{\alpha = 0.8, b = 0.09, c = 0.15, R_L = 1, R_H = 2, \sigma = 0.5, \tau = 0.414, f(z) = \left(1 + e^{-z}\right)^{-1}\}$. Clearly, the quantitative features of the simulations will depend on the logistic form we have chosen for $f(.)$. But note that the foregoing theoretical results do not make an assumption about the form for $f(.)$ other than that it is increasing.

[12] High return-high ability banks also raise finance and invest twice over, also expanding their balance sheets 'rapidly'. But when gambling by low return banks takes place, the aggregate banking sector balance sheet expands more rapidly than when gambling by low return banks does not occur.

penalises at the margin low return banks whose choice to gamble requires them to raise extra funds. Higher capital requirements imply that these marginal funds are more costly as long as $c > 0$ (e.g. debt has a tax advantage).

Figure 7 plots the optimal capital adequacy requirement k^*, for a different range of the public signal about the fundamentals, y, under our baseline calibration. As this shows, the optimal capital requirement is zero when y is below a threshold, but pro-cyclical for an intermediate range of y, and then becomes zero again when y is above a certain threshold.

To understand why this is the case, note that capital requirements have a non-linear impact on banks' incentives to gamble, as Figure 8 illustrates. When the capital requirement is low, almost all banks gamble in expectation, whereas when it is high, almost all of them are expected to choose to play safe. In the intermediate range of k, a small increase in capital requirements will lead to a rapid reduction in gambling as banks switch from gambling to playing safe. As y becomes larger, banks' incentives to gamble becomes greater, and hence a higher capital requirement is needed to deter gambling.

As a result, the social benefit of increasing k is non-linear. By contrast, the cost of increasing k is linear given the opportunity cost of raising capital c. Consequently, the social welfare function (9), is not globally concave, as shown in Figure 9. This is why we have corner solutions for some range of y.

The comparative statics are intuitive, too. For instance, as the cost of raising equity, c, falls, it becomes optimal for the regulator to set a higher capital requirement for any given y (see Figure 10). Moreover, the optimal capital requirement becomes more strongly counter-cyclical as c falls.[13]

4 Discussion

4.1 The Policy Problem

Our analysis clearly illustrates the trade-off facing the policymaker in setting an aggregate countercyclical capital adequacy requirement. In our model, as fundamentals improve, more banks become genuinely profitable, and this gives those banks that turned out to be

[13]Similarly, when the policymaker's objective is characterised by a concern for low return banks, which is increasing in parameter δ, we can show that as δ rises – i.e. the regulator becomes more concerned about the social cost associated with gambling – the optimal capital adequacy requirement becomes more stringent *and* more strongly counter-cyclical.

unprofitable the incentive to gamble for resurrection to preserve their reputation. This triggers an inefficient credit boom. To prevent this, the policymaker can raise the aggregate capital adequacy requirement which raises the cost of gambling for banks. However, this also raises the cost of investment for all banks, including those successful high ability banks, which do not have the incentive to gamble. Although it is optimal for policymakers to raise the capital adequacy requirement as macroeconomic fundamentals improve for some range of fundamentals, there will be a point at which the marginal benefit of deterring gambling by some banks through a higher capital adequacy requirement becomes less than the marginal cost of increasing funding cost for all banks. This is where an aggregate capital adequacy requirement loses traction.

Thus, 'across-the-system' counter-cyclical capital requirements can only achieve a 'constrained' optimum; and so, when macroeconomic fundamentals are very strong, instruments which target specific risk-taking activities may be needed in order to prevent an inefficient credit boom. In the context of our model, it would of course be more efficient to increase capital requirements only for those banks that have the incentives to gamble (i.e. those that have observed R_L in the interim), than imposing a higher requirement across the banking sector; but this requires the policymaker to be able to observe banks' balance sheets accurately and determine which subset of banks are likely to gamble. Although obtaining detailed information about banks' balance sheets and investment strategies is likely to be a costly exercise, our analysis highlights the limitation of aggregate counter-cyclical capital requirements and suggests that investing in acquiring more detailed information in order to design targeted instruments may be particularly desirable during boom times.

Note that the objective of the policymaker in our formulation is to maximise average bank returns. The policymaker achieves this by setting a capital requirement that leans against value-destroying gambles. An alternative, distinct form of policy objective, which is important in practice, is that of financial *resilience*. Were resilience per se valued by the policymaker, (s)he is unlikely to want to cut the capital requirement to zero for $y > \overline{y}$. Hence a resilience objective in combination with a cyclical objective would likely eliminate the 'second trigger' discontinuity in our model at $\overline{y}$, replacing it instead with a smooth function of k in y. We intend to investigate this additional objective in future work.

4.2 Limited Liability

In our analysis, we have abstracted from the distortions caused by limited liability in order to focus on the role of a 'relative return friction' - in our case generated by reputational concerns - on risk-taking incentives. The standard arguments around limited liability would imply the addition of a further distortion to our model, which would tend to reinforce the proclivity of bankers concerned about their reputations to take excessive risk. If the write-downs suffered by equity holders were shifted to some other agent (e.g. the government) when risky gambles fail or when low returns are announced, the marginal incentive to gamble in the private signals game becomes[14]

$$\pi(\theta, l) = b[2R_H + p(\theta, l)] - 2bck.$$

When $p(\cdot)$ takes the linear form above, the corresponding limited liability ('LL') cut-off becomes

$$\theta^*_{LL} = \frac{1}{2} + 2ck - 2R_H,$$

which falls below θ^* (equation 3) whenever $b < (R_L/2ck) + (1/2)$. Hence, intuitively, limited liability would enhance incentives to gamble in our model. Increases in the capital requirement would continue to disincentivise gambling, by $\partial\theta^*_{LL}/\partial k > 0$.

4.3 Pecuniary spillovers

We have also abstracted from pecuniary spillovers that may operate through asset values. Such spillovers can generate reductions in measured risk, relaxing value-at-risk constraints, or bring about mark-to-market increases in net worth, both of which can lead to an endogenously generated elevated incentive for balance sheet expansion (see e.g. Adrian & Shin (2010)). A simple way to include such an effect in our model would be as follows. Suppose that the risky gambles undertaken by low return banks bid up the collateral values of the (ultimately loss-making) projects in which they invest. In this way, the larger is the proportion of gamblers, the smaller the loss faced by unsuccessful gambles. Let the loss associated with a failed gamble by $\zeta l - 2ck < 0$ (where in our baseline model we set $\zeta = 0$ for all l

[14] Since then the payoff to a failed gamble is simply $-p(\theta, l)$ as is the payoff to announcing low returns when $R_L - ck < 0$.

when a gamble fails). The parameter $\zeta \geq 0$ measures the extent of the positive pecuniary spillover that arises from gambling. Using this in the private signals model yields a marginal gambling incentive of

$$\pi'(\theta, l) = b\left[2R_H + p(\theta, l) + \frac{1-b}{b}\zeta l\right] - R_L - ck.$$

In the private signals game, the cut-off then becomes

$$\theta_g^* = 1 - \left[1 + \frac{1-b}{b}\zeta\right]\frac{1}{2} + \frac{R_L + ck}{b} - 2R_H,$$

such that $\theta_g^* = \theta^*$ only when $\zeta = 0$. In the presence of pecuniary spillovers, such that $\zeta > 0$, the cut-off falls ($\theta_g^* < \theta^*$), and risk-taking is more likely. Once more, this would reinforce the case for capital regulation, which would lean against the pecuniary effects through $\partial\theta_g^*/\partial k > 0$.

