The Disturbing Interaction Between Countercyclical Capital Requirements and Systemic Risk

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Abstract

We consider an economy in which flat capital requirements are costly because they inefficiently reduce lending when aggregate conditions are unfavorable. Countercyclical capital requirements – which impose lower capital demands in bad aggregate states – have the potential to improve welfare. However, we show that such capital requirements also have a cost as they increase systemic risk taking at banks. This is because they insulate banks against sector-wide fluctuations (but not against bank-specific risk) and thus create incentives to invest in correlated activities. As a result, the economy's sensitivity to aggregate conditions increases and systemic crises may become more likely when countercylical policies are in place. By contrast, efficient capital requirements incentivize banks to make less correlated investments – which reduces both systemic risk-taking and procyclicality.

Keywords: systemic risk, regulation, procyclicality

JEL classification: G01, G21, G28

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1 Introduction

A key focus of the recent policy debate is on whether the financial system responds efficiently to shocks. While the macroeconomic literature tended to focus on models where the real economy adjusts optimally to shocks, there is now a strong notion that this is not an appropriate assumption for the financial sector. This is because the environment in which agents in the financial system operate is subject to various constraints that tend to amplify shocks. This environment includes borrowing constraints that fluctuate with asset prices, risk-sensitive capital requirements, portfolio insurance trading strategies or remuneration schemes based on relative performance.[1] Because of this there are good reasons to believe that the financial system responds excessively to changes in aggregate conditions, leading to excessive lending in good times and sharp contractions in lending when conditions deteriorated. A point in case is the crisis of 2007-2009, which was preceeded by a lending boom in many countries. Due to the experience with the crisis, there is now a significant interest in policies that mitigate procyclicality. The new Basel-accord includes countercyclical requirements and there also are discussions about including a countercyclical element into new liquidity requirements. On the accounting side, there is a discussion about whether mark-to-market accounting – which may exacerbate market price fluctuations – should be suspended when prices are depressed.

The idea of this paper is that procyclicality may be connected to another dimension of systemic risk: the extent to which bank behaviour is correlated. Bank correlation is a key source of systemic costs and can arise through various channels, such as herding in investments by banks (Rajan (1994), Acharya and Yorulmazer (2007), Farhi and Tirole (2012)), interconnectedness (causing bank failures to be correlated, see Allen and Gale (2000) for an example) or homogeneity in risk management or trading strategies. In this paper we study an environment that has both dimensions of systemic risk and analyze the consequences of countercyclical policies. In particular, we are interested in how such policies affect systemic risk taking by banks and whether these policies are preferred over alternative macroprudential policies.

[1] See Galati and Moessner (2011) for some examples of the sources of procyclicality in the financial sector. Blum and Hellwig (1995) are among the first to point out the potentially adverse macroeconomic effects of constant capital adequacy requirements imposed on banks.

In our economy, banks have financing costs that are both subject to aggregate and bank-specific uncertainty. A role for capital requirements arises as capital mitigates moral hazard at banks.[2] We show that "flat" capital requirements (capital requirements that are not dependent on the state of the economy) are inefficient. This is because when aggregate conditions are favorable, it becomes less costly to put extra capital into banks in order to limit moral hazard. Similarly, capital is more valuable under unfavorable conditions, making it less efficient to employ capital solely to contain moral hazard. Taking as given the investment choices of banks, optimal capital requirements are countercyclical: capital charges should be higher in good states of the economy than in bad states of the economy.

However, this result changes when banks can influence how exposed they are to aggregate shocks. We consider a situation where banks can choose to be either fully exposed to economy-wide conditions (implying that banks are also fully correlated with each other) or to be only partially exposed (in this case, banks also take on idiosyncratic risk and are are imperfectly correlated with each other).[3] We show that countercyclical policies increase the incentives for banks to become correlated. The intuition for this result is simple. Countercyclical capital requirements isolate banks from *aggregate* business cycle fluctuations (they increase costs at banks when the econmy is doing well and reduce costs when the econonomy is in a bad state) but not against *bank-specific* shocks. Investments that are subject to idiosyncratic risk are hence becoming relatively more costly for banks (a bank runs the risk of receiving a bad shock when the economy is doing well, in which case it would be subjected to more stringent capital requirements at times when holding more capital is particularly costly). As a consequence, banks have higher incentives to become exposed to the aggregate state and to choose correlated investments.

We show that this can undo the beneficial effects of countercyclical capital requirements. Perversely, countercylical policies can even increase procyclicality. This is because when banks become more exposed to the same risks, the response of the economy to aggregate shocks becomes larger and hence the system displays more procyclicality. Optimal capital requirements trade off the ex-post benefits from stabilizing the economy through the cycle

[2]There is a minimum level of capital that ensures that banks only invest in "worthwhile" projects as in Holmstrom and Tirole (1997).

[3]In our model, exposures realize through funding costs (but similar considerations arise with respect to asset risk).

with the cost of higher ex-ante systemic risk-taking by banks. For plausible parameter values we show that this entails limited countercyclicality of capital requirements, which hedge banks partially against aggregate fluctuations but not fully.

Finally, we also show that policies that directly address correlation risk (if feasible) dominate countercylical policies. This is because they address both sources of systemic risk: they discourage herding but also make the system less procyclical as less correlated institutions will respond less strongly to aggregate fluctuations. In sum, our paper shows that two dimensions of systemic risk (procyclicality and bank correlation) are inherently linked. The consequence is that policies addressing one risk dimension will also affect the other dimension. Regulators should take this into account when designing macroprudential policies.

Related literature (To be completed) – There is a growing literature that investigates how countercyclical policies can mitigate procyclicality in the financial system. Kashyap and Stein (2004) assess the procyclical effects of Basel II on actual capital requirements and argue that countercyclical capital requirements might be socially desirable. Repullo and Suarez (2012) show that fixed risk-capital requirements (such as in Basel II) result in significant procyclical effects in lending activity, even though banks hold precautionary capital buffers to mitigate the effects of increased capital requirements at times of adverse economic conditions. Repullo et al. show that introducing a slightly countercyclical risk-capital requirement profile reduces credit rationing in bad states significantly at the cost of a minor increase in bank insolvency. By contrast, in our model the scope for countercyclical capital regulation arises because it reduces banks' average funding costs and is not due to credit rationing.

