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\* Views expressed are those of the author and do not necessarily reflect official positions of De Nederlandsche Bank.

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# Capital Requirements and Credit Rationing

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## Abstract

This paper analyzes the trade-off between financial stability and credit rationing that arises when increasing capital requirements. It extends the Stiglitz-Weiss model of credit rationing to allow for bank default. Bank capital structure then matters for lending incentives. With default and rationing endogenous, optimal capital requirements can be analyzed. Introducing bank financiers, the paper also shows that uninsured funding raises the sensitivity of rationing to capital requirements. In a world with much wholesale finance, capital requirements have a stronger impact on the real economy. But wholesale finance also amplifies capital requirements' effect on default rates.

Keywords: Rationing, Capital requirements, Regulation, Wholesale finance, Deposit Insurance

JEL Classification: G21, G28

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# 1 Introduction

If regulators will soon require banks to hold larger capital buffers, how will this affect the supply of bank loans relative to demand? Will more borrowers get rationed? Empirical evidence from the early 1990s credit crunch indicates that the imposition of Basel I capital requirements exacerbated this episode.<sup>1</sup> In this paper I propose a mechanism to understand the relationship between capital requirements and credit rationing. I extend the seminal model on credit rationing, Stiglitz and Weiss (1981) (henceforth SW), to allow for bank default, which makes it possible to differentiate between debt and equity financing.

In SW rationing comes about through the volatility of borrower's returns. Borrowers are indistinguishable to banks, and higher risk borrowers are willing to accept higher loan rates. A bank's loan rate then has a sorting effect: the higher the rate, the greater the volatility of returns among the pool of loan applicants. This can lead banks to optimally charge a loan rate below the market clearing rate, which implies excess demand for loans in equilibrium.

When the regulator raises capital requirements banks are forced to delever their balance sheets. This expands credit rationing in two ways. Firstly, smaller balance sheets reduce the amount of credit that banks can supply. And, secondly, with a lower debt-to-equity ratio banks have a greater incentive to reduce the volatility of their asset portfolio. They are willing to give up more returns on successful loans in order to improve on the composition of loan applicants. Therefore, they lower loan rates, which increases credit demand. With fewer loans supplied and more demanded, credit rationing rises.

Capital requirements thus create a cost that needs to be weighed against their benefit in terms of financial stability. The model contains an endogenous probability of bank default, which falls when capital requirements rise. I define the problem of a regulator that minimizes the social costs of bank failure and credit rationing to its capital requirement. Here, exogenous parameters represent the two types of social costs. Optimal capital requirements are shown to fall in borrower quality - as financial stability concerns ease - and rise in bank funding rates. The latter provides an interesting connection to monetary policy, which directly affects the cost of short-term bank funding. Monetary easing creates incentives to soften regulatory standards.

In the basic model these bank funding rates are taken as exogenous. However, I extend the model to endogenous bank financiers. In particular, I consider two types of financiers, those that are uninsured and those that are covered by deposit insurance. The latter represent commercial retail depositors. Instead, uninsured depositors represent wholesale investors. In the years before the crisis, wholesale bank finance boomed (Brunnermeier et al. (2009), Diamond and Rajan

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<sup>1</sup>See Bernanke et al. (1991), Furlong (1992), Jacklin (1993), Haubrich and Wachtel (1993), Hancock and Wilcox (1994), Hancock et al. (1995) and Peek and Rosengren (1995a,b). For an opposing view, see Berger and Udell (1994).

(2009)). The model allows me to investigate the relationship of this stylized fact to the effects of capital requirements. I find that wholesale finance raises the sensitivity of credit rationing to capital requirements. That is, in a world in which banks are largely wholesale financed, capital requirements have a larger impact on the real economy. However, they then also have a larger impact on financial stability. Both effects come about from the feedback between loan rates and funding rates that wholesale finance creates. Since uninsured financiers care about the risk of the bank they are lending to, higher loan rates, by worsening the pool of bank borrowers, lead to higher funding rates. This feedback amplifies the impact of capital requirements.

I consider robustness of the results to risk-weighted capital requirements. In the basic model capital requirements are not weighed by the quality of bank loans. If the regulator designs a mapping between bank risk taking and capital requirements, the trade-off between financial stability and credit rationing unambiguously improves. That is, the regulator can achieve both fewer bank defaults and less rationing. However, the comparative statics of the model are otherwise unchanged.

This theory gives rise to three sets of testable implications:

1. Capital requirements raise the incidence of credit rationing and lower bank default rates;
2. Wholesale finance amplifies both effects in 1;
3. Capital requirements lower bank loan rates.