5 The role of public information: can 'moral suasion' work?

We turn next to the role of public information in our model. We separate out the two effects of counter-cyclical capital requirements on banks' risk-taking incentives, namely (i) the direct effect of raising the cost of risk taking, and (ii) the indirect effect of making information about the state of macroeconomic fundamentals public – for example, via the publication of the Bank of England's *Financial Stability Report*. If in our set up, banks were not to observe y directly, but were instead to find out y only because the regulator announces it in order to explain their choice of counter-cyclical capital requirements (and that the regulator can be trusted to announce the true state of y), capital adequacy requirements would affect banks' gambling incentives through two distinct channels. First, higher capital adequacy requirements would increase the cost of gambling directly. Second, information about y would play a role in coordinating banks' actions between gambling and non-gambling equilibria.

To distinguish these two effects, Figure 11 plots the switching point, θ^*, in the game where banks only have private information (given by equation 3), and in the game where they are also given public information about y (given by equation 6); all the other parameters, including k, are held constant. Thus, the gap between the two lines gives us the marginal effect of public information on banks' risk-taking incentives for different values of y. As the figure illustrates, public information has a powerful effect in deterring gambling when y is low. This suggests that 'moral suasion' – i.e. telling banks to stop taking risks – can potentially act as a powerful deterrence when the fundamentals are deteriorating and the policymakers' warning is thought to reveal accurate information about fundamentals.

By contrast, telling banks that fundamentals are currently good can have a counter-productive effect of encouraging them to coordinate to the gambling equilibrium, when the lack of detailed information about banks' risk-taking activities prevents policymakers from implementing a targeted policy. So how should policymakers communicate when fundamentals are good? If future fundamentals are affected by banks' current risk-taking decisions[15] then an effective communication strategy for policymakers might be to highlight the future risks to the banking system created by banks' current risk-taking. For instance, the public release of stress test results could serve this purpose. Although our static framework does not allow us to model explicitly the impact of future fundamentals on banks' current risk-taking incentives, banks in the real world make long-term investments which are affected by current as well as future fundamentals, and it is plausible that future fundamentals are endogenous to banks' current risk-taking, as losses caused by unproductive investments could ultimately lead to a banking crisis and a large output loss. In this sense, publicly announcing the results of stress tests can serve as a macroprudential policy tool in itself to the extent that stress tests 'look through' contemporaneous exuberance to reveal underlying fragilities. The macroprudential toolkit can therefore operate both directly on costs (through k), and indirectly on beliefs, which affect outcomes in a world of imperfect information.

6 Conclusions

This paper contributes to the nascent literature on macroprudential regulation by articulating the trade-off faced by policymakers in setting counter-cyclical capital adequacy requirements when banks have the incentives to make high-risk, high-return investments in order to maintain their reputations. We show that counter-cyclical capital adequacy requirements are socially optimal for an intermediate range of fundamentals but not when fundamentals

[15] Rajan (1994) makes such an assumption, as does Aikman et al (2010). Current lending to impaired borrowers could impair bank capital, contstraining intermediaries' future ability to lend to fund productive investment, leading to declining output, see e.g. Gertler & Karadi (2010) and related models.

are either very weak or very strong. In the intermediate range, improved fundamentals imply high ability banks perform well. In order to safeguard their reputations, low ability banks then have an increased incentive to gamble – to 'keep up with the Goldmans'. Optimal macroprudential policy works against this incentive by raising the cost of gambling as fundamentals improve.

When fundamentals are very weak however, few banks make profits and hence unprofitable banks have no incentive to gamble in order to preserve their reputations; thus, there is no need to increase capital adequacy requirements in response to a small improvement in fundamentals. And when fundamentals are very strong, most high ability banks make profits and hence the unprofitable banks have very strong incentives to gamble in order to avoid being labelled as 'low ability'; in this case, policymakers cannot deter gambling by the unprofitable banks without also imposing excessively high funding costs on high ability banks, which have no incentive to gamble. This suggests that, when fundamentals are very strong, the need for policymakers to invest in obtaining detailed information about banks' balance sheets and their investment strategies in order to devise targeted instruments is particularly strong.

Our analysis also clarifies the role of central bank communication in deterring gambling via its impact on banks' beliefs. In particular, we show that a warning by policymakers that the fundamentals are deteriorating can be effective in preventing inefficient credit booms when that warning is seen to reveal the true state of the fundamentals and thus helps to coordinate banks' beliefs to the efficient equilibrium. When fundamentals are good, policymakers may wish to focus on communicating the potential damage to future fundamentals and banks' profitability caused by their current risk-taking activities – for example by releasing stress test results or regular conjunctural analysis of financial stability issues.

Our analysis focuses on a particular role for capital adequacy requirements, namely, that of preventing banks from investing in risky projects that have negative net present value. There are other rationales for counter-cyclical capital adequacy requirements which we have not considered here, including enhancing loss absorbance. Our analysis also focuses on the role of capital adequacy requirements in preventing inefficient credit booms, and does not examine its potential role in preventing inefficient credit crunches. Examining all these aspects of counter-cyclical capital requirements in a single framework is left for future research.

A Annex

A.1 Proof of Proposition 1

Our model already satisfies two conditions set out in Morris & Shin (2003), whose technology we subsequently employ, namely:

Condition 1: *Action Monotonicity*: By $\frac{\partial p(\theta,l)}{\partial l} > 0$, $\pi(\theta, l)$ is non-decreasing in l;

Condition 2: *State Monotonicity*: By $\frac{\partial p(\theta,l)}{\partial \theta} > 0$, $\pi(\theta, l)$ is non-decreasing in θ;

and we specify $p(\theta, l)$ is such that:

Condition 3: *Strict Laplacian State Monotonicity*: there exists a unique θ^* solving

$$\int_{l=0}^{1} \pi(\theta^*, l)dl = 0;$$

holds. Next, suppose $p(\cdot)$ implies that

Condition 4: There exist $\underline{\theta} \in \mathbb{R}, \overline{\theta} \in \mathbb{R}$ and $\varepsilon \in \mathbb{R}_{++}$, such that (a) $\pi(\theta, l) \leq -\varepsilon$ for all l and for $\theta < \underline{\theta}$; and (b) $\pi(\theta, l) > \varepsilon$ for all l and $\theta > \overline{\theta}$.