The possibility for banks in our paper to alter their correlation is related to Acharya and Yorulmazer (2007). Acharya et al. show that regulators may not be able to commit not to bail out banks if they fail jointly. Anticipating this, banks have an incentive to herd in order to increase the likelihood of joint failures. In our baseline model the regulator has no commitment problem. Instead, the regulator has the option to commit to capital requirements conditional on aggregate states, which in turn affects banks' correlation choice. An interesting difference to Acharya et al. is that higher correlation – by itself – is welfare improving as it allows the regulator to set more efficient capital requirements. This is because the regulator can only set capital requirements conditional on the aggregate state

– but not on bank-specific conditions. When banks all face the same funding condition, capital requirements thus better reflect individual banks' conditions and inefficiencies are lowered.

Martínez-Miera and Suarez (2012) consider a model where flat capital requirements have an impact on banks' correlation choices. The reason is that capital requirements increase the value of capital to surviving banks in a crisis. This in turn provides banks with incentives to invest in uncorrelated activities in order to increase the chance of surviving while other banks are failing (the "last bank standing" effect). In our model a last-banking standing effect is also present (and works to reduce correlation incentives) but the key mechanism that affects correlation arises from the ability for countercyclical policies to lower the cost for individual banks when aggregate conditions are unfavourable.

The remainder of the paper is organized as follows. Section 2 first introduce the model. We show that without systemic externalities optimal capital requirements are countercyclical. We then allow for banks to choose cross-bank correlation, which introduces systemic risk shifting. In Section 3 we relax the assumption that the regulator can fully commit to the policy rule. In Section 4 discusses the results. Section 5 concludes

2 Model

There are two banks in the economy. The model is static, there is an investment date when banks make funding and investment decisions, and a second date when projects mature. Investment size is fixed to one and projects are risky: a project yields a gross return of $R > 1$ at maturity with probability $0 < p < 1$ and zero otherwise. Projects have positive net present value ($pR - 1 > 0$). Further, banks have access to a monitoring technology, which raises the success rate by $\Delta p > 0$, such that $p + \Delta p \leq 1$. Monitoring costs c per unit of investment.

Banks are financed by equity and deposits. Depositors are insured and require a repayment of one per unit of deposit. In return for the insurance, banks pay a fixed deposit insurance premium denoted by C. Banks also enjoy limited liability, which may result in socially inefficiently low levels of monitoring as a result of a moral hazard problem. To align private and social incentives, a regulator may require banks to hold a minimum level of equity capital (banks' own money) denoted by k. If k is sufficiently high, banks have a large enough stake in the project so as to behave prudently. If capital was costless, the regulator's problem was trivial, she could always require banks to hold sufficiently large amounts of capital. Instead, we assume that capital is costly: each unit of equity costs $\rho > 0$ to the bank. This introduces a trade-off for the regulator; it can set high capital requirements, but it is both privately and socially costly and in some cases it is better to relax capital requirements.

Capital costs are exogenous in the economy, they are uncertain, but their distribution is known to all agents. There is a large tradition in banking to model bank capital as costly without explicitly modeling the sources of capital costs. Such costs might include forgone tax benefits, etc. In our model capital costs have an even wider interpretation, as we think of them as proxies of the state of the aggregate economy. We associate high capital costs with adverse economic conditions, as in such conditions raising capital can be relatively difficult, imposing costs on banks. In contrast, in benign conditions such implicit costs are lower.

Capital costs play another important role in this economy, as banks choose the extent to which they wish to correlate with each other on the liability side of their balance sheets. This is a convenient modeling choice to introduce cross-bank correlation.[4] We allow banks to choose from various funding sources that are heterogenous in terms of their correlation to the aggregate state. All banks have access to a common funding source, which we call systemic fund, with corresponding capital costs ρ^S. Alternatively, each bank can draw on bank specific funds, which are only available to one, but not to the other bank. The cost of these funds are ρ^A and ρ^B for banks A and B, respectively. All three costs are random, distributed independently with the same mean $\mathrm{E}[\rho^S] = \mathrm{E}[\rho^A] = \mathrm{E}[\rho^B] = \mu$.[5] Thus, if both banks choose the systemic source, their capital costs are perfectly correlated, otherwise they are uncorrelated.

There are many ways through which banks can achieve more or less correlated balance sheets, and in particular, liabilities. One possibility is that banks can either rely on global or regional capital markets to fund themselves. In reality global and regional financial markets are not completely separated, but as long as regional markets are driven at least

[4]Our focus on funding choices does not reduce the generality of our results, as we will discuss below.

[5]Banks do not choose the riskiness of their exposures, therefore differences in the distribution of capital costs does not matter.

to some extent by local events, banks relying on different regional markets should exhibit lower cross-bank correlation than banks sharing the same funding source. Our choice to restrict attention to polar cases (perfect correlation or no correlation) simplifies the analysis without changing the qualitative results.[6]

The third source of uncertainty in the economy – beside uncertainty about project success and capital costs – are shocks to the supply of bank capital. With probability p_d funding sources dry up, which occurs independently across funding sources. If there is insufficient supply of a certain type of bank capital, a bank that previously chose this source must give up its project.[7] In this setup correlation between banks' lending activity arises endogenously as a result of their funding choice: if banks rely on the same source they will stop lending in the same states of the world. Importantly, a bank that stops lending can sell the access to its project to an expanding bank (one that is not hit by the capital supply shock), which can then finance and additional unit of investment.

We think of this setup as a model in which banks decide to extend their lending activity. Both banks have ongoing activities which require no intervention by the bank management. When banks decide about credit expansion they take into account the marginal capital requirement of financing an additional unit of investment (k), the availability of bank capital (a random shock with probability p_d) and they choose the level of portfolio risk (i.e. the level of monitoring effort). At the aggregate level, there are three outcomes. Under normal economic conditions there is sufficient supply of bank capital and capital costs are low. In this case banks choose to monitor (under optimal capital regulation), all available projects are financed and succeed at a high rate. Furthermore, if one bank is short of bank capital as a result of a decline in capital supply, the other bank can finance the project, if it has access to capital. Second, if economic conditions are bad, the regulator relaxes capital requirements to provide relief to banks, but in this case banks lower their level of monitoring. Lastly, if neither of the banks can raise capital, they stop lending – a credit freeze happens.