The connection between capital requirements and bank default rates is certainly not unique to this theory. I refer to VanHoose (2007) for the literature on this topic. However, the amplification of this relationship through wholesale finance is new, to the best of my knowledge. As is the amplification of the effect on credit rationing through wholesale finance. Unfortunately, neither of these have been empirically investigated. The hypothesis that capital requirements increase credit rationing has been empirically studied, as referred to in the first footnote.<sup>2</sup> There exists only one competing theoretical explanation for this effect, namely that of Thakor (1996).

In Thakor's model higher capital requirements lead to more credit rationing through an entirely different mechanism. Banks choose the probability with which they screen a loan applicant. The applicant can only receive a loan if it is screened and the bank receives a positive signal from this process. The bank makes a profit if it is the only one to accept an applicant. In equilibrium all banks screen borrowers with a probability less than one, so that each has some chance of being

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<sup>2</sup>There is also a sizeable literature on the so-called "bank capital channel" which investigates the amplification of monetary transmission through bank capital. Several key references are Blum and Helwig (1995), Repullo and Suarez (2000), Kishan and Opiela (2000), Chen (2001), Gambacorta and Mistrulli (2004), and Bolton and Freixas (2006). See Drumond (2009) for a comprehensive survey.

a monopolist on the applicant. When capital requirements rise, banks face a higher cost of loan-funding. In response, all banks reduce the probability with which they screen applicants and thus more potential borrowers get rationed.

Interestingly, the third testable implication in the list above can be used to empirically differentiate between Thakor's theory and mine. In my paper higher capital requirements induce banks to lower loan rates (an incentive effect), whereas in Thakor's paper they then raise loan rates (a cost-price effect).<sup>3</sup> Hubbard et al. (2002) find that better capitalized banks charge lower loan rates. However, this finding concerns "voluntarily" raised capital rather than regulatory bounds. It is not clear if this affects the applicability of the finding. The distinction between voluntary and mandatory capital holding is not formalized in my paper. Like Thakor, I implicitly assume that capital requirements are always binding. That is, implicitly equity is assumed to be more costly than debt, so that the bank takes on as much leverage as is allowed.

This paper relates to the debate on taxing bank liabilities (Perotti and Suarez, 2009). In terms of lending incentives a tax on liabilities or a binding capital requirement are equivalent. They both reduce the debt-to-equity ratio. This paper also relates to the literature on the rationale for having positive, but limited bank capital requirements. Here the social costs of bank capital arise from the value that liquid deposits have for households (Van den Heuvel (2008)) or as a bargaining tool for investors, due to the threat of a bank run (Diamond and Rajan (2000)).

The next section introduces the basic model of credit rationing. Section 3 derives the regulator's trade-off with financial stability. Section 4 extends to bank financiers and discusses the consequences of the rise of wholesale funding. Subsequently, section 5 considers the effects of risk-weighted capital requirements. Finally, section 6 concludes.

## 2 Model

The setup follows SW, except in introducing limited liability and different forms of financing for banks. Both borrowers and banks are risk neutral. There is a discrete number,  $N$ , of projects, each of which is tied to one given borrower. Projects are numbered  $\theta = \{1, 2, \dots, N\}$ , and the return on project  $\theta$  is called  $R_\theta$ . It is known that all projects have same mean return, but they differ in the volatility of returns. The distributions of projects' returns,  $F(R_\theta)$ , are known to borrowers but not to banks. Borrowers' projects are sorted by their risk, in the sense that a larger  $\theta$  corresponds to a mean-preserving spread over a smaller  $\theta$ . By the definition of second-order stochastic dominance:

$$\int_0^\infty R_2 f(R_2) dR = \int_0^\infty R_1 f(R_1) dR \quad (1)$$

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<sup>3</sup>Thakor (1996) does not highlight this feature in his paper, but it is simple to derive from the model. A proof is available upon request.

and for  $y \geq 0$

$$\int_0^y F(R_2)dR \geq \int_0^y F(R_1)dR \quad (2)$$

To start up a project, a borrower needs an amount  $B$ , which he can obtain at the prevailing bank loan rate,  $\hat{r}^b$ . If the return on his project is insufficient to pay the bank back the promised amount, he defaults on his loan. Formally, this occurs when:

$$C + R_\theta \leq (1 + \hat{r}^b) B \quad (3)$$

where  $C$  is the collateral pledged on the loan. Then, the net return to a borrower can be written as:

$$\max \{R_\theta - (1 + \hat{r}^b) B, -C\} \quad (4)$$

By SW Theorem 1, for a given loan rate,  $\hat{r}^b$ , there is a critical value  $\hat{\theta}$  such that a firm borrows from the bank if and only if  $\theta \geq \hat{\theta}$ . Thus,  $\theta \geq \hat{\theta}$  constitutes the set of individuals that requests loans from the bank. With high returns borrowers make large profits, with low returns they default. Therefore, greater volatility implies greater expected returns, and a willingness to pay higher loan rates. Then, by SW Theorem 2:  $\frac{d\hat{\theta}}{d\hat{r}^b} > 0$ . A higher loan rate brings about a riskier pool of loan applicants.