This condition implies that, for sufficiently low (high) values of fundamentals, choosing the safe (risky) option having observed low returns is a dominant action regardless of the aggregate proportion of banks that do so too. In the intervening interval, the dominant action depends on the proportion of banks that follow that action too. Finally, we require that

Condition 5: *Continuity*: $\int_{l=0}^{1} g(l)\pi(x, l)dl$ is continuous with respect to signal x and density $g(.)$.

Condition 6: *Finite expectations of signals*: $\int_{z=-\infty}^{\infty} zf(z)dz$ is well defined.

These six conditions ensure the model complies with the generic formulation of Morris & Shin (2003). We therefore use the following result, taken from their paper:

Lemma 1 *(Morris & Shin (2003), Prop. 2.2): Let θ^* be defined by Condition 3. For any $\delta > 0$, there exists $\overline{\sigma} > 0$ such that for all $\sigma < \overline{\sigma}$, if strategy s survives iterated deletion of strictly dominated strategies, then $s(x) = \{safe\}$ for all $x \leq \theta^* - \delta$ and $s(x) = \{gamble\}$ for all $x \geq \theta^* + \delta$.*

(We refer readers to Morris and Shin (2003) for the proof.). In words, this says that the support of fundamentals can be divided into two regions: one, for which $\theta < \theta^*$, in which banks coordinate on choosing the safe option conditional on observing low initial returns. Intuitively, fundamentals are not sufficiently high to cause severe reputational damage to announcing low returns when all other banks do so too. In the second region, in which $\theta > \theta^*$, high fundamentals imply a large degree of reputational damage to announcing low returns. Hence, all banks coordinate on the gambling option to minimize the reputational downside to having made a bad initial investment.

Lemma 1 and equation 2 together prove Proposition 1.

A.2 Proof of Proposition 2

(Morris & Shin (2003), Prop. 3.1): A banker who has observed a private signal x_i believes that any other player's signal x' is distributed normally with mean $\bar{\theta}$ and standard deviation

$$\sqrt{\frac{2\sigma^2\tau^2 + \sigma^4}{\sigma^2 + \tau^2}}.$$

Suppose that the bank believed that all other banks played a switching strategy of gambling if and only if $\frac{\sigma^2 y + \tau^2 x'}{\sigma^2 + \tau^2} > \theta^*$. Thus, the bank's belief about other banks' probability of gambling – and hence his best guess about l – is given by:

$$l = 1 - \Phi\left(\frac{\theta^* - \bar{\theta} + \frac{\sigma^2}{\tau^2}(\theta^* - y)}{\sqrt{\frac{2\sigma^2\tau^2+\sigma^4}{\sigma^2+\tau^2}}}\right). \tag{11}$$

We know that each bank's payoff from gambling is given by (2). Assuming a simple functional form $p(\theta, l) = \theta + l - 1$, its expected payoff from gambling is now given by:

$$\pi(\bar{\theta}, \kappa) = b\left\{2R_H + \bar{\theta} - \Phi\left(\frac{\theta^* - \bar{\theta} + \frac{\sigma^2}{\tau^2}(\theta - y)}{\sqrt{\frac{2\sigma^2\tau^2+\sigma^4}{\sigma^2+\tau^2}}}\right)\right\} - R_L - ck.$$

A symmetric equilibrium with switching point θ occurs exactly when $\pi^*(\theta, \theta) \equiv \pi(\theta, \theta) = 0$, where

$$\begin{aligned} \pi^*(\theta, \theta) &= b\left\{2R_H + \theta^* - \Phi\left(\frac{\sigma^2(\theta^* - y)}{\tau^2\sqrt{\frac{2\sigma^2\tau^2+\sigma^4}{\sigma^2+\tau^2}}}\right)\right\} - R_L - ck \qquad (12) \\ &= b\left\{2R_H + \theta^* - \Phi\left[\sqrt{\gamma}(\theta^* - y)\right]\right\} - R_L - ck, \end{aligned}$$

where

$$\gamma \equiv \frac{\sigma^2}{\tau^4}\left(\frac{\sigma^2 + \tau^2}{\sigma^2 + 2\tau^2}\right).$$

As Morris and Shin (2001) illustrate, this game has a unique equilibrium if and only if (12) is strictly increasing in θ^*. The necessary condition for this is

$$\frac{d\pi^*}{d\theta^*} = b\left[1 - \sqrt{\gamma}\phi(\theta^* - y)\right] \geq 0.$$

Since the normal density $\phi(x)$ reaches its maximum at $\frac{1}{\sqrt{2\pi}}$, the above condition holds as long as $\gamma \leq 2\pi$. Assuming that this condition holds, the unique switching equilibrium θ^* solves:

$$\theta^* = \Phi\left[\sqrt{\gamma}(\theta^* - y)\right] + \frac{R_L + ck}{b} - 2R_H.$$

A.3 Derivation of Pr(safe)

Given banks' strategy, the probability of a bank gambling in the symmetric switching equilibrium is given by l in (11) when $\theta^* = \bar{\theta}$. Thus, the probability of a bank which has observed R_L at $t = 1$ choosing to gamble is:

$$\Pr(\text{gamble}) = 1 - \Phi\left[\sqrt{\gamma}(\theta^* - y)\right],$$

where $\gamma \equiv \frac{\sigma^2}{\tau^4}\frac{\sigma^2+\tau^2}{\sigma^2+2\tau^2}$, and θ^* is given by (6). Rearranging (6) and substituting into the above gives:

$$\begin{aligned}\Pr(\text{gamble}) &= 1-\left[\theta^*(k,y)-\frac{R_L+ck}{b}+2R_H\right],\\ \Pr(\text{safe}) &= \theta^*(k,y)-\frac{R_L+ck}{b}+2R_H.\end{aligned}$$

A.4 The first and the second order conditions of the policymaker's maximisation problem

The policymaker's first order condition is given by:

$$\frac{\partial S(k,y)}{\partial k} = -\alpha f(y)2c + [1-\alpha f(y)]\frac{\partial X(k,\theta^*)}{\partial k} = 0, \tag{13}$$

where:

$$\frac{\partial X(k,\theta^*)}{\partial k} = -2c + c\Pr(\text{safe}) + \frac{\partial \Pr(\text{safe})}{\partial k}(u^s-u^g).$$

Re-arranging (13), we obtain the first order condition in the text, since

$$-\alpha f(y)2c - 2c[1-\alpha f(y)] + [1-\alpha f(y)]\left[c\Pr(\text{safe}) + \frac{\partial \Pr(\text{safe})}{\partial k}(u^s-u^g)\right] = 0.$$

The second order condition for the maximization problem is satisfied if and only if:

$$\frac{\partial^2 S(k,y)}{\partial k^2} = [1-\alpha f(y)]\frac{\partial^2 X(k,\theta^*)}{\partial k^2} < 0,$$

where

$$\frac{\partial^2 X(k,\theta^*)}{\partial k^2} = 2c\frac{\partial \Pr(\text{safe})}{\partial k} + \frac{\partial^2 \Pr(\text{safe})}{\partial k^2}(u^s-u^g),$$