Our model is macroprudential in the sense that the regulator is allowed to set state

[6]Another example of systemic and idiosyncratic funding sources might be convertible equity and pure equity, if the conversion of equity takes places at a systemic scale.

[7]We assume that banks commit to a funding source when they make the funding decision and it is prohibitively expensive to switch to another source after supply shocks have realized.

varying capital requirements, but she cannot condition on idiosyncratic shocks as banks' individual funding conditions are privation information. The regulator can condition the required minimum capital ratio on systemic capital costs (ρ^S). We assume that the regulator can fully commit to this capital requirement rule.

Banks maximize expected payoff by deciding to invest or not[8], by choosing the funding source (systemic or alternative) and by deciding to monitor the project they finance or not. The regulator's aim is to maximize total welfare, which is the sum of the expected social surpluses on projects undertaken.

The timing of the model is as follows. The regulator announces the capital requirement rule $k(\rho^S)$. Banks choose the type of equity funding. Uncertainty about funding is revealed – capital supply shocks and capital costs realize. Capital requirements are enforced. Banks invest in projects and raise the necessary amount of equity. Banks decide about their monitoring effort, after which uncertainty about projects is revealed and projects deliver.

2.1 A simple model of countercyclical capital regulation

To highlight the basic properties of the model, we start with a simpler version of it. Banks can only choose from one funding source, which is the same for both banks and the cost of which the regulator can condition on. For simplicity we also assume that there are no bank capital supply shocks. This assumption is not restrictive, since when all banks share the same source of funding, the occurrences of such shocks coincide, no asset-takeover is possible and there are no systemic externalities. Under these assumptions we can concentrate w.l.o.g. on the problem of a representative bank.

Banks' monitoring problem

We solve the model by backward induction. We assumed that it is always profitable for banks to invest in the project, hence the only decision they need to make is the monitoring choice. At the time when this decision is made capital costs ρ^S and capital requirements

[8] Under optimal capital regulation it is always optimal to invest.

k are known. Taken these as given, the representative bank's expected payoff is

$$\pi^S\big|_{M=1} = (p + \Delta p)[R - (1 - k)] - (1 + \rho^S)k - C - c \qquad \text{with monitoring, and}$$
$$\pi^S\big|_{M=0} = p[R - (1 - k)] - (1 + \rho^S)k - C \qquad \text{without monitoring,}$$

where $M = 1$ if the bank monitors the project and zero otherwise. The first term is expected returns net of repayments to depositors in case of success, the second term is total capital cost, the third is the deposit insurance fee, and finally, banks pay monitoring costs when they choose to monitor.

Comparing the two lines we find that the expected payoff of the representative bank is larger with monitoring if the minimum required capital is large enough:

$$k \geq 1 - R + \frac{c}{\Delta p} \equiv \bar{k}.$$

In what follows we assume that banks choose to monitor the project at the margin when they are indifferent (when $k = \bar{k}$). To ensure that $\bar{k}$ is between zero and one, we assume that 1) $\Delta pR - c > 0$, so monitoring is cost efficient, and 2) $c > \Delta p(R - 1)$, so that the moral hazard problem is severe enough to induce banks to bad behaviour in the absence of regulation.

Welfare and policy functions

The regulator sets minimum capital requirements in order to provide incentives for banks to carry out the socially optimal level of monitoring. We have shown, that banks choose to monitor, if capital requirements are high enough. However, if capital costs are too high, the costs of forcing banks to hold capital may outweigh the benefits of monitoring projects. This suggests that optimal capital requirements are countercyclical in the sense that they are high when capital costs are low and vice versa.

Lemma 1 *In the baseline model countercyclical capital regulation is socially optimal:*

$$\mathrm{Cov}(k^*(\rho^S), \rho^S) < 0,$$

where $k^*(\rho^S)$ denotes optimal capital requirements.

Proof. The regulator maximizes total expected social surplus, which is

$$W^S(k) = \mathrm{E}\left[(p + M\Delta p)R\right] - 1 - \mathrm{E}[\rho^S k] - \mathrm{E}[Mc] \tag{1}$$

by choosing a policy function $k = k(\rho^S)$.

We show that the optimal policy function $k^*(\rho^S)$ belongs to the family of step functions of the form

$$k(\rho^S; \hat{\rho}) = \begin{cases} \bar{k} & \text{if } \rho^S \leq \hat{\rho} \\ 0 & \text{otherwise.} \end{cases} \tag{2}$$

To see this, consider a capital requirement of some $\hat{k} > \bar{k}$ for any fixed level of capital costs $\rho_0^S > 0$. This is suboptimal, because a marginal decrease in capital requirements does not affect banks' monitoring incentives, but it decreases total capital costs. Further, any $\hat{k} \in (0, \bar{k})$ is also suboptimal for the same reason, with the exception that in this region banks do not monitor. Now assume that for ρ_0^S it is optimal to set $\hat{k} = 0$. Then

$$(p + \Delta p)R - 1 - \rho_0^S \bar{k} - c < pR - 1.$$

and hence for any $\rho^S > \rho_0^S$ it is also optimal to have $\hat{k} = 0$. ■

The intuition behind this result is straightforward. If capital costs are too high, capital requirements impose too high costs on the banking sector, which outweighs the benefits of capital regulation. Thus, the regulator finds it optimal to relax capital requirements in bad states of the economy (high capital costs). In good times, however, high capital requirements enhance total social surplus by incentivizing banks to behave prudently and are therefore desirable. The optimal threshold is thus set such, that it equates the marginal costs of regulation (capital requirements times capital costs) to the marginal benefits (net return on monitoring). Assuming an interior solution, the optimal threshold is then $\hat{\rho}^* = (\Delta pR - c)/\bar{k}$, which can be obtained by maximizing the social surplus function W^S subject to (2).

2.2 Correlation choice and aggregate risk shifting

We now allow for banks to choose the source of equity funding. We also allow for the possibility of bank withdrawal, which occurs with probability p_d.

Banks' problem

Banks now have to make two decisions, a monitoring and a funding decision. Expected bank payoff when the funding decision has already been taken changes only because of the possibility to take over a failing bank's project. This, however, does not influence monitoring incentives, because it does not change the relative payoffs in case of success and failure of the project. As before, banks optimally choose to monitor when $k \geq \bar{k}$.

