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CREDIT DERIVATIVES, THE LIQUIDITY OF BANK ASSETS AND BANKING STABILITY

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Comments and suggestions would be welcomed by the author.

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Credit Derivatives, the Liquidity of Bank Assets, and Banking Stability*

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Abstract

The emerging markets for credit derivatives have improved the liquidity of bank assets by providing banks with various new possibilities for selling and hedging their risks. This paper examines the consequences for banking stability.

In a simple model where liquidation of bank assets is costly, we show that increased asset liquidity benefits stability by encouraging a representative bank to reduce the risks on its balance sheet. Stability is further enhanced because the bank can now liquidate assets in a crisis more easily. However, we find that these stability effects are counteracted by increased risk-taking by the bank. Overall, stability actually falls because the improved possibilities for liquidating assets in a crisis make a crisis less costly for the bank. The bank therefore takes on an amount of risk that more than offsets the initial positive impact on stability.

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1 Introduction

Bank loans have always been considered as illiquid. This is usually explained by the private information banks have about the quality of their loans: because this information is not easily verifiable, potential buyers are reluctant to take on risk from such assets. There were a few possibilities for banks to sell loans, such as through mortgage securitization or loan sales, but this was mainly restricted to assets with low informational problems.

The recent advent of credit derivatives, however, has provided banks with a whole range of instruments for selling loans and transferring loan risk (for an overview of these instruments, see Standard & Poors, 2003). For example, *pure credit derivatives*, such as Credit Default Swaps (CDS) or total return swaps (TRS), allow banks to buy protection on a single exposure or on a basket of exposures. *Hybrid products*, such as Credit-Linked Notes (CLN), embed credit protection into other securities. Perhaps as the greatest challenge to the illiquidity of loans, *portfolio products*, such as Collateralized Debt Obligations (CDO), enable banks to sell risks from their entire loan portfolio. A main advantage of these new instruments over traditional forms of credit risk transfer is that their flexibility mitigates informational problems[1]. Their introduction has also been facilitated by the growing availability of ratings and the build-up of credit analysis departments in non-bank institutions (such as the insurance sector), which have helped to reduce the asymmetry of information between the bank and the risk buyer. Growing regulatory pressure to manage credit risk has been another driving factor behind the introduction of credit derivatives.

Since its inception in 1996, the credit derivatives market has been quickly expanding, with annual growth rates of around 70−100%. The outstanding value of credit derivatives is

[1] For example, the flexible maturity of credit derivatives can be used to address adverse selection problems (see for example, Duffie and Zhou, 2001) and improve banks' liquidation incentives (Arping, 2004). Nicolo' and Pelizzon (2004) show that credit derivatives can be desgined to lead to the reveleation of private information. Portfolio products are typically structured such that banks retain a part of the risk, thus helping to keep incentives aligned. Portfolio products obviously, also reduce adverse selection problems compared to the sale of a single loan.

currently estimated at around U$ $5,000$ bn and the market is expected to continue to grow at a high pace (BBA 2004). Although the market for credit derivatives is still relatively small if compared to other derivatives, its mere existence has undermined the traditional inability of banks to manage their loan risk: "Derivatives and the more liquid markets they encourage make possible a new discipline at commercial banks, that of active portfolio management. ...unwanted credit risks can be divested in a variety of forms, through hedges or purchases of insurance as well as outright sales in the secondary markets." (Standard & Poors, 2003).

The emergence of the credit derivative markets has naturally received widespread attention among financial regulators. Although there are remaining concerns, regulators have been largely welcoming their development on the grounds that the relative illiquidity of loans has been a main source of banking fragility.[2] The intuitive argument goes that an improved ability to sell assets will make banks less vulnerable to liquidity shocks and is further expected to reduce the overall level of risks on banks' balance sheets by facilitating diversification and the transfer of risk out of the banking sector.