On each borrower to which the bank lends it receives

$$\min \{R_\theta + C, (1 + \hat{r}^b) B\} \quad (5)$$

and the bank's total revenues can be written as

$$\sum_{\theta \in \Theta} \min \{R_\theta + C, (1 + \hat{r}^b) B\} \quad (6)$$

where  $\Theta$  is the subset of loan applicants  $\theta \geq \hat{\theta}$  to which the bank is randomly matched.

The bank's funding consists of equity,  $Q$ , and debt,  $D$ :

$$X = Q + D \quad (7)$$

Its only costs are the payments to its creditors:

$$(1 + \hat{r}^d) D \quad (8)$$

where  $\hat{r}^d$  is the return that creditors demand on the funds they provide. This funding rate is taken

as exogenous (until section 4). I assume that a bank has a given amount of equity

$$Q = \bar{Q} \quad (9)$$

and that any required adjustments to its balance sheet are made by adding or reducing debt, rather than by issuing or shedding equity. In particular, like Thakor (1996), I assume that capital requirements are always binding. Implicitly equity is assumed to be a more expensive form of financing than debt, and banks prefer to take on as much debt as is allowed. Capital requirements are defined here as fixing a minimum to the ratio  $\frac{X}{Q}$ : at least a given fraction of liabilities must be in equity. For given  $\bar{Q}$  this means that the regulator's capital requirements fixes a maximum debt level, called  $D^{\max}$ . Thus, a lower  $D^{\max}$  means tougher capital requirements.

If revenues exceed costs the residual is paid out to shareholders. If not, then the bank defaults. Total profits can then be written as

$$\Pi = \max \left\{ \left[ \sum_{\theta \in \Theta} \min \{ R_{\theta} + C, (1 + \hat{r}^b) B \} \right] - (1 + \hat{r}^d) D, 0 \right\} \quad (10)$$

where the bank's problem is

$$\max_{\hat{r}^b} E [\Pi] \quad (11)$$

Note that SW, beyond stating that banks are not price takers (p.395), do not discuss the mode of competition between banks. There is no need to choose a specific type of competition here either. I do assume that banks are identical (meaning here that they all have the same amount of equity,  $\bar{Q}$ ).

Define the extent of rationing as

$$\Omega = B \left( N - \hat{\theta} \right) - MX \quad (12)$$

where  $B \left( N - \hat{\theta} \right)$  is total loan demand by borrowers, and, letting  $M$  be the number of banks,  $MX$  is total loan supply.

Proposition 1 proves that credit rationing increases in capital requirements. Intuitively, equity holders only receive what remains of returns after bank creditors have been paid. They are like the owners of a call option. The larger the debt burden of a bank, the more its shareholders have to gain from upside risk. And the less they have to lose from downside risk, since the bank can default when returns are low. If bank management represents shareholders' interests, therefore, it will like volatile returns more when the bank is more debt financed. Forcing the bank to shed leverage implies that the taste for volatility reduces. The bank will charge a lower loan rate to improve on the quality of its borrower pool. At lower loan rates demand for bank credit rises,



while at the same time banks supply less credit due to their downsized balance sheets. Thus, credit rationing becomes more prevalent.

**Proposition 1** *Higher capital requirements imply more credit rationing:  $\frac{\partial \Omega}{\partial (X/\bar{Q})} > 0$ .*

**Proof.** A change in  $\hat{r}^b$  has two effects on the bank's profit in equation (10). Firstly, it affects the term given by (6). By the arguments in SW, this term is first increasing and then decreasing in  $\hat{r}^b$ . The reason is that beyond a threshold the negative sorting effect, through  $\frac{d\hat{\theta}}{d\hat{r}^b}$ , dominates the higher return per successful loan  $(1 + \hat{r}^b)$ . Define  $\bar{r}^b$  as this threshold:

$$\bar{r}^b \equiv \hat{r}^b : \frac{\partial}{\partial \hat{r}^b} \sum_{\theta \in \Theta} \min \{ R_\theta + C, (1 + \hat{r}^b) B \} = 0 \quad (13)$$

and call the bank's optimal loan rate  $(\hat{r}^b)^*$ .