Consider now banks' funding problem. Since capital is costly, banks always hold the minimum required level of capital. The optimal funding mix boils down to choosing between the two sources of equity funding, systemic or alternative. This decision is made before uncertainty about capital costs is revealed, and only the policy function is known to banks.

For the moment, abstract from the possibility that surviving banks can buy up the failing bank's assets. In this case, conditional on surviving, the expected payoff of bank $i \in \{A, B\}$ is

$$\pi_i^S = \mathrm{E}\left\{(p + M_i \Delta p)[R - (1-k)]\right\} - \mathrm{E}[(1+\rho^S)k] - \mathrm{E}[M_i c] - C$$

with systemic funding, and

$$\pi_i^I = \mathrm{E}\left\{(p + M_i \Delta p)[R - (1-k)]\right\} - \mathrm{E}[(1+\rho^i)k] - \mathrm{E}[M_i c] - C$$

with idiosyncratic funding. Since payoffs are symmetric, we will drop subscript i in the rest of the paper and denote systemic and idiosyncratic profits by π^S and π^I, respectively. The two profit functions only differ in expected capital costs, which leads us to the following lemma.

Lemma 2 *The size of the wedge between systemic and idiosyncratic profits depends on the cyclicality of capital requirements:*

$$\pi^S - \pi^I = -\mathrm{Cov}(\rho^S, k)$$

If the regulator implements countercyclical capital regulation, then banks have private incentives to expose themselves to the aggregate state ($\pi^S > \pi^I$).

Proof. Since the regulator cannot condition on idiosyncratic capital costs and $\mathrm{E}[\rho^i] = \mathrm{E}[\rho^S]$ for $i \in \{A, B\}$, we have $\mathrm{E}[\rho^i k] = \mathrm{E}[\rho^S]\mathrm{E}[k]$. ■

Absent the possibility for banks' to buy the assets of failing banks, their correlation choice does not affect the other bank's payoff. We now allow for the takeover of assets,

	Strategies of bank A	
	Systemic	Idiosyncratic
Systemic	π^S	$(1+p_d)\pi^I$
Idiosyncratic	$(1+p_d)\pi^S$	$(1+p_d)\pi^I$

Table 1: Payoffs of bank A conditional on surviving. Bank B's payoff matrix is the transpose of the above payoff matrix.

which introduces a systemic externality: by choosing systemic funding a bank might eliminate the possibility for the other bank to benefit from asset takeovers.

Banks' payoffs conditional on surviving are shown in Table 1 from the perspective of bank A (the payoffs of bank B are the transpose of the payoff matrix of bank A). If one bank cannot raise funds to finance its project, the other bank obtains access to the project. This bank then raises equity and deposit funding from its own source, and doubles its expected payoff. We assume that the surplus from financing an additional project is fully captured by the acquiring bank. This assumption simplifies the analysis below, but is not essential. If all the surplus accrues to the seller bank, the sign of the externality remains the same and our main result of systemic risk shifting remains unchanged.[9]

This correlation-choice game has the following Nash equilibria, assuming that banks make simultaneous decisions. If banks follow mixed strategies, then the equilibrium mixing probability, with which they choose systemic funding, is $\max\{0, \min\{\lambda^c, 1\}\}$, with

$$\lambda^c = (1+p_d)\frac{-\mathrm{Cov}(\rho^S, k)}{p_d \pi^S}. \tag{3}$$

When the benefits from aggregate risk sharing are sufficiently high relative to the benefits from asset takeover, λ^c reaches its maximum and both banks choose systemic funding. If $\lambda^c < 1$, there is another type of equilibria in pure strategies, in which one bank chooses systemic funding, while the other bank relies on idiosyncratic funding.

The mixing probability and the correlation between bank failures are closely related. Let α_{λ^c} and β_{λ^c} denote the random variables indicating the failure of bank A and bank B, respectively, given the symmetric mixing probability λ^c. It can be shown that $\sqrt{\mathrm{Corr}(\alpha_{\lambda^c}, \beta_{\lambda^c})} =$

[9]Banks do not need funds to buy a failing bank's license. This is consistent with the assumption that all the surplus goes to the acquirer bank. In the opposite case we assume that the acquirer pays a fee to the seller in case of success.

λ^c. λ^c is thus also an equilibrium correlation measure between banks if they choose mixing strategies, otherwise they are either fully correlated ($\lambda^c \geq 1$) or uncorrelated ($\lambda^c < 1$).

The efficiency of this correlation choice is our main interest, hence in what follows, we derive the correlation that the social planner would choose.

Regulator's problem

In this section we derive the regulator's unconstrained problem. We have already defined total social surplus per project when it is financed with systemic funding by (1) and we denoted it by W^S. If, instead, idiosyncratic funding is used, then expected total social surplus becomes

$$W^I = \mathrm{E}\left[(p + M\Delta p)R\right] - 1 - \mathrm{E}[\rho^I k] - \mathrm{E}[Mc],$$

where ρ^I stands for idiosyncratic capital costs.

As with private payoffs, the difference between total surplus with systemic versus idiosyncratic funding is equal to the covariance between systemic capital costs and capital requirements:

$$W^S - W^I = -\mathrm{Cov}(\rho^S, k).$$

Total welfare is the sum of per-project total surpluses, and hence depends on the likelihood of asset-takeovers, which, in turn, depends on the combination of banks' funding sources. In parallel with the types of Nash equilibria, we concentrate on two cases. First, we compare the equilibrium mixing probability in the mixing Nash equilibrium with the socially optimal mixing probability - in this case the regulator is free to choose the probability with which any of the two banks relies on systemic funding. Note that this is inefficient for two reasons: 1) in some cases both banks will have systemic funding and no asset-takeovers occur (these are systemic costs), and 2) sometimes both banks will tap idiosyncratic funds, which is inefficient because one bank could enjoy aggregate risk sharing without any cost. Then we also compare equilibria in pure strategies. In this case the regulator is allowed to freely choose the funding source for each bank.