Substituting in $\frac{\partial \Pr(\text{safe})}{\partial k} = \frac{d\theta^*(k,y)}{dk} - \frac{c}{b}$ and $\frac{\partial^2 \Pr(\text{safe})}{\partial k^2} = \frac{d^2\theta^*(k,y)}{dk^2}$, the SOC is satisfied iff:

$$\frac{\partial^2 X(k,\theta^*)}{\partial k^2} = 2c\left(\frac{d\theta^*(k,y)}{dk} - \frac{c}{b}\right) + (u^s-u^g)\frac{d^2\theta^*(k,y)}{dk^2} < 0. \tag{14}$$

From (7),

$$\frac{d^2\theta^*(k,y)}{dk^2} = \frac{-c/b \times \gamma^{3/2}\left[\theta^*(k,y)-y\right] \times \phi\left\{\sqrt{\gamma}\left[\theta^*(k,y)-y\right]\right\}}{\left(1-\phi\left\{\sqrt{\gamma}\left[\theta^*(k,y)-y\right]\right\}\sqrt{\gamma}\right)^2} \times \frac{d\theta^*(k,y)}{dk}.$$

The last line uses $\phi'(x) = -x\phi(x)$. The LHS of (14) becomes

$$\frac{\sqrt{\gamma}\frac{c^2}{b}\phi\left\{\sqrt{\gamma}\left[\theta^*(k,y)-y\right]\right\}}{1-\phi\left\{\sqrt{\gamma}\left[\theta^*(k,y)-y\right]\right\}\sqrt{\gamma}}\left\{2-(u^s-u^g)\frac{(1/b)*\gamma\left[\theta^*(k,y)-y\right]}{\left(1-\phi\left\{\sqrt{\gamma}\left[\theta^*(k,y)-y\right]\right\}\sqrt{\gamma}\right)^2}\right\},$$

where $\frac{\sqrt{\gamma}\frac{c^2}{b}\phi\left\{\sqrt{\gamma}[\theta^*(k,y)-y]\right\}}{1-\phi\left\{\sqrt{\gamma}[\theta^*(k,y)-y]\right\}\sqrt{\gamma}} \geq 0$. If $\gamma = 0$, this becomes zero; but as $\gamma \to 2\pi$, the SOC becomes negative as long as $\theta^*(k,y) > y$. In other words, as long as γ is sufficiently large (i.e. the public signal is quite precise relative to the private signal), the SOC is satisfied of the policymaker's optimal choice is to set k^* such that $\theta^*(k^*,y) > y$.

A.5 Proof of Proposition 3

For there to be a case for countercyclical capital adequacy requirement, i.e. $\frac{dk^*}{dy} > 0$, it must be the case for the relevant range of y (i.e. $y < \bar{y}$) that $\frac{\partial^2 S(k,y)}{\partial k \partial y} > 0$. From (13),

$$\frac{\partial^2 S(k,y)}{\partial k \partial y} = -\alpha f'(y)2c - \alpha f'(y)\frac{\partial X(k,\theta^*)}{\partial k} + [1-\alpha f(y)]\frac{\partial^2 X(k,\theta^*)}{\partial k \partial y},$$

where $f'(y) > 0$. Evaluated at k^* given by FOC (13),

$$\frac{\partial X(k,\theta^*)}{\partial k} = -\frac{(1-\delta)\alpha f'(y)2c}{\delta \alpha f'(y)}.$$

So

$$\frac{\partial^2 S(k,y)}{\partial k \partial y} = [1-\alpha f(y)]\frac{\partial^2 X(k,\theta^*)}{\partial k \partial y}.$$

So the necessary and sufficient condition for countercyclical capital adequacy requirement is $\frac{\partial^2 X(k,\theta^*)}{\partial k \partial y} > 0$.

Note that

$$\frac{\partial X(k,\theta^*)}{\partial k} = -2c + c\Pr(\text{safe}) + \frac{\partial \Pr(\text{safe})}{\partial k}(u^s - u^g),$$

so

$$\frac{\partial^2 X(k,\theta^*)}{\partial k \partial y} = c\frac{\partial \Pr(\text{safe})}{\partial y} + \frac{\partial^2 \Pr(\text{safe})}{\partial k \partial y}(u^s - u^g),$$

where

$$\begin{aligned}
\frac{\partial \Pr(\text{safe})}{\partial y} &= \frac{d\theta^*(k,y)}{dy} = \frac{-\phi\left\{\sqrt{\gamma}\left[\theta^*(k,y)-y\right]\right\}\sqrt{\gamma}}{1-\phi\left\{\sqrt{\gamma}\left[\theta^*(k,y)-y\right]\right\}\sqrt{\gamma}} < 0,\\
\frac{\partial^2 \Pr(\text{safe})}{\partial k \partial y} &= \frac{d^2\theta^*(k,y)}{dkdy},\\
\frac{d\theta^*(k,y)}{dk} &= \frac{c/b}{1-\phi\left\{\sqrt{\gamma}\left[\theta^*(k,y)-y\right]\right\}\sqrt{\gamma}} > 0,\\
\frac{d^2\theta^*(k,y)}{dkdy} &= \frac{-(c/b)\gamma\left[\theta^*(k,y)-y\right]\phi\left\{\sqrt{\gamma}\left[\theta^*(k,y)-y\right]\right\}}{\left(1-\phi\left\{\sqrt{\gamma}\left[\theta^*(k,y)-y\right]\right\}\sqrt{\gamma}\right)^2}\sqrt{\gamma}\left(\frac{d\theta^*(k,y)}{dy}-1\right),
\end{aligned}$$

in which

$$\frac{d\theta^*(k,y)}{dy} - 1 = \frac{-1}{1-\phi\left\{\sqrt{\gamma}\left[\theta^*(k,y)-y\right]\right\}\sqrt{\gamma}} < 0.$$

So

$$\frac{d^2\theta^*(k,y)}{dkdy} = \frac{(c/b)\gamma\left[\theta^*(k,y)-y\right]\phi\left\{\sqrt{\gamma}\left[\theta^*(k,y)-y\right]\right\}}{\left(1-\phi\left\{\sqrt{\gamma}\left[\theta^*(k,y)-y\right]\right\}\sqrt{\gamma}\right)^2}\frac{\sqrt{\gamma}}{1-\phi\left\{\sqrt{\gamma}\left[\theta^*(k,y)-y\right]\right\}\sqrt{\gamma}},$$

which is positive iff $\theta^*(k,y) - y > 0$. Use this in $\frac{\partial^2 X(k,\theta^*)}{\partial k \partial y}$ to give

$$\frac{\partial^2 X(k,\theta^*)}{\partial k \partial y} = c\frac{\phi(\cdot)\sqrt{\gamma}}{1-\phi(\cdot)\sqrt{\gamma}}\left\{-1 + \frac{(1/b)\gamma\left[\theta^*(k,y)-y\right]}{\left(1-\phi(\cdot)\sqrt{\gamma}\right)^2}(u^s - u^g)\right\},$$

which is positive iff

$$\frac{(1/b)\gamma\left[\theta^*(k,y)-y\right]}{\left(1-\phi(\cdot)\sqrt{\gamma}\right)^2}(u^s-u^g)>1.$$