This is a static view. It ignores that banks may change their behavior as a result of the increased liquidity of their assets. To start with, they may simply take on new risks following a reduction in the risks on their balance sheet through credit risk transfer. Consistent with this, Cebenoyan and Strahan (2004) provide evidence that banks that manage their risks in a loan sale market hold a larger share of their portfolio in risky assets than banks inactive in loan sales. Furthermore, the fact that an increased liquidity of loans helps banks to withstand a liquidity shock may encourage banks to engage even more in risky activities. For example, despite the greater dependence of borrowers on banks in the past, the portion of loans in banks' portfolios has increased from 30% percent in the mid-1930s to 60% in the mid-1980s. This has been attributed to a reduced sensitivity to liquidity shocks following the introduction of the deposit insurance in the early 1930s (e.g., England, 1991).

[2] See FSA (2002), IMF (2002), OECD (2002), IAIS (2003), BIS (2004).

The aim of this paper is to analyze whether such motives for increased risk taking may lead to a reduction or even a reversal of the initial beneficial impact of an increased liquidity of banks assets. To address this issue, we consider a simple model of an unregulated representative bank that has an incentive for taking on excessive risks because of limited liability. Crises occur because a low return on loans can trigger bank runs. Bank loans are partly illiquid in that they can only be sold at a discount to their economic value. This creates a motive for the bank to limit the risks it retains on its balance sheet in order to avoid a crisis in which it has to sell loans. In this framework, the bank's optimization amounts to choosing a probability of default that balances the benefits of higher riskiness of the bank (i.e., a higher return if the bank survives) with its costs (an increased likelihood of a crisis). Increased asset liquidity is modelled as an (exogenous) reduction in the discount at which loans can be sold in normal times and in times of a crisis.[3]

We find that an increase in liquidity in normal times does not affect stability. It initially improves stability by facilitating the transfer of risk via a secondary market and by increasing bank's profits. However, it does not affect the bank's optimal probability of default. As a consequence, the bank increases risk taking in the primary market by an amount that exactly offsets the initial impact on stability. These results are consistent with the empirical work of Cebenoyan and Strahan (2004), who find that better access to secondary markets increases banks' profits and lending, but does not necessarily reduce banking risk.

By contrast, an increase in asset liquidity in times of crisis, paradoxically, reduces stability. There is an initial positive impact on stability, this time because it makes the bank less vulnerable to bank runs. This is counteracted by increased incentives for taking on risks, first, because the likelihood of a bank run is reduced, and, second, because the

[3] In our analysis, there is in normal times no difference between the impact of increased selling possibilities and increased risk transfer possibilities. We therefore interpret asset liquidity in normal times as also comprising risk transfer possibilities. By contrast, crisis liquidity is solely determined by the ability to sell assets.

costs of a bank run for the bank are reduced since the losses from selling loans in a crisis are lowered. The latter leads to an increase in the bank's optimal probability of default and as a result the bank takes on an amount of risk that more than offsets the initial impact on stability.[4]

Perhaps surprisingly, we therefore find that although the increased liquidity of the bank's assets removes a main cause of banking fragility, stability is not increased. The reason for this is that any reduction in the bank's stability reduces the bank's costs from retaining risk on its balance sheet and causes an offsetting change in the bank's behavior in the primary market. Stability even falls if the losses from selling assets in a crisis are reduced; the reason being that this undermines the bank's incentives to limit its risk-taking, while retaining its incentives for taking on excessive risks due to limited liability.

To be sure, the recent advent of credit derivatives and the increase in liquidity is has brought about undoubtedly has benefits. It provides investors with a more efficient means of investing in credit risk. As our analysis shows, it can also foster firm financing by reducing bank's costs of bearing risk. However, the message of this paper is that these benefits can come at the cost of reduced stability.

Financial regulators may want to address this stability problem and we study the possibilities for doing this. To this end we extend our analysis to an environment in which deposits are fully insured and regulators can impose Basel-style capital requirements. We demonstrate that a negative stability impact arising from increased liquidity can be counteracted by increasing capital requirements. However, we find that as asset liquidity increases, capital requirements become a less effective instrument for ensuring stability. We show that a preferable means for undoing the impact of increased liquidity on stability is to reduce the pay-offs for shareholders in a banking closure.

The paper proceeds as follows. In the next section we relate the paper to the existing literature. Section 3 describes the model of the unregulated economy and solves for the

[4] We also find that both types of liquidity increase the loss given default, and thus externalities associated with the bank's failure.

equilibrium banking stability. Section 4 analyzes then the impact of increased liquidity. Regulation is studied in Section 5 and the final section summarizes.