Socially optimal mixing probability

In the first case, when the regulator chooses the mixing probability, total expected surplus is the following:

$$
\begin{aligned}
W^{\lambda} = 2\lambda^2(1-p_d)W^S& \\
&+ 2(1-p_d)\lambda(1-\lambda)[(1-p_d)(W^S+W^I)+2p_dW^S] \\
&+ 4p_d(1-p_d)\lambda(1-\lambda)W^I \\
&+ 2(1-\lambda)^2(1-p_d)^2W^I + 4(1-\lambda)^2(1-p_d)p_dW^I. \qquad (4)
\end{aligned}
$$

The first line corresponds to total welfare when both banks happen to be systemic, which occurs with probability λ^2. The probability that they survive is $1-p_d$. The second and third line aggregate total surplus when a systemic bank survives or fails, respectively, while the other bank is idiosyncratic. Finally, surplus, when both banks are funded with idiosyncratic sources, is shown in the last line.

The socially optimal mixing probability is $\max\{0, \min\{\lambda^u, 1\}\}$, with

$$\lambda^u = (1+p_d)\frac{-\mathrm{Cov}(\rho^S, k)}{2W^Sp_d}.$$

We defer the discussion of this result to Proposition 1.

Socially optimal outcome in pure strategies

Now assume the regulator has full control over banks' funding choices. Firstly, it is never socially optimal to assign idiosyncratic funding to both banks, because that is dominated by the welfare outcome when one bank is systemic and the other is idiosyncratic. In the latter case asset-takeover probabilities are unchanged, but one bank can benefit from aggregate risk sharing. Therefore, we only have two compare to possibilities, one in which both banks have systemic funding with another, in which one of them has idiosyncratic funding. Let the corresponding welfare levels be denoted by W^{SS} and W^{SI}, respectively. Aggregating per-project-expected total surpluses yields

$$
\begin{aligned}
W^{SI} &= (1-p_d)^2(W^S+W^I) + 2(1-p_d)p_dW^S + 2(1-p_d)p_dW^I \\
W^{SS} &= 2(1-p_d)W^S.
\end{aligned}
$$

Comparing the two lines we find

$$W^{SI} \leq W^{SS} \Leftrightarrow 1 \leq \lambda^u.$$

So far we were silent about deposit insurance fees. We assume that banks are required to pay a fair fee, which compensates the deposit insurance fund for the incurred losses in expectation. The consequence of fair deposit insurance fees is that the per-project private and social surpluses are equal:

$$\pi^S = W^S \text{ and } \pi^I = W^I,$$

which leads us to the following proposition.

Proposition 1 *Assume that the regulator implements countercyclical capital requirements* ($\mathrm{Cov}(\rho^S, k) < 0$)*.*

1. *Without systemic externalities private and social incentives are aligned and full cross-bank cross-bank correlation is optimal . This is the case when* $p_d = 0$*.*
2. *Assume* $p_d > 0$*. Then* $\lambda^c \geq \lambda^u$*, thus countercyclical capital requirements induce inefficient systemic risk shifting and banks become excessively correlated from a social point of view.*

Proof. If $p_d = 0$, then $\pi^S - \pi^I = W^S - W^I = -\mathrm{Cov}(\rho^S, k) > 0$ and hence maximum correlation between banks is privately and socially optimal. Comparing equilibrium and optimal mixing probabilities yields $2\lambda^u = \lambda^c$. ■

To understand the source of inefficiency that drives a wedge in the equilibrium and first best outcomes when banks' correlation choice is associated with systemic costs consider the case when one bank, say Bank B, has already chosen systemic funding. Then Bank A benefits from choosing systemic funding by sharing the aggregate risk insurance that countercyclical capital requirements provide. At the same time, Bank A loses the possibility to take over Bank B's project in case it fails to raise capital. Bank A thus compares the benefits from aggregate risk sharing with the opportunity cost of not being able to finance an additional unit of investment. The regulator makes the same comparison, but she also takes into account that Bank A's decision to choose systemic funding also eliminates the possibility for Bank B to benefit from asset takeovers. This reduces social gains from aggregate risk sharing and incentivizes banks to become excessively correlated.

Finally, we emphasize that the above results hold for any given –fixed– policy function, as long as it is countercyclical. In particular, a different micro foundation for countercyclical policy could be introduced in our model – for example based on Repullo and Suarez (2012) – and Proposition 1 would still survive. In the next section we derive the constrained and unconstrained optimal policy functions in our model setup.

2.2.1 Optimal amount of counter cyclicality

Recall that in the baseline model without systemic externalities the optimal policy function is a step function taking two values, zero and $\bar{k}$. The optimal threshold of capital costs (ρ^S) below which high capital requirements are implemented is $\hat{\rho} = \hat{\rho}^*$.

In what follows we restrict attention to step functions and look for the optimal policy rule within this family.[10] The regulator chooses the threshold variable $\hat{\rho}$ to maximize total surplus. There are two cases to be considered. First we derive the optimal threshold when the regulator also chooses the mixing probability λ, then we let the regulator have full control banks' funding choice. Substituting $k = k(\rho^S; \hat{\rho})$ in W^λ (Equation 4) and manipulating the first order condition with respect to $\hat{\rho}$ yields the unconstrained optimal threshold when the regulator chooses the mixing probability λ

$$\hat{\rho}^u_\lambda = \hat{\rho}^* + \gamma \frac{(1-\lambda^u)(1+p_d)}{\lambda^{u2} + \lambda^u(1-\lambda^u)(1+p_d)}, \tag{5}$$

where $\lambda^u = \lambda^u(\hat{\rho}^u_\lambda)$ is now evaluated using the policy function defined by $\hat{\rho}^u_\lambda$; and $\gamma = \hat{\rho}^* - \mu$.