A necessary condition for this is $\theta^*(k,y)-y>0$. For this, since $\frac{d\theta^*(k,y)}{dy}-1<0$, there exists a value of y, $\overline{y}$, such that $\theta^*(k,y)-y>0$ for $y<\overline{y}$. Then as $\gamma\to 2\pi$, $\phi(\cdot)\sqrt{\gamma}\to 1$, such that when $y\in[\underline{y},\overline{y}]$ there exists some γ, $\underline{\gamma}<2\pi$, such that, for $\gamma\in(\underline{\gamma},2\pi]$, $\frac{\partial^2 X(k,\theta^*)}{\partial k\partial y}>0$. The lower bound on the noise ratio, $\underline{\gamma}$, solves:

$$\frac{(1/b)\underline{\gamma}\left[\theta^*(k,y)-y\right]}{1-\phi\left\{\sqrt{\underline{\gamma}}\left[\theta^*(k,y)-y\right]\right\}\sqrt{\underline{\gamma}}}(u^s-u^g)=1.$$

A.6 An example for $p(\theta,l)$

We provide one example of a motivation for the restrictions we impose on the reputational penalty function $p(\theta,l)$. Let the payoff matrix include the possibility that low ability banks achieve a zero return following their initial investment with probability $1-\lambda$. Under this set-up, the combinations of ability and returns are given Table A1:

Table A1: Payoffs

		High ability	Low ability
	R_H	$\alpha f(\theta)$	0
Initial Return	R_L	$\alpha[1-f(\theta)]$	$(1-\alpha)\lambda$
	0		$(1-\alpha)(1-\lambda)$

Suppose that the fraction $1-\lambda\in[0,1]$ of low ability banks that obtain a zero return on their initial investment are forced to exit the game thereafter, such that they affect nothing else in the model. In a more fleshed out dynamic model, λ could be thought to capture the 'steady state' exit rate of low ability banks. For now, it is exogenous.

The market observes neither ability nor fundamentals. Bankers conjecture the market's priors over these parameters to be (α,θ).

A *reputational penalty* is associated with failing to achieve high returns. This is given by the market's assessment of the probability of being low ability conditional on observing a bank's failing to post high returns.

The $(1-\alpha)\lambda$ low ability banks and the $\alpha[1-f(\theta)]$ high ability banks who enjoyed R_L in the interim have the choice as to whether to gamble or not. A fraction l of these banks gamble, while a fraction $1-l$ do not. Of those that gamble, a fraction $1-b$ fail to be successful, and fail to post high returns. The $1-l$ who do not gamble also fail to realise high returns.

Using this the conditional probability relevant to reputation is given by

$$P\equiv\Pr(\text{low ability}|\text{not high returns}). \tag{15}$$

Using the structure of the model, we then have that the joint probability of being low ability and failing to achieve high returns divided by the probability of failing to achieve high returns is

$$P(\theta,l)=\frac{(1-\alpha)\lambda(1-lb)+(1-\alpha)(1-\lambda)}{\{(1-\alpha)\lambda+\alpha[1-f(\theta)]\}(1-lb)+(1-\alpha)(1-\lambda)}. \tag{16}$$

This expression can be re-written as

$$P = \frac{1}{1+\Omega(\theta,l)}, \tag{17}$$

$$\text{where } \Omega(\theta,l) = \frac{\alpha[1-f(\theta)](1-lb)}{(1-\alpha)\lambda(1-lb)+(1-\alpha)(1-\lambda)}. \tag{18}$$

Note that as $\lambda \to 1$, this reduces to

$$P|_{\lambda=1} = \frac{1-\alpha}{1-\alpha f(\theta)}, \tag{19}$$

which satisfies $\partial \left. P\right|_{\lambda=1} / \partial\theta > 0$: conditional on achieving low returns, the probability of being assessed as low ability is increasing in fundamentals. This is familiar given the intuition that as fundamentals improve, more high ability banks make high returns, so high returns are a better signal of high ability. Since the Morris and Shin framework requires only that $p(\cdot)$ be non-decreasing in θ and l, this would be sufficient for our results.

When $\lambda < 1$, we have that

$$\begin{aligned} \frac{\partial\Omega(\theta,l)}{\partial l} &= \frac{\alpha[1-f(\theta)]b}{(1-\alpha)\lambda(1-lb)+(1-\alpha)(1-\lambda)} \\ &\quad \times \left[-1+\frac{(1-lb)}{[(1-\alpha)\lambda(1-lb)+(1-\alpha)(1-\lambda)]}(1-\alpha)\lambda\right] \end{aligned} \tag{20}$$

which is negative iff the term in $[\cdot]$ is negative, which is always true for $\lambda < 1$. Then $\partial\Omega(\theta,l)/\partial l < 0$, implying that $\partial P/\partial l > 0$. This says that as more banks gamble, failing to post high returns is a better signal of low ability. So for $\lambda < 1$ we have both that $\partial P/\partial\theta > 0$ and $\partial P/\partial l > 0$. This provides one example of how a form for $p(\cdot)$ can be written satisfying the conditions required for the solution to the global game.

The simplified functional form for $p(\cdot)$ that we use in the text is $p(\theta,l) = \theta + l - 1$. We show now how this could be thought of as an approximation to the banker's disutility associated with bad reputation using the conditional probability P. Suppose the banker's utility cost associated with announcing low returns is proportional to $P(\theta,l)$:

$$p(\theta,l) = \varphi_0 + \varphi_1 P(\theta,l),$$

where (φ_0,φ_1) are coefficients that parametrise the disutility associated with bad reputation. We can think of the linear function employed in the text as an approximation to this disutility. In particular, a first order Taylor approximation of $P(\theta,l)$ around approximation points $(\widehat{\theta},\widehat{l})$ yields

$$P(\theta,l) \simeq P(\widehat{\theta},\widehat{l}) + P_\theta(\widehat{\theta},\widehat{l})(\theta-\widehat{\theta}) + P_l(\widehat{\theta},\widehat{l})(l-\widehat{l})$$

where subscripts denote partial derivatives such that

$$\begin{aligned} P_\theta(\widehat{\theta},\widehat{l}) &= P(\widehat{\theta},\widehat{l})\frac{\alpha f'(\widehat{\theta})(1-\widehat{l}b)}{\Gamma} \\ P_l(\widehat{\theta},\widehat{l}) &= \frac{-(1-\alpha)\lambda b}{\Gamma} + P(\widehat{\theta},\widehat{l})\frac{(1-\alpha)\lambda+\alpha[1-f(\widehat{\theta})]}{\Gamma}b \end{aligned}$$

in which

$$\Gamma \equiv \left\{(1-\alpha)\lambda + \alpha[1-f(\widehat{\theta})]\right\}(1-\widehat{l}b) + (1-\alpha)(1-\lambda).$$