Secondly, the option value created by the bank's limited liability is affected by the volatility of its returns. In particular, we can rewrite (11) to

$$\begin{aligned} & \max_{\hat{r}^b} E \left[ \max \left\{ \left[ \sum_{\theta \in \Theta} \min \{ R_\theta + C, (1 + \hat{r}^b) B \} \right] - (1 + \hat{r}^d) D, 0 \right\} \right] \\ = & \max_{\hat{r}^b} E \left[ \max \left\{ \left[ \sum_{\theta \in \Theta} \min \{ R_\theta + C, (1 + \hat{r}^b) B \} \right], (1 + \hat{r}^d) D \right\} \right] - (1 + \hat{r}^d) D \quad (14) \end{aligned}$$

which has the structure of a call option with expected payoff  $E [\max \{y, k\}]$  where  $y$  is the value of the underlying asset and  $k$  is the option's strike price. By the standard arguments of option theory, the expected value of a call option is increasing in the volatility of the underlying asset (Hull, 2002). Here, the volatility of  $[\sum_{\theta \in \Theta} \min \{ R_\theta + C, (1 + \hat{r}^b) B \}]$  is determined by  $\hat{\theta}$ : the higher it is, the more volatile the returns among potential borrowers (by the assumptions of SW). Given that  $\frac{d\hat{\theta}}{d\hat{r}^b} > 0$ , it follows that increasing  $\hat{r}^b$  raises the volatility of returns, and thereby increases the option value. For any  $\hat{r}^b > \bar{r}^b$  the trade-off of increasing  $\hat{r}^b$  thus consists of  $E [\max \{y, k\}]$  being decreased through a lower expected value of  $y$ , but being increased by a greater volatility of  $y$ .

Finally, the higher is the strike price,  $k$ , of a call option, the more valuable is the volatility of  $y$  (Hull, 2002). As here  $k = (1 + \hat{r}^d) D$ , the volatility of  $y$  is more valuable when  $D$  is higher. And therefore,

$$\frac{\partial (\hat{r}^b)^*}{\partial D_{\max}} > 0 \quad (15)$$

Relating this to credit rationing:

$$\frac{\partial \Omega}{\partial (X/\bar{Q})} > 0 \Leftrightarrow \frac{\partial \Omega}{\partial D_{\max}} < 0 \quad (16)$$

$$\begin{aligned}
\frac{\partial \Omega}{\partial D^{\max}} &= \frac{\partial B(N - \hat{\theta})}{\partial D^{\max}} - \frac{\partial MX}{\partial D^{\max}} \\
&= \frac{\partial B(N - \hat{\theta})}{\partial \hat{\theta}} \frac{d\hat{\theta}}{d(\hat{r}^b)^*} \frac{\partial (\hat{r}^b)^*}{\partial D^{\max}} - M \frac{\partial X}{\partial D^{\max}}
\end{aligned} \tag{17}$$

where  $\frac{\partial B(N - \hat{\theta})}{\partial \hat{\theta}} < 0$  and  $\frac{d\hat{\theta}}{d(\hat{r}^b)^*} > 0$ . Therefore, by equation (15) it follows that  $\frac{\partial B(N - \hat{\theta})}{\partial D^{\max}} < 0$ . Moreover,  $\frac{\partial X}{\partial D^{\max}} > 0$ , so that  $\frac{\partial \Omega}{\partial D^{\max}} < 0$  and higher capital requirements lead to more credit rationing to borrowers. ■

### 3 Trade-off with financial stability

Capital requirements are a tool that regulators use to improve the stability of the banking system. As the model highlights, however, such a financial stability benefit comes at the cost of increased credit rationing. To formalize this trade-off I place exogenous social cost parameters on bank default and on credit rationing. To begin with, the expected probability of bank default is endogenous in the model. It is given by:

$$E[PD] = E \left[ \Pr \left[ \sum_{\theta \in \Theta} \min \{ R_{\theta} + C, (1 + \hat{r}^b) B \} < (1 + \hat{r}^d) D \right] \right] \tag{18}$$

Lemma 1 below confirms that the the model matches the financial stability channel of capital requirements. Namely, higher capital requirements reduce the expected probability of bank failure. The intuitive explanation of the proof below is that leverage pushes banks away from minimizing the probability of default. Because of the option value of limited liability, maximizing profits becomes disjoint from minimizing failure rates. Note that this effect is not about the "buffer" value of capital requirements, which would raise the ability to withstand shocks. Rather, the mechanism here comes purely from the different incentives that debt and equity create. Forcing a bank to hold a larger fraction of equity on its balance sheet, aligns its incentives more closely with those of society.