Let us turn to the second case, in which the regulator can assign funding sources to each bank separately. The regulator compares maxima of two welfare functions, W^{SS} and W^{SI}, corresponding to the full and zero correlation cases, respectively. Comparing the two welfare levels at the optimal covariance levels as defined by the thresholds $\hat{\rho}$ (assuming interior solutions) yields

$$\hat{\rho}^u = \begin{cases} \hat{\rho}^* + \gamma & \text{if } \lambda^u(\hat{\rho}^*) < 1 + \Theta \quad \text{(zero correlation case)} \\ \hat{\rho}^* & \text{otherwise} \quad \text{(perfect correlation case)}, \end{cases}$$

[10] In the Appendix we show that the optimal rule is indeed a step function and our restriction is not constraining.

where $\Theta = \left[(1+p_d)\bar{k}\int_{\hat{\rho}^*}^{\hat{\rho}^*+\gamma} \hat{\rho}^* + \gamma - \rho^S \, \mathrm{dP}(\rho^S)\right] \frac{1}{2p_d \, W^S|_{\hat{\rho}=\hat{\rho}^*}} > 0$. In the first case systemic costs of cross-bank correlation are sufficiently high so as to make full correlation between banks socially suboptimal. The regulator assigns systemic funding to one bank, and idiosyncratic funding to the other. In contrast, if systemic costs are low, full cross-bank correlation is optimal, in which case the regulator provides more aggregate risk insurance by decreasing the threshold variable from $\hat{\rho}^* + \gamma$ to $\hat{\rho}^*$ and consequently increasing the countercyclicality of capital requirements, since

$$\mathrm{Cov}(\rho^S, k(\rho^S; \hat{\rho}^*)) \leq \mathrm{Cov}(\rho^S, k(\rho^S; \hat{\rho}^* + \gamma)).$$

2.3 Constrained efficient regulation

Constrained efficient regulation with mixing strategies

In this section we derive the constrained efficient regulation for the case when banks follow mixing strategies. We maintain the assumption that the policy function is a step function. The regulator chooses threshold value $\hat{\rho}$ of systemic capital costs, at which capital requirements are relaxed, such that total welfare (4) is maximal subject to the constraint on banks' mixing probability $\lambda^c(\hat{\rho})$ as defined by (3).

$$\frac{\partial W^\lambda}{\partial \hat{\rho}} = \gamma \underbrace{\left[\frac{(1-\lambda^c)(1+p_d)}{\lambda^{c2} + \lambda^c(1-\lambda^c)(1+p_d)} + \frac{1}{1-\lambda^c \frac{p_d}{1+p_d}}\right]}_{>0}.$$

Since the term in brackets is strictly positive, the sign of the slope of the welfare function depends on γ. Unless $\gamma = 0$, we thus find that the regulator's problem has no interior solution. When capital regulation adds to the social surplus of projects funded from idiosyncratic sources ($\gamma > 0$), it is optimal to set the threshold to the maximum and always have high capital requirements. In the opposite case having zero capital requirements are optimal. Consequently, flat capital requirements are preferred when banks play mixing strategies and γ is not equal to zero. If $\gamma = 0$, the regulator is indifferent between any level of countercyclicality.

Constrained efficient regulation with pure strategies

When banks choose to play pure strategies, the following outcomes are possible. The first best outcome is achievable and banks choose 1) full correlation or 2) zero correlation.

The regulator would choose zero correlation, but the first best covariance is incompatible with banks' correlation choice. In this case the regulator might choose 3) low covariance compatible with banks equilibrium choice of zero correlation, or 4) high covariance, to provide as much aggregate risk insurance as possible, and let banks be fully correlated.

Firstly, notice, that if under the first best policy full correlation is optimal, then it is also achievable under decentralized decision making as a direct consequence of Proposition 1. This is the case, when $\lambda^u(\hat{\rho}^*) \geq 1 + \Theta$, and then the optimal threshold is $\hat{\rho}^*$, which is also constrained efficient. Similarly, optimal regulation with zero cross-bank correlation is not necessarily constrained either. If $\lambda^u(\hat{\rho}^*) < 1 + \Theta$, then the first best policy assigns zero correlation between banks and sets the threshold equal to $\hat{\rho}^* + \gamma$. If $2\lambda^u(\hat{\rho}^* + \gamma) = \lambda^c(\hat{\rho}^* + \gamma) < 1$, then this solution is also consistent with banks' choice of zero correlation.

In contrast to the previous cases, regulation is compromised if $\lambda^u(\hat{\rho}^*) < 1 + \Theta$ and $2\lambda^u(\hat{\rho}^* + \gamma) > 1$, which is the region for inefficient systemic risk shifting. To find the second best policy rule in this case, the regulator compares welfare under high cross-bank correlation and high covariance with that under low correlation and low covariance. In the first case the optimal threshold is $\hat{\rho}^*$ and both banks choose systemic funding. In the second case the policy rule makes banks indifferent between high correlation and low correlation, and so the threshold solves $\lambda^c(\hat{\rho}) = 1$. In general this equation has multiple solutions, let us denote the set of solutions by Ω. The optimal threshold is $\tilde{\rho} = \arg\max_{\hat{\rho}\in\Omega} W^{SI}(\hat{\rho})$. To simplify the analysis we assume that if $\gamma > 0$, it is true that $\tilde{\rho} > \hat{\rho}^* + \gamma$ and if $\gamma < 0$, then $\tilde{\rho} < \hat{\rho}^* + \gamma$ holds. This assumption guarantees the following relationship between various levels of capital costs:

$$\begin{aligned} &\mu < \hat{\rho}^* < \hat{\rho}^* + \gamma < \tilde{\rho} \quad \text{if} \quad \gamma > 0 \\ &\mu > \hat{\rho}^* > \hat{\rho}^* + \gamma > \tilde{\rho} \quad \text{if} \quad \gamma < 0 \end{aligned} \tag{6}$$

If $\gamma = 0$, then $\mu = \hat{\rho}^* = \hat{\rho}^* + \gamma$ and additionally, if $\lambda^c(\mu) > 1$, then $\tilde{\rho}$ is strictly greater or smaller than μ.

By comparing the two welfare levels, we find that the constrained optimal threshold – when the regulator is truly constrained – is

$$\hat{\rho}^c = \begin{cases} \tilde{\rho} & \text{if } \lambda^u(\hat{\rho}^*) < 1 + \Theta - \tilde{\Theta} \quad \text{(zero correlation case)} \\ \hat{\rho}^* & \text{otherwise} \qquad\qquad\qquad\;\; \text{(perfect correlation case),} \end{cases}$$

where $\tilde{\Theta} = -\left[(1+p_d)\bar{k}\int_{\hat{\rho}^*+\gamma}^{\tilde{\rho}} \hat{\rho}^* + \gamma - \rho^S \, \mathrm{dP}(\rho^S)\right] \frac{1}{2p_d W^S|_{\hat{\rho}=\hat{\rho}^*}} > 0$. Whether the regulator finds it optimal to choose $\hat{\rho}^*$ or $\tilde{\rho}$ depends on $\tilde{\Theta}$, and in particular the distribution of systemic capital costs. If $\tilde{\Theta}$ is small, then the zero cross-bank correlation/low countercyclicality outcome is preferred with $\hat{\rho} = \tilde{\rho}$ and (S, I) or (I, S); otherwise the regulator chooses $\hat{\rho} = \hat{\rho}^*$ and consequently banks choose high correlation (S, S).