Inserting this approximation into the function for the disutility of bad reputation gives

$$\begin{aligned} p(\theta,l) &\simeq \varphi_0+\varphi_1\left[P(\widehat{\theta},\widehat{l})-P_\theta(\widehat{\theta},\widehat{l})\widehat{\theta}-P_l(\widehat{\theta},\widehat{l})\widehat{l}+P_\theta(\widehat{\theta},\widehat{l})\theta+P_l(\widehat{\theta},\widehat{l})l\right] \\ &= \varphi_0+\varphi_1\left[P(\widehat{\theta},\widehat{l})-P_\theta(\widehat{\theta},\widehat{l})\widehat{\theta}-P_l(\widehat{\theta},\widehat{l})\widehat{l}\right]+\varphi_1 P_\theta(\widehat{\theta},\widehat{l})\theta+\varphi_1 P_l(\widehat{\theta},\widehat{l})l \end{aligned}$$

For given parameters of the model (α, b) and the disutility of bad reputation (φ_0, φ_1), one can then find an approximation point $(\widehat{\theta},\widehat{l})$ such that

$$\begin{aligned} \varphi_1 P_l(\widehat{\theta},\widehat{l}) &= 1 \\ \varphi_1 P_\theta(\widehat{\theta},\widehat{l}) &= 1 \end{aligned}$$

and that

$$\varphi_0+\varphi_1\left[P(\widehat{\theta},\widehat{l})-P_\theta(\widehat{\theta},\widehat{l})\widehat{\theta}-P_l(\widehat{\theta},\widehat{l})\widehat{l}\right]=-1$$

In this case,

$$p(\theta,l)\simeq\theta+l-1$$

as in the text. For example, the parametrisation we use for our simulations has $\alpha = 0.8, b = 0.09$. If $\lambda = 0.5$, then for $\varphi_1 = 124.23$, these result in approximation points around $[f(\widehat{\theta}) = 0.05, \widehat{l} = 0.5]$ such that $P_l(\widehat{\theta},\widehat{l}) = 0.008 = P_\theta(\widehat{\theta},\widehat{l})$, which in turn mean that $\varphi_1 P_l(\widehat{\theta},\widehat{l}) = \varphi_1 P_\theta(\widehat{\theta},\widehat{l}) = 1$. These also yield $P(\widehat{\theta},\widehat{l}) = 0.21$ such that we then have to choose $\varphi_0 = -29.80$ to ensure that $\varphi_0+\varphi_1\left[P(\widehat{\theta},\widehat{l})-P_\theta(\widehat{\theta},\widehat{l})\widehat{\theta}-P_l(\widehat{\theta},\widehat{l})\widehat{l}\right]=-1$.

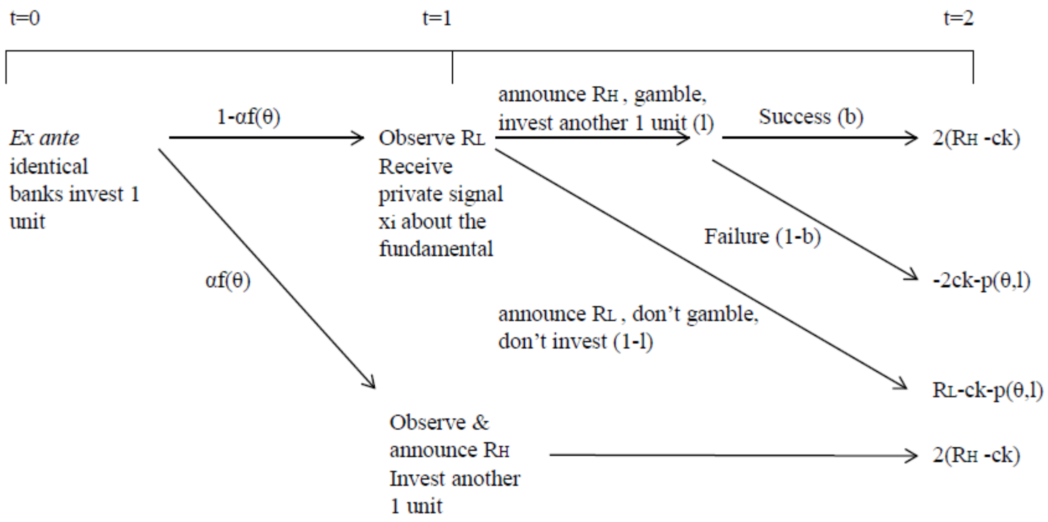

Figure 1: The timing and payoffs of the game

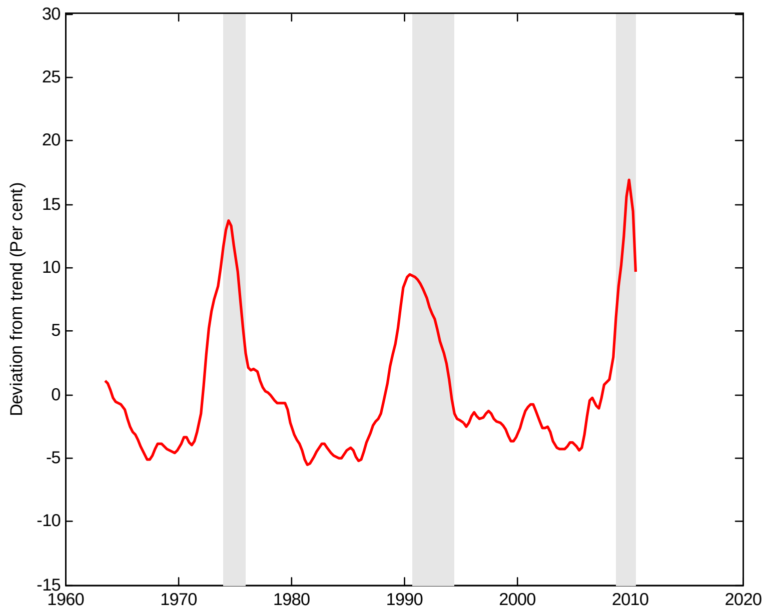

Figure 2: Band pass filtered ratio of UK credit:GDP, 1963Q2-2010Q2. The credit series is M4 Lending, which comprises monetary financial institutions' sterling net lending to private sector. The filter returns cyclical variation in the ratio over the 1-20 year frequency range. Shaded regions indicate periods of distress: 1973Q4-1975Q4 (secondary banking crisis); 1990Q3-1994Q4 (small banks crisis); 2008Q3–2010Q2.