2 Related Literature

A large part of the academic literature on innovations in credit derivative markets has concentrated on their impact on the borrower-lender relationship. Duffee and Zhou (2001) have argued that the flexibility of credit derivatives can be used to mitigate adverse selection problems arising from the credit risk transfer. Morrison (2001) has shown that credit derivative markets can reduce banks' incentives to monitor, which can be detrimental to welfare by eroding the certification value of bank loans. While these papers take the stand that bank's incentives are potentially harmed through the transfer of credit risk, Arping (2004) has shown that credit risk transfer can actually improve incentives by leading to a more efficient liquidation of firms. There is also a related, older, literature focusing on bank's motives for selling loans in the secondary market, which seems to contradict banks' comparative advantage in acquiring information about borrowers (e.g., Gorton and Pennacchi, 1995 and Carlstrom and Samolyk, 1995).

While in our framework financial innovation is treated as exogenous, there is a strand of the literature that has analyzed 'optimal financial innovations'. Most of this work takes the view of innovations that complete markets and increase spanning (see the surveys in Allen and Gale, 1994, and Duffie and Rahi, 1995). One would therefore expect financial innovations to be welfare enhancing. Indeed, Allen and Gale (2004) find that in a financial crisis setting the market completion function of financial innovations can be welfare enhancing by increasing risk sharing possibilities. By contrast, Elul (1995) shows that the introduction of new securities can have an almost arbitrary effect on welfare. Similar results are also obtained in Allen and Gale (1994), where innovations in an environment with short-selling constraints are considered.

Our paper is most closely related to the literature that explores the relation between financial innovations and bank's risk taking. Santomero and Trester (1997) consider innovations that reduce the cost of overcoming informational asymmetries when selling assets in a crisis, which correspond to our notion of an increase in crisis liquidity. They find that such innovations lead to increased risk taking by banks. However, the focus of their analysis is only on banks' risk taking; the net impact on banking stability is not considered. Instefjord (2005) analyzes risk taking by a bank that has access to credit derivatives for risk management purposes. He finds that innovations in credit derivatives markets (which correspond to an increase in liquidity in normal times in our paper) lead to increased risk taking because of enhanced risk management opportunities. Again, the analysis focuses on the impact on risk taking. In particular, since Instefjord considers a dynamic risk management problem with infinitesimal small shocks, there are no banking defaults in equilibrium and hence the banking sector is perfectly stable.[5]

3 The Model

An economy has the following time structure. At $t = 0$ a representative bank decides on how much to invest in a risky asset, which we interpret as extending loans. At $t = 1$, the bank has the possibility to sell off a fraction of the risky asset it has bought at a secondary market (this can be seen more generally as a transfer of credit risk because in the model, risk transfer and sales of the risky asset at $t = 1$ are equivalent). At $t = 2$, uncertainty about the return on the risky asset is resolved and the bank's depositors decide whether to run on the bank or not. At $t = 3$ asset returns are realized and all parties are compensated.

The bank has an exogenously given capital structure, consisting of deposits D and equity W (in Section 4.1 we discuss the bank's choice of its capital structure). The return

[5] Although no explicit solution for the equilibrium risk exposure is obtained, the paper conjectures that if the loan market is elastic, banks' retained risk can increase and that this may reduce banking stability. Our analysis qualifies this conjecture by showing that the motivation for increasing retained risk is precisely to offset an initial impact on stability. Thus, stability is not affected by such type of innovations, even if the loan market is perfectly elastic.

required by depositors is 1 and the interest on deposits is i. We consider an unregulated banking sector, in particular, deposit are not insured (in Section 5 we analyze deposit insurance combined with capital requirements). Deposits are assumed to be made before the bank decides about its risk taking. Hence, the interest rate i is independent of the bank's *actual* risk taking. Rather, the interest rate will reflect *expected* risk taking and compensate depositors for their expected losses from default.