Irrespective of whether banks choose pure or mixing strategies or not, optimal regulation takes into account banks' systemic risk shifting incentives and encourages them to take less correlated decisions. The regulator can achieve this by decreasing the countercyclicality of capital requirements, which can be done by increasing (decreasing) the threshold variable $\hat{\rho}$ if γ is positive (negative). If banks choose mixing strategies, this effect is unambiguous (excluding the special case when $\gamma = 0$): the regulator's best decision is to implement flat capital requirements. If banks play pure strategies, the situation is more subtle, as in certain cases flat capital requirements are relatively too costly and the regulator finds it best to accommodate banks' choice of high correlation and provides as much aggregate risk insurance as possible by increasing countercyclicality. The following proposition summarizes these results.

Proposition 2 *Constrained efficient capital regulation takes the following form in the economy.*

- *If banks choose mixing strategies, then the optimal threshold is*

$$\hat{\rho}^c_\lambda = \begin{cases} 0 & \text{if } \gamma < 0 \\ \infty & \text{if } \gamma > 0 \\ \text{any } \hat{\rho} \in \mathcal{R}^+ & \text{if } \gamma = 0. \end{cases}$$

- *If banks choose pure strategies, then the following cases are possible.*

  1. *If $\lambda^u(\hat{\rho}^*) \geq 1 + \Theta$, then $\hat{\rho}^c = \hat{\rho}^u = \hat{\rho}^*$ and banks choose full correlation and the regulator is unconstrained.*
  2. *If $1 + \Theta - \tilde{\Theta} \leq \lambda^u(\hat{\rho}^*) < 1 + \Theta$ and $2\lambda^u(\hat{\rho}^* + \gamma) > 1$, then $\hat{\rho}^c = \hat{\rho}^*$ and banks choose full correlation. The regulator is constrained by banks' systemic shifting incentives.*

3. *If* $\lambda^u(\hat{\rho}^*) < 1 + \Theta - \tilde{\Theta}$ *and* $2\lambda^u(\hat{\rho}^* + \gamma) > 1$*, then* $\hat{\rho}^c = \tilde{\rho}$ *and banks choose zero correlation. The regulator is constrained by banks' systemic shifting incentives.*

4. *If* $\lambda^u(\hat{\rho}^*) < 1 + \Theta$ *and* $2\lambda^u(\hat{\rho}^* + \gamma) < 1$*, then* $\hat{\rho}^c = \hat{\rho}^u = \hat{\rho}^* + \gamma$ *and banks choose zero correlation and the regulator is unconstrained.*

A consequence of Proposition 2 is that constrained efficient regulation encourages smaller cross-bank correlation by decreasing the countercyclicality of capital requirements.

Corollary 1 *Let* $k^c(\hat{\rho})$ *and* $k^u(\hat{\rho})$ *denote the constrained efficient and unconstrained policy rules, respectively. Then*

$$|\mathrm{Cov}(k^c(\hat{\rho}), \rho^S)| \leq |\mathrm{Cov}(k^u(\hat{\rho}), \rho^S)|.$$

Proof. Notice that the covariance between capital costs and capital requirements as a function of the threshold variable $\hat{\rho}$ attains its minimum at $\hat{\rho} = \mu$ and is a monotonous function on the intervals $[0, \mu]$ and $[\mu, \bar{\rho}]$. If $\gamma = 0$, then the unconstrained optimal threshold is μ and the result is immediate. Now assume $\gamma \neq 0$. For the case of pure strategies the result follows from the relations shown in (6), while in case of mixing flat capital requirements are constrained efficient. ■

3 The role of credibility

In the previous sections we implicitly assumed that the regulator could commit to the announced policy rule. Instead, we now assume that the regulator chooses a level of minimum capital requirements, which is optimal ex post, that is when banks have already made their correlation choice. We do not consider the two-way interaction between banks and the regulator. Such interaction would be expected if banks took into account the impact of their correlation decision on ex post regulation. Instead, we assume that banks behave as atomistic agents in the economy, taken the expected policy rule as given. As a result of this assumption, the analysis of the previous section in which we derived banks' optimal decisions continues to apply.

Equilibria in mixing strategies

As before, in a mixing equilibrium banks choose systemic funding with probability $\lambda^c(\hat{\rho}_\lambda^d)$, for a given policy rule defined by $\hat{\rho}_\lambda^d$. We assume rational expectations, that is, banks correctly anticipate the value of the threshold, set by the regulator after banks' correlation choice has been made. Given this correlation choice, the regulator sets the threshold such that it maximizes social surplus (4). Assuming an interior solution, this yields

$$\hat{\rho}_\lambda^d = \hat{\rho}^* + \gamma \frac{(1-\lambda^c)(1+p_d)}{\lambda^{c2} + \lambda^c(1-\lambda^c)(1+p_d)}. \tag{7}$$

The equilibrium threshold is then a fixed point of the above equation, with $\lambda^c = \lambda^c(\hat{\rho}_\lambda^d)$.

Equilibria in pure strategies

There are two possible outcomes if banks play pure strategies: either one bank chooses systemic funding, or both. Optimal ex post regulation reflects this by providing the optimal level of countercyclicality, depending on the cross-bank correlation. In the low correlation case the optimal policy rule is defined by a threshold equal to $\hat{\rho}^* + \gamma$, while in the high correlation case the optimal threshold is $\hat{\rho}^*$ (see the discussion on the unconstrained optimal policy). Banks rationally anticipate the two possible policy versions and depending on their expectations, the following outcomes are possible.