**Lemma 1** *Larger capital requirements reduce the expected probability of bank default:  $\frac{\partial E[PD]}{\partial (X/Q)} < 0$ .*

**Proof.** By the arguments in the proof of Proposition 1,  $\bar{r}^b < (\hat{r}^b)^*$  (because of the option value of the bank's limited liability). Here  $\bar{r}^b$  is the  $\hat{r}^b$  that maximizes  $\sum_{\theta \in \Theta} \min \{ R_{\theta} + C, (1 + \hat{r}^b) B \}$ . Therefore,  $\bar{r}^b$  necessarily also minimizes the expected probability of default as given by equation

(18). Then, as  $\frac{\partial(\hat{r}^b)^*}{\partial D^{\max}} > 0$ , which holds by equation (15), it follows that higher capital requirements bring  $(\hat{r}^b)^*$  closer to  $\bar{r}^b$ . Therefore,  $\frac{\partial E[PD]}{\partial D^{\max}} > 0$ , which implies  $\frac{\partial E[PD]}{\partial (X/Q)} < 0$ . ■

The social cost of bank default is  $\gamma^d$ , which represents both lost bank-specific relations and the economy-wide ramifications of bank failure. The social cost of credit rationing is  $\gamma^{cr}$ . This captures welfare losses from, for instance, the frictional reallocation of labor and capital that come about when firms fail from the inability to obtain refinancing, or the decrease in entrepreneurial investment in an environment of scarce finance. The regulator aims at

$$\min_{\frac{X}{Q}} [\gamma^d E[PD] + \gamma^{cr} \Omega] \quad (19)$$

and I assume that it solves its optimization problem before the banks move.

Define the optimal level of capital requirements as

$$\left(\frac{X}{Q}\right)^* \equiv \frac{X}{Q} : \frac{\partial}{\partial (X/Q)} [\gamma^d E[PD] + \gamma^{cr} \Omega] = 0 \quad (20)$$

Proposition 2 records various relevant characteristics of  $\left(\frac{X}{Q}\right)^*$ . Quite obviously, higher social costs of default call for larger capital requirements, whereas higher costs of credit rationing lead to smaller optimal capital requirements. More interestingly, however, when borrower quality improves, financial stability concerns lessen, and the regulator places greater emphasis on preventing credit rationing, hence lowering capital requirements. Technically, better borrower quality reduces the marginal benefit (through bank default rates) of higher capital requirements, which implies lower optimal capital requirements. Finally, optimal capital requirements rise in bank funding rates. When funding rates go up, banks effectively become more indebted, which increases their probability of default and results in higher optimal capital requirements (as the marginal benefit of capital requirements increases). This presents an interesting link to monetary policy. When the monetary authority chooses to tighten it could push regulators towards more stringent policies. Conversely, monetary easing may induce the easing of optimal regulatory standards. This is related to the debate on the consequences of possible "loose" monetary policy in the years before the crisis.<sup>4</sup>

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<sup>4</sup>References include Taylor (2009), Diamond and Rajan (2009), and Adrian and Shin (2009).

**Proposition 2** *The optimal level of capital requirements depends upon:*

1. *The social costs of bank default and credit rationing:*  $\frac{\partial(X/\bar{Q})^*}{\partial\gamma^d} > 0$  and  $\frac{\partial(X/\bar{Q})^*}{\partial\gamma^{cr}} < 0$ ;
2. *The quality of borrowers:*  $\frac{\partial(X/\bar{Q})^*}{\partial C} < 0$  and  $F_2(R_\theta) \succeq F_1(R_\theta) \forall \theta \Rightarrow \left(\frac{X}{\bar{Q}}\right)_2^* < \left(\frac{X}{\bar{Q}}\right)_1^*$   
(where  $\succeq$  means first-order stochastic dominance)
3. *Bank funding rates:*  $\frac{\partial(X/\bar{Q})^*}{\partial\hat{r}^d} > 0$ ;