More specifically, the bank's decision at $t = 0$ is how much of its capital to invest in the risky asset and how much to hold in reserves. Denoting the amount invested in the risky asset by X and the amount held in reserves by R we thus have

$$D + W = X + R \tag{1}$$

Reserves are perfectly liquid and have a return of zero. The return on the risky asset is $r = \mu + \varepsilon$, with $\mu \geq 1$. The asset shock ε is uniformly distributed on $[-1, 1]$ with probability density $\phi(\varepsilon) = 1/2$. Hence $E[\varepsilon] = 0$ and the expected return is $E[r] = \mu \geq 1$. As in Gennotte and Pyle (1991), the excess return on the risky asset is therefore not restricted to be zero. We think of this as being the result of the bank's superior ability to screen and monitor local firms, giving it a monopoly in the local loan market (Carlstrom and Samolyk, 1995). The counterpart of this excess return, however, is that the risky asset is partly illiquid, in a sense we specify below.

At $t = 1$, the bank sells off the risky asset to investors. If the asset were fully liquid, investors would be prepared to pay for an amount Y of the risky asset

$$pY = (\mu - \alpha(Y))Y$$

where p is the expected value of the asset net of a possible risk premium $\alpha(Y)$, with $\alpha(Y) \geq 0$ and $\alpha'(Y) \geq 0$ (non-decreasing absolute risk aversion).

However, even though the bank is assumed to be a monopolist in the secondary market, it cannot extract fully the price p because of asset illiquidity. This is interpreted as being the result of the bank's private information about its loans, which gives rise to a lemon problem (as in Duffie and Zhou, 2001), or of reduced bank's incentives to monitor and evaluate the borrower following the sale of the asset (Gorton and Pennacchi, 1995). An alternative interpretation, and one that is potentially unrelated to informational problems, is that there are simply imperfections on the buyer's side, leading to *market* illiquidity.

Specifically, as in Rochet (2004), we assume the bank can only sell the asset at a proportional discount β. Hence, denoting the amount of the risky asset sold by Y ($Y \leq X$), the bank's proceeds from the selling at the secondary market are

$$(1-\beta)pY$$

The extreme cases where the asset is completely illiquid and perfectly liquid can then be represented by $\beta = 1$ and $\beta = 0$, respectively. We refer to β in the following as *risk transfer* costs; the reason being that the motivation for the bank to sell at the second market arises from the asset's riskiness (if the asset were not risky, the bank would prefer to retain it on the balance sheet and recoup the full value at $t = 2$).

At $t = 2$, uncertainty regarding the asset shock ε is resolved and r becomes known. If, as a result, depositors decide to demand their deposits back and the bank's liquidity is not sufficient to meet depositors' demands, the bank has to liquidate the risky asset. We assume that there are again proportional costs γ of selling the asset, for similar reasons as for risk transfer costs. We term this costs *liquidation costs* and assume $\gamma > \beta$ because of the higher urgency of asset sales in a bank run. Thus, if the bank sells an amount V of the risky asset, it receives in return

$$(1-\gamma)pV$$

where $p = \mu + \varepsilon$ (there is no risk premium since uncertainty is resolved at $t = 2$).

The decision of depositors whether to run on the bank depends on their expectation of the behavior of other depositors, giving rise to multiple equilibria and creating a need for an equilibrium selection mechanism. We solve here for the *risk dominant* equilibrium (Harsani and Selten, 1988). Applied to our context, this concept says that each depositor believes that all other depositors (collectively) decide to run with probability 1/2 (flat beliefs) and simply plays its best response to this.

Assume that the bank's value is shared on a pro-rata basis in a run and that if the expected pay-off from running is identical to the one from not running, depositors do not run. Assume, furthermore, that interest has already been incurred at $t = 1$. The unique risk dominant equilibrium is then to run whenever the liquidation value of the bank, denoted L, is lower than depositors' claim to the bank, $(1 + i)D$, and not to run otherwise. To see this, consider first $L \geq (1 + i)D$. Then, even if all other depositors decide to run on the bank, a depositor still receives the same amount as when he decides not to run. Hence, he will not run. However, when $L < (1 + i)D$, a depositor's expected return from running is $1/2 \cdot L + 1/2 \cdot (1 + i)D$, while his return from not running is $1/2 \cdot 0 + 1/2 \cdot (1 + i)D = 1/2 \cdot (1 + i)D$ and he therefore decides to run (in fact, any positive probability attached to other depositors running on the bank yields the same unique equilibrium).