If $\lambda^c(\hat{\rho}^* + \gamma) > 1$, then the only equilibrium is full correlation, because banks choose this outcome even if regulation provides relatively little aggregate risk insurance. Also, if $\lambda^c(\hat{\rho}^*) < 1$, then the only equilibrium is zero correlation, because banks choose not to correlate even though regulation is more countercyclical (than the optimal one under zero correlation). Multiple equilibria is also possible when $\lambda^c(\hat{\rho}^*) > 1$ and $\lambda^c(\hat{\rho}^* + \gamma) < 1$, in which case both expectations are confirmed ex post. Under the assumption that in case of multiple equilibria banks form expectations that are consistent with the time consistent equilibrium, we can state the following proposition:[11]

Proposition 3 *If the regulator cannot commit to the policy rule ex ante, it tends to set a more countercyclical rule ex post than the constrained optimal rule with commitment.*

[11] In a repeated game in which the regulator has some, even if not full, credibility, this outcome could be sustained under reasonable assumptions.

Corollary 2 *Without commitment banks choose at least as high cross-bank correlation as under the constrained efficient policy rule, to which the regulator can commit, and sometimes higher.*

In the mixing equilibrium case banks' excessive risk shifting as a result of the regulator's lack of credibility follows from Proposition 1 and the fact that, in general, the solution of (7) yields a covariance between capital requirements and capital costs that is nonzero. Let us consider now equilibria in pure strategies. There are four parameter regions with different outcomes to be compared.

1. Assume $\lambda^u(\hat{\rho}^*) \geq 1+\Theta$ (case 1 in Proposition 2). Then $\lambda^c(\hat{\rho}^*) \geq 2+2\Theta$ and multiple equilibria are possible if $\lambda^c(\hat{\rho}^* + \gamma) < 1$, but we exclude this case by assumption (see above). The time consistent and time inconsistent outcomes coincide in this case.

2. Assume $2\lambda^u(\hat{\rho}^* + \gamma) > 1$ (cases 2 and 3). Then the unique equilibrium is the high correlation case.

3. Assume $2\lambda^u(\hat{\rho}^* + \gamma) < 1$ (case 4). When the regulator can commit to the policy rule ex ante, banks choose low correlation in equilibrium. Without commitment, there is either a unique equilibrium with low correlation or both (low and high correlation) equilibria are possible.

4 Discussion

Ex ante measures to control systemic risk

Our model highlights the importance of ex ante measures to control banks' incentives to choose excessively correlated balance sheets. In our framework the first best outcome would be the one in which individual capital requirements can be conditioned on idiosyncratic capital costs. Then banks would be fully insured against adverse economic conditions and would never bear the burden of excessive capital costs. They would also find it optimal to minimize cross-bank correlation, because that would increase the chances that they can benefit from asset takers from liquidating banks, minimizing the risk of systemic crises at the same time. However, introducing a fully idiosyncratic countercyclical policy has its own costs, too. Firstly, in practice it might not be feasible or efficient to implement such a policy because of information asymmetries between the bank and the regulator. Second, it could also cause moral hazard, since banks would enjoy even more policy help, and might increase their risk appetite.

For this reason it might be better to provide aggregate insurance to the banking sector and address banks' correlation choice ex ante. Access to tools[12] that help achieve the second objective might not only decrease cross-sectional systemic risk, but also enhances the efficacy of countercyclical policy devices. Being not constrained by banks' inefficient systemic risk shifting, the regulator can provide as much aggregate risk insurance as needed. In the model this leads to a welfare improvement to the second best level –a potentially large increase form its constrained level.

Ex post bailout

We neglected the possibility that the regulator might intervene in case of a systemic crisis, when both banks fail to raise sufficient funding. In such a situation, the central bank could step in and replace funding markets, like the Fed did after the fall of Lehman Brothers. In terms of our model, the regulator could provide access to equity markets, or relax capital requirements in case there is a systemic crisis. As long as some social costs are attached to such ex post interventions, our results survive. Instead of a credit crunch, however, where the costs of systemic crises arise from unrealized positive NPV projects, inefficiencies stem from the costs of ex post interventions.

Other types of countercyclical policies

The same intuition for systemic risk shifting as a result of countercyclical policies should hold for other kinds of macroprudential policies that are countercyclical and are conditioned on aggregate information. Under Basel III banks are required to hold a certain amount of liquid assets as a fraction of their balance sheets. To the extent that banks expect these requirements to be relaxed under general bad economic conditions, this regulation might also be subject to systemic risk shifting.

[12]Examples of such tools include capital requirements based on various measures of banks' systemic importance, such as CoVar (Adrian and Brunnermeier, 2011) or Systemic Expected Shortfall (Acharya et al., 2012)

Effect of competition

In our model with two banks there can only be at most one bank bidding for the withdrawing bank's asset, therefore the assumption that all the surplus from asset takeover accrues to the acquirer bank seems reasonable. With more banks two additional effects influence correlation choice. On one hand, fiercer competition at the bidding for assets, after capital supply shocks have occurred, drives up asset prices and reduces the return on acquired assets. Similarly, more competition on the lending market reduces bank returns on all assets. Both effects reduce diversification incentives and exacerbates systemic risk shifting.

5 Conclusion

In this paper we have shown that countercyclical prudential policies that are based on aggregate information give incentives to banks to make correlated decisions. The reason is that banks benefit from countercyclical policies at times of general stress in the economy, and thus they choose to be exposed to aggregate shocks, as opposed to idiosyncratic risk. Since correlated exposures give rise to systemic risk, which banks do not fully internalize, equilibrium cross-bank correlation is larger than what is social optimal.

Our results have consequences for the design of capital regulation. Under Basel III a national countercyclical capital buffer will be imposed when regulators find that the risk of excessive credit expansion is high. Although this policy tool will be implemented on a discretionary basis, guidance by the BCBS (2010) recommends that the buffer be linked to the gap between the credit-to-GDP ratio and its trend. The document provides recommendations on the calibration of the policy tool, which is based on historical data, and as such, does not take into account banks' systemic risk shifting incentives in response to a more countercyclical regulatory framework. The resulting outcome might be that the financial sector becomes more procyclical, as opposed to the desired objectives. This conclusion is similar to that of Repullo and Saurina (2011), who also warn that the mechanical use of the countercyclical buffer, as described in BCBS (2010), might lead to increased procyclicality because of the inappropriateness of the credit-to-GDP gap measure, to which the buffers are linked.

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