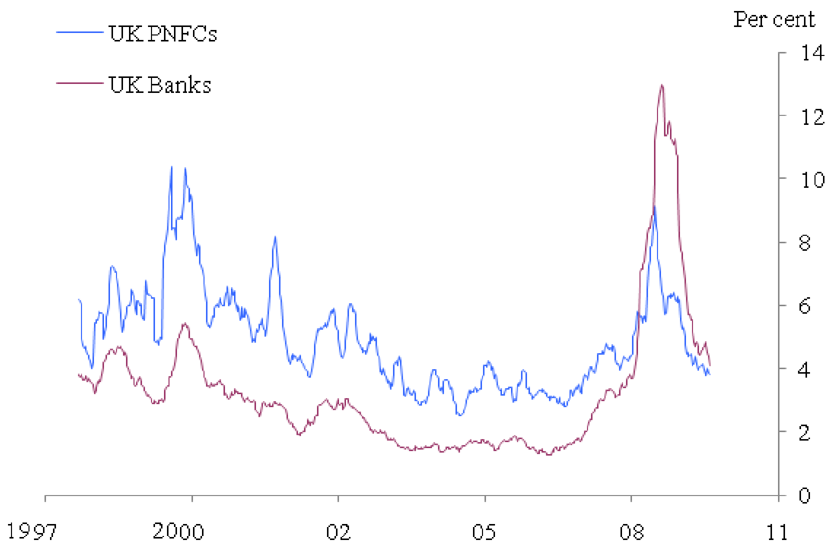

Figure 3: Dispersion of equity returns of major UK banks and top UK 100 PNFCs (by market cap)

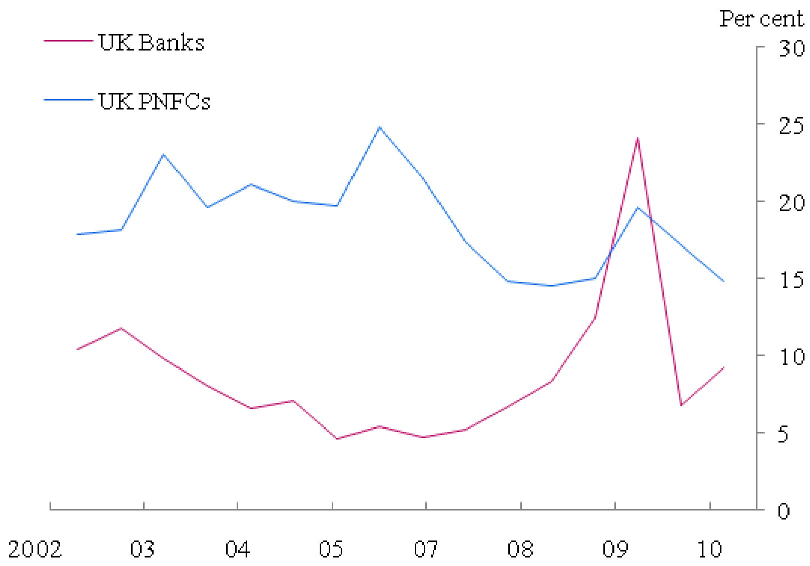

Figure 4: Dispersion of ROE of top 10 UK banks and top 10 UK PNFCs (by market cap)

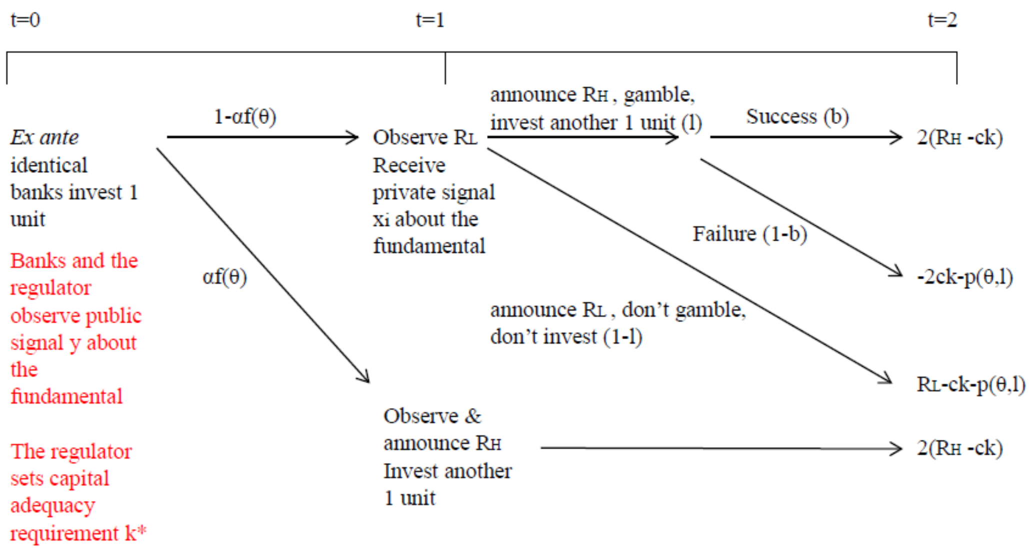

Figure 5: The timing and the payoffs of the game with optimal capital adequacy regulation