The condition for no bank run taking place ($L \geq (1 + i)D$) can hence be written as

$$(1 - \gamma)(\mu + \varepsilon)(X - Y) + (1 - \beta)pY + R \geq (1 + i)D \tag{2}$$

Using (1) and denoting with Z the amount of risk the bank has taken that is retained on the balance sheet ($Z = X - Y$), (2) can be rearranged to

$$((1 - \gamma)(\mu + \varepsilon) - 1)\, Z + ((1 - \beta)p - 1)\, Y + W - iD > 0 \tag{3}$$

From (3), we define the minimum asset shock $\widehat{\varepsilon}$ that has to prevail in order for no bank run occurring

$$\widehat{\varepsilon} = \frac{1 - [W + ((1 - \beta)p - 1)\, Y - iD]\,/Z}{1 - \gamma} - \mu \tag{4}$$

Because depositors run only when $L < (1 + i)D$, the bank has to fully liquidate its asset in a run. Since this is not enough to fully meet depositors' claims, a run always leads to the default of the bank. If default occurs, the return on equity is zero due to limited liability and the bank simply ceases to exist.

If the bank survives, the return on equity is the value of the bank's portfolio net of payments to depositors at $t = 3$

$$\begin{aligned} \pi &= (\mu + \varepsilon)Z + (1 - \beta)pY + R - (1 + i)D \\ &= (\mu + \varepsilon - 1)Z + ((1 - \beta)p - 1)Y + W - iD \end{aligned} \tag{5}$$

The return on equity in case of survival consists thus of the excess return from loans that are retained $(\mu+\varepsilon-1)Z$, the excess return from loans that are sold in the secondary market $((1 - \beta)p - 1)Y$, and bank's equity at $t = 0$ minus interest payments $W - iD$. Figure 1 depicts bank's equity as a function of the asset return r $(= \mu + \varepsilon)$, where $\widehat{r}\colon = \mu + \widehat{\varepsilon}$.

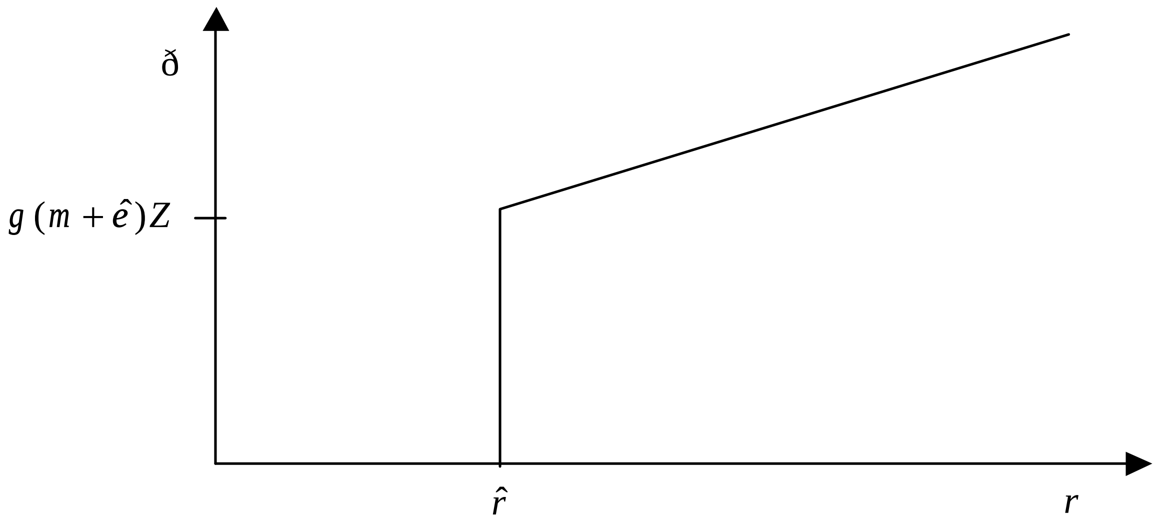

Figure 1: The Banks's Pay-Off as a Function of the Return on the Risky Asset

The *expected* return on equity is then

$$E[\pi] = \int_{\widehat{\varepsilon}}^{1} [(\mu + \varepsilon - 1)Z + ((1 - \beta)p - 1)Y + W - iD]\phi(\varepsilon)d\varepsilon \tag{6}$$