**Proof.** We again apply the inverse relation between  $\frac{X}{\bar{Q}}$  and  $D^{\max}$  and optimize to  $D^{\max}$ . Statement 1 follows from rewriting the derivative in (20) to

$$\left[ \gamma^d \frac{\partial}{\partial D^{\max}} E[PD] + \gamma^{cr} \frac{\partial}{\partial D^{\max}} \Omega \right] \quad (21)$$

which, in conjunction with Lemma 1 and Proposition 1, implies that  $(D^{\max})^*$  falls in  $\gamma^d$  while it increases in  $\gamma^{cr}$ . Statement 2 follows from the increase in the left-hand side of the inequality in  $E[PD]$  in equation (18) as a result of  $F_2(R_\theta) \succeq F_1(R_\theta) \forall \theta$  or a larger  $C$ . To see this, consider that in the limit (for instance,  $C \rightarrow \infty$ ) both  $E[PD] \rightarrow 0$  and  $\frac{\partial}{\partial D^{\max}} E[PD] \rightarrow 0$  as a marginal increase in the right-hand side of the inequality in equation (18) makes no difference to  $E[PD]$  anymore. Instead, as the left-hand side approaches the value of the right-hand side,  $\frac{\partial}{\partial D^{\max}} E[PD]$  rises. An upward shift in  $\frac{\partial}{\partial D^{\max}} E[PD]$  implies a decline in  $(D^{\max})^*$ . Conversely, the downward shift caused by  $F_2(R_\theta) \succeq F_1(R_\theta) \forall \theta$  or a larger  $C$  implies a rise in  $(D^{\max})^*$ . Statement 3 holds because  $\hat{r}^d$  raises the right-hand side of the inequality in equation (18). By the same argument as above, this increases  $\frac{\partial}{\partial D^{\max}} E[PD]$ , and, thus, optimal capital requirements,  $(D^{\max})^*$ . ■

## 4 Funding costs

So far, I have assumed a constant, exogenous bank funding rate,  $\hat{r}^d$ . This section considers bank financiers. As a group, financiers obtain an expected return of

$$E[\Psi] = E \left[ \min \left\{ \left[ \sum_{\theta \in \Theta} \min \{ R_\theta + C, (1 + \hat{r}^b) B \} \right] - D, \hat{r}^d D \right\} \right] \quad (22)$$

on their loan of  $D$  to the bank. Consistently with SW's treatment of banks and borrowers, we need not specify the exact game form or mode of competition. Rather we work with the following reduced-form definition:

**Definition 1** *Under deposit insurance*  $\frac{\partial(\hat{r}^d)^*}{\partial\hat{r}^b} = 0$ , *while without it*  $\frac{\partial(\hat{r}^d)^*}{\partial\hat{r}^b} > 0$ .

This definition simply means that when there is no deposit insurance, bank financiers demand a higher risk premium on their loans if the bank becomes more risky (higher  $\hat{r}^b$  meaning a riskier pool of borrowers). Instead, with deposit insurance the financiers are not exposed to bank risk, and the return they demand is not related to  $\hat{r}^b$ . The difference between insured and uninsured depositors is of particular relevance in relation to the rise of wholesale bank financing. Wholesale bank financiers are uninsured, whereas traditional retail depositors are largely covered by deposit insurance.

**Proposition 3**  $\frac{\partial \Omega}{\partial (X/\bar{Q})}$  increases due to wholesale funding: uninsured deposits raise the sensitivity of credit rationing to capital requirements.

**Proof.** When  $\frac{\partial(\hat{r}^d)^*}{\partial \hat{r}^b} > 0$  then a rise in  $D$  (through a change in  $D^{\max}$ ) by increasing  $\hat{r}^b$  (equation (15)) also raises  $\hat{r}^d$ . This, in turn, is equivalent to a further increase in  $D$ : in the bank's profit function in equation (10) a higher  $\hat{r}^d$  is equivalent to a higher  $D$ , as both increase  $(1 + \hat{r}^d) D$ . Therefore, any change in capital requirements gets reinforced when  $\frac{\partial(\hat{r}^d)^*}{\partial \hat{r}^b} > 0$  rather than  $\frac{\partial(\hat{r}^d)^*}{\partial \hat{r}^b} = 0$ . Hence,  $\Omega$  is more sensitive to capital requirements when depositors are uninsured:

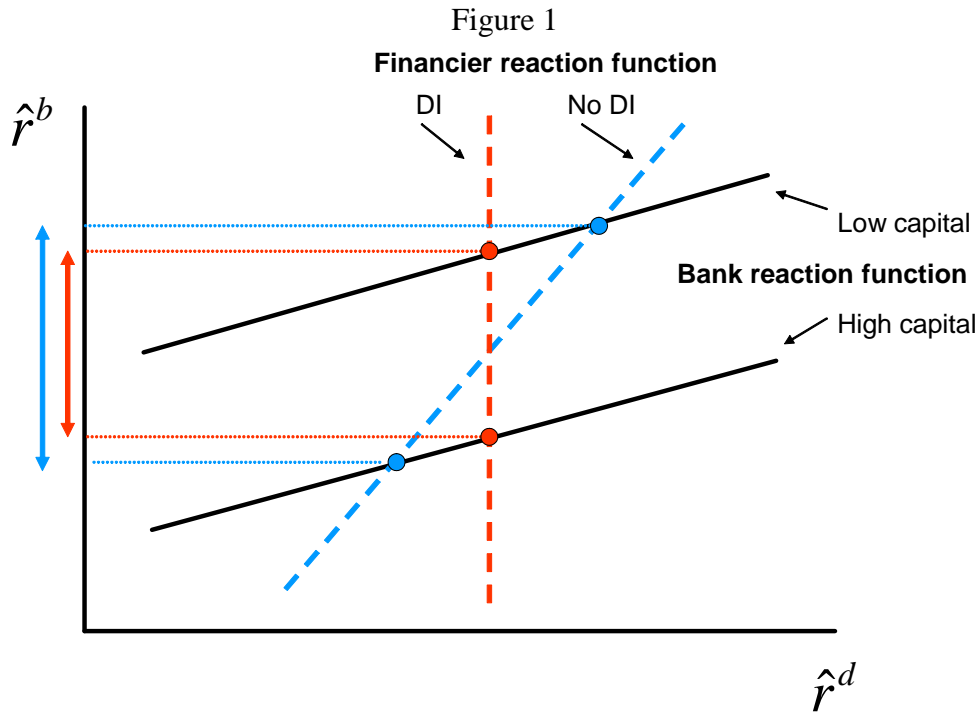
$$\left. \frac{\partial \Omega}{\partial (X/\bar{Q})} \right|_{\frac{\partial(\hat{r}^d)^*}{\partial \hat{r}^b} = 0} < \left. \frac{\partial \Omega}{\partial (X/\bar{Q})} \right|_{\frac{\partial(\hat{r}^d)^*}{\partial \hat{r}^b} > 0} \quad (23)$$

■

The intuition is depicted in figure 1, an example for the case of a simultaneous moves game. Here the solid lines are the bank's reaction functions given low and high capital requirements, respectively. The lines slope upwards because the higher the funding rate,  $\hat{r}^d$ , the more leveraged a bank effectively becomes and, therefore, the more volatility it is willing to incur. This implies a higher optimal loan rate,  $\hat{r}^b$  (and, thereby, a riskier pool of borrowers, as  $\hat{\theta}$  goes up). The broken lines are bank financiers' reaction functions, given deposit insurance (DI) and no deposit insurance (No DI), respectively. An uninsured financier internalizes that a higher loan rate means a riskier pool of borrowers, and hence demands a higher  $\hat{r}^d$  for a higher  $\hat{r}^b$ : his reaction function slopes upward. With deposit insurance, instead, it is constant over  $\hat{r}^b$ .

Consider a shift from low capital requirements to high capital requirements. As shown in the proof of Proposition 1 this will lead to lower loan rates, for any given  $\hat{r}^d$ . The bank's reaction function shifts downward, that is. When there is deposit insurance, there is no feedback between loan rates and funding rates. Instead, without deposit insurance a reduction in the loan rate reduces the funding rate, which, in turn reduces the loan rate, etcetera. This reinforcing effect means that the reaction of the equilibrium loan rate to a given change in capital requirements is larger when depositors are uninsured. This is represented by the arrows parallel to the vertical axis. An

increase in capital requirements has a more pronounced effect on rationing when fewer depositors are covered by a safety net. Thus, the rise of wholesale funding should have raised the impact of capital requirements on the real economy.



We can also ask how wholesale funding alters the relationship between capital requirements and financial stability. Proposition 4 proves what can already be intuited from Figure 1: wholesale funding increases the sensitivity of bank risk taking to capital requirements. After all,  $\hat{r}^b$  is positively related to  $\hat{\theta}$ . Therefore, since the feedback between loan rates and funding rates raises the sensitivity of  $\hat{r}^b$  to capital requirements, it also raises the sensitivity of the quality of bank borrowers ( $\hat{\theta}$ ) to capital requirements.

Given that wholesale funding then raises both the marginal cost and the marginal benefit of capital requirements, one may wonder what is the overall effect on optimal capital requirements. Unfortunately, without specifying functional forms and parameter values, this question cannot be answered. In general, no unambiguous relation between wholesale funding and optimal capital requirements can be derived.

**Proposition 4**  $\frac{\partial E[PD]}{\partial (X/\bar{Q})}$  becomes more negative by wholesale funding: uninsured deposits raise the sensitivity of the probability of bank default to capital requirements.