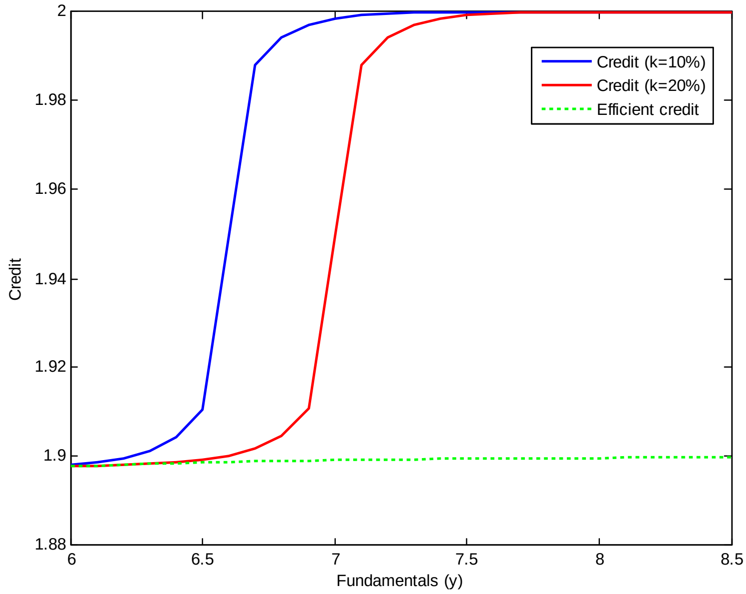

Figure 6: Aggregate credit supply

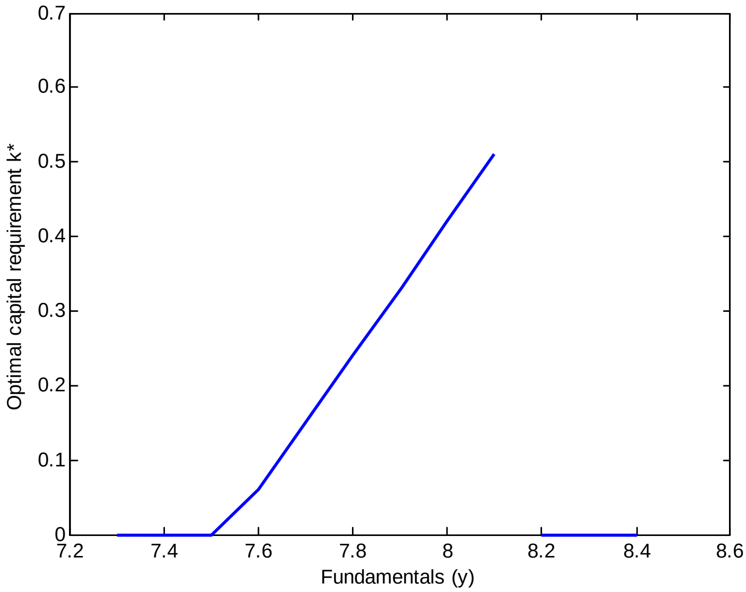

Figure 7: Optimal capital adequacy requirement, k^*

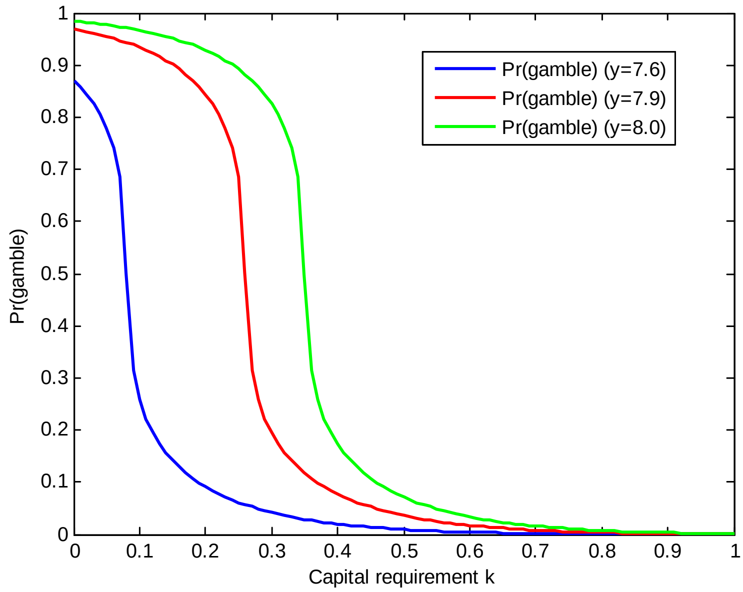

Figure 8: The impact of capital adequacy requirement on banks' incentives to gamble

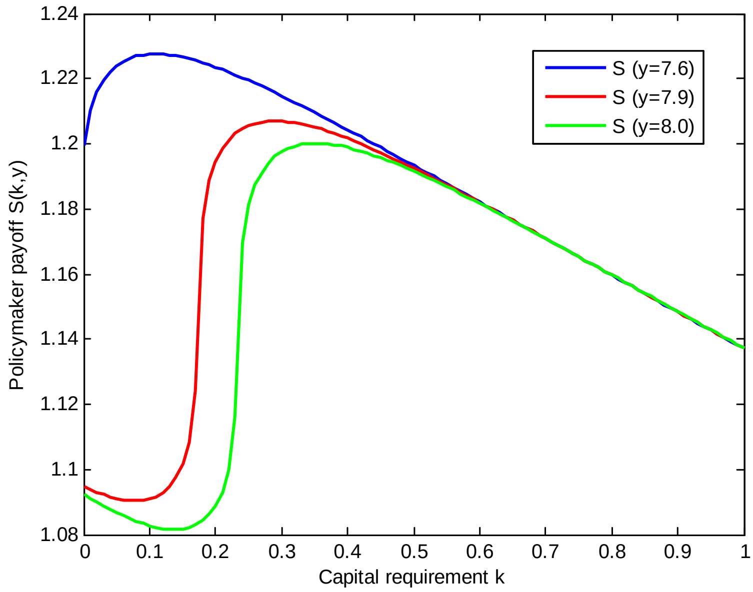

Figure 9: Social welfare function

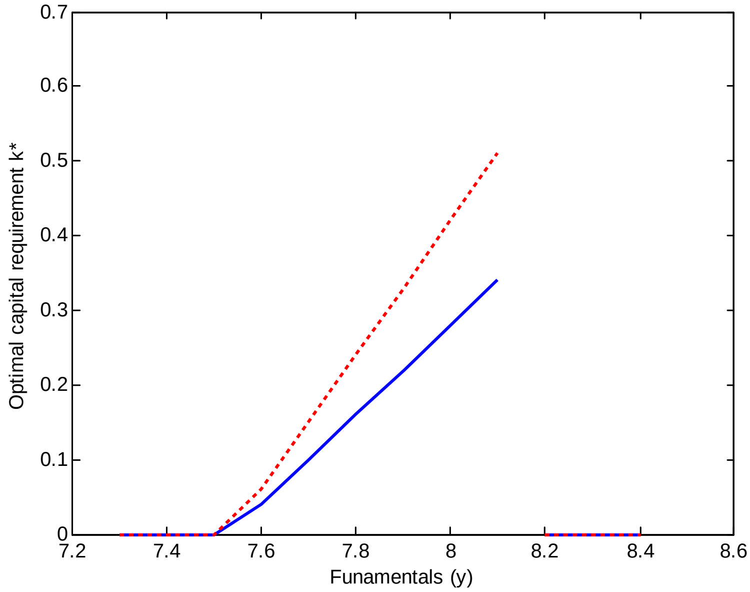

Figure 10: The effect of lower costs of raising equity on optimal capital adequacy requirements, blue ($c = 15\%$), red dashed ($c = 10\%$).

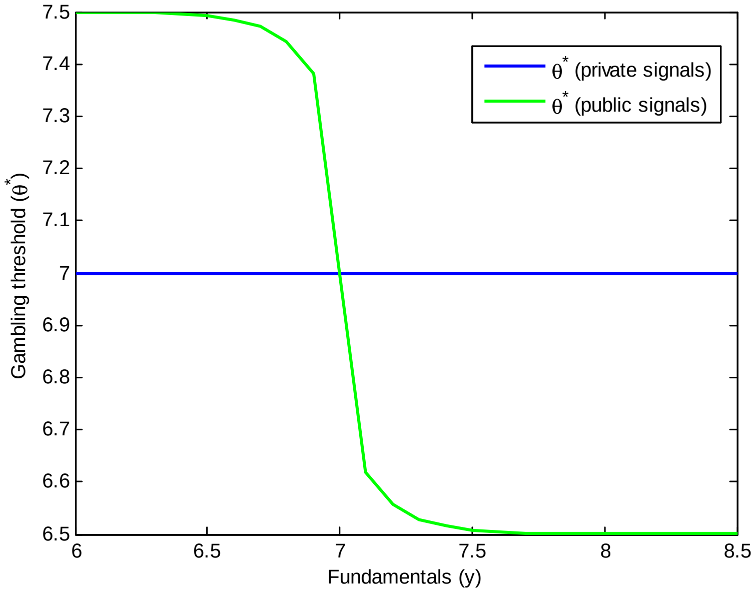

Figure 11: The role of public information

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