Depositors return when the bank survives is $(1 + i)D$. When the bank defaults $(\varepsilon < \widehat{\varepsilon})$, they receive the liquidation value L. Using (1) and (4), L can be written as

$$L = (1 + i)D - (\widehat{\varepsilon} - \varepsilon)(1 - \gamma)Z$$

Since depositors require a return of 1, the equilibrium interest rate on deposits has to fulfill

$$D = \int_{-1}^{\widehat{\varepsilon}} [(1 + i)D - (\widehat{\varepsilon} - \varepsilon)(1 - \gamma)Z]\,\phi(\varepsilon)d\varepsilon + \int_{\widehat{\varepsilon}}^{1} (1 + i)D\phi(\varepsilon)d\varepsilon$$

Rearranging for iD gives

$$iD = \int_{-1}^{\widehat{\varepsilon}} (\widehat{\varepsilon} - \varepsilon)(1-\gamma) Z \phi(\varepsilon) d\varepsilon \tag{7}$$

Since interest payments iD compensate depositors for their losses from default, the RHS of (7) represents the expected loss from default for depositors. Note that (7) is an equilibrium condition, i.e., Z and $\widehat{\varepsilon}$ in (7) refer to depositors' expectations about the bank's choice of these variables and not to the actual choices of Z and $\widehat{\varepsilon}$. Depositors' expectations, however, may depend on β and γ. More formally, we can thus write $i = i(\beta, \gamma)$ in (7).

3.1 Equilibrium Risk Taking and Banking Stability

We measure the stability of the representative bank by its probability of default, which is given by

$$\Pr(\varepsilon < \widehat{\varepsilon}) = \int_{-1}^{\widehat{\varepsilon}} \phi(\varepsilon) d\varepsilon = (\widehat{\varepsilon} + 1)/2 \tag{8}$$

and determined by the minimum asset shock $\widehat{\varepsilon}$. We also compute the expected loss given default (LGD), which is a measure of externalities associated with banking failure. Recalling that the RHS of (7) gives the expected loss from default to depositors, the LGD is given by

$$LGD = \frac{\int_{-1}^{\widehat{\varepsilon}} (\widehat{\varepsilon} - \varepsilon)(1-\gamma) Z \phi(\varepsilon) d\varepsilon}{\Pr(\varepsilon < \widehat{\varepsilon})} = \frac{\int_{-1}^{\widehat{\varepsilon}} (\widehat{\varepsilon} - \varepsilon)(1-\gamma) Z d\varepsilon}{\widehat{\varepsilon} + 1} \tag{9}$$

We assume that the bank's managers maximize the wealth of shareholders, who are assumed to be risk-neutral. Thus managers maximize $E[\pi]$ over Y and Z, taking as given D, W, μ and the interest rate i. Note that Y and Z are independent variables, i.e., an increase in Z represents an increase in X for given Y. We focus in the following on parameter values of the model for which interior solutions for Y and Z obtain.

We turn first to the optimal choice of Y. Denoting the excess return from secondary market activity at $t = 1$ by $A(Y)$, with $A(Y)$

$$A(Y) := ((1-\beta)p - 1)Y \tag{10}$$

we get the FOC for Y (from 6)

$$\partial E[\pi]/\partial Y = \int_{\widehat{\varepsilon}}^{1} A'(Y)\phi(\varepsilon)d\varepsilon - \pi(\widehat{\varepsilon})\frac{\partial \widehat{\varepsilon}}{\partial A}A'(Y)\phi(\varepsilon) = 0 \tag{11}$$

Using the definition of the minimum shock $\widehat{\varepsilon}$ (equation 4) this can be simplified to

$$A'(Y)\phi(\varepsilon)\left(\int_{\widehat{\varepsilon}}^{1} d\varepsilon - \gamma(\mu+\widehat{\varepsilon})Z\frac{\partial \widehat{\varepsilon}}{\partial A}\right) = 0$$

Since $\int_{\widehat{\varepsilon}}^{1} d\varepsilon \geq 0$ and $\partial\widehat{\varepsilon}/\partial A < 0$ the expression in brackets is strictly positive, hence the FOC implies that

$$A'(Y) = 0 \tag{12}$$

Note that because the optimal Y simply maximizes the excess revenue from secondary market activity, it is independent of retained risk Z and the liquidation costs γ.