**Proof.** When  $\frac{\partial(\hat{r}^d)^*}{\partial \hat{r}^b} > 0$  a given increase in  $D^{\max}$  affects  $E[PD]$  not only through a increase in  $\hat{r}^b$ , but also through an additional increase in  $\hat{r}^d$ . A higher  $\hat{r}^b$  raises  $E[PD]$  (as argued in the proof of

Lemma 1). And so does a higher  $\hat{r}^d$ , because it reduces the right hand side of the inequality in (18) (this follows by the same arguments as in the proof of Proposition 2). Therefore, with  $\frac{\partial(\hat{r}^d)^*}{\partial \hat{r}^b} > 0$  it must be that  $\frac{\partial E[PD]}{\partial D^{\max}}$  is greater than when  $\frac{\partial(\hat{r}^d)^*}{\partial \hat{r}^b} = 0$ . Consequently,  $\frac{\partial E[PD]}{\partial (X/Q)}$  is larger in absolute terms. ■

## 5 Risk-weighted capital requirements

In the context of the model, bank risk is given by  $\hat{\theta}$ , which represents the quality of the borrower pool. Instead of the simple capital requirements considered so far, therefore, the regulator could design a risk-weighted capital requirement rule  $\frac{X}{Q}(\hat{\theta})$ . This would assign a maximum debt-to-equity ratio on the basis of the quality of bank lending, in the spirit of the Basel Accords. Proposition 5 shows that risk-weighted capital requirements are a better tool for the regulator than unweighted capital requirements. They are more sophisticated and allow the regulator to improve on both aspects of its financial stability versus credit rationing trade-off. However, the trade-off itself remains unchanged: larger risk-weighted capital requirements reduce bank default rates at the cost of a more frequent occurrence of credit rationing on the loan market.

**Proposition 5** *Compared to unweighted capital requirements, risk-weighted capital requirements allow the regulator to achieve both smaller bank risk ( $\hat{\theta}$ ) and less credit rationing ( $\Omega$ ). However, the comparative statics of a rise in capital requirements, as given by Proposition 1 and Lemma 1, are unchanged.*

**Proof.** As given by the objective function of the regulator (19), the regulator has two aims: safeguarding financial stability ( $E[PD]$ ) and limiting the extent of borrower rationing ( $\Omega$ ). The regulator sets optimal capital requirements  $(D^{\max})^*$  (using the equivalence to  $\frac{X}{Q}$ ) at the point where the marginal benefit of greater financial stability equals the marginal cost of increased credit rationing. With risk-weighted capital requirements,  $D^{\max}(\hat{\theta})$ , bank optimization to  $\hat{r}^b$  includes an additional term:

$$\frac{\partial D^{\max}(\hat{\theta})}{\partial \hat{\theta}} \frac{d\hat{\theta}}{d\hat{r}^b} < 0 \quad (24)$$

A given increase in capital requirements (fall in  $D^{\max}$ ) then first lowers  $\hat{r}^b$ , and thereby also  $\hat{\theta}$ , which in turn dampens the extent of the rise in capital requirements because of the risk weight. This implies that a given change in bank risk is achieved by a smaller increase in capital requirements. Excess demand for credit in equation (12) is less affected, therefore. The marginal cost of raising  $D^{\max}$  in terms of credit rationing ( $\Omega$ ) is then smaller when capital requirements are risk weighted. With an improved trade-off between  $E[PD]$  and  $\Omega$ , the regulator can improve on both its targets.

Moreover, the second sentence of the proposition follows from the fact that equation (24) does not affect the signs of (17) or the derivative of equation (18). Comparative statics are qualitatively unaffected, therefore. ■

## 6 Conclusions

At a time when the supply of credit is still scarce, calls for stronger bank regulation are widely heard, and reform plans are being drawn up around the world.<sup>5</sup> Policy makers thus face a double-edged sword. The desire to prevent future crises suggests higher capital requirements, which help limit leverage and affect bank risk-taking incentives in ways that seem favorable. But, as this paper suggests, these outcomes are not costless. Banks ability to leverage and their willingness to take on risk is connected to their capacity to supply credit to firms.

The way that banks are financed further complicates the trade-off between financial stability and credit rationing. As this paper shows, the more banks are funded by uninsured deposits, the stronger the impact of capital requirements on both bank default rates and the rationing of borrowers. With the grown role of wholesale finance, getting the level of capital requirements right has thus become a more important task than ever.

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<sup>5</sup>Of particular importance are the new plans of the Basel Committee (<http://www.bis.org/press/p100726.htm>).



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