We study next the choice of Z. From (6) we obtain the FOC

$$\begin{aligned}\partial E[\pi]/\partial Z &= \int_{\widehat{\varepsilon}}^{1} (\mu+\varepsilon-1)\phi(\varepsilon)d\varepsilon - \left((\mu+\widehat{\varepsilon}-1)Z + A(Y) + W - iD\right)\phi(\varepsilon)\partial\widehat{\varepsilon}/\partial Z \\ &= \int_{\widehat{\varepsilon}}^{1} (\mu+\varepsilon-1)d\varepsilon - \gamma(\mu+\widehat{\varepsilon})Z\partial\widehat{\varepsilon}/\partial Z = 0 \qquad (13)\end{aligned}$$

The first term in (13) is the standard expression for the marginal benefits from retaining more risk. Since $\mu \geq 1$, this expression is always positive. The second term in (13) represents the marginal costs of retaining risk, which arise because more retained risk increases the asset returns for which a bank run occurs ($\partial\widehat{\varepsilon}/\partial Z > 0$) and thus raises the probability that the liquidation costs $\gamma(\mu+\widehat{\varepsilon})Z$ have to be incurred. An interior solution for Z equates then the benefits from a higher return on equity if the bank survives with higher expected costs due to liquidation. Proposition 1 identifies the conditions under which an interior solution exists.

Proposition 1 *For $\mu < \gamma/(1-\gamma)$, $\gamma > 1/2$ and $W + A - iD > 0$ there is a unique interior solution Z^* with $Z^* \in (0,\infty)$.*

Proof. See Appendix.

The first condition, $\mu < \gamma/(1-\gamma)$, implies that for sufficiently large Z the minimum asset shock $\widehat{\varepsilon}$ is 1 (i.e., the probability of survival is zero). This ensures that the marginal benefits from retaining risk become eventually zero as the bank increases its retained risk and thus allows for an interior solution. By contrast, if $\mu > \gamma/(1-\gamma)$, one cas easily verify from (4) that $lim_{Z->\infty}\widehat{\varepsilon} < 1$. The second condition, $\gamma > 1/2$, ensures the concavity of the problem. For $\gamma < 1/2$, the problem becomes convex and only corner solutions exist. The third condition, $W + A - iD > 0$, ensures that an increase in retained risk Z increases the minimum asset shock (4). For $W + A - iD < 0$, the expected value of the bank at $t = 0$ is negative for $Z = 0$ (from 6). An increase Z would then actually increase the bank's chance of survival because of $\mu \geq 1$ ("gambling for resurrection").

For convenience we define for the following analysis the marginal benefits MB and the marginal costs MC from retaining risk

$$MB = \int_{\widehat{\varepsilon}}^{1} (\mu + \varepsilon - 1)\, d\varepsilon \tag{14}$$

$$MC = \gamma(\mu + \widehat{\varepsilon}) Z \partial\widehat{\varepsilon}/\partial Z \tag{15}$$

and using the definition of $A(Y)$ we simplify the expression for the minimum asset shock

$$\widehat{\varepsilon} = \frac{1 - (W + A(Y) - iD)/Z}{1-\gamma} - \mu \tag{16}$$

from which we can derive the sensitivity of $\widehat{\varepsilon}$ with respect to retained risk ($\partial\widehat{\varepsilon}/\partial Z$)

$$\partial\widehat{\varepsilon}/\partial Z = \frac{W + A(Y) - iD}{1-\gamma}\frac{1}{Z^2} \tag{17}$$

$$= (\frac{1}{1-\gamma} - \mu - \widehat{\varepsilon})/Z \tag{18}$$

where we have made use of (16). Using (18) we can then simplify the expression for MC (15) to yield

$$MC = \gamma(\mu + \widehat{\varepsilon})(\frac{1}{1-\gamma} - \mu - \widehat{\varepsilon}) \tag{19}$$

4 Asset Liquidity and Banking Stability

We start with the impact of a reduction in the liquidation costs γ, i.e., an increase in crisis liquidity. Note first that a change in crisis liquidity does not affect secondary market activity, i.e., $dY/d\gamma = 0$. This can be seen from the definition of $A(Y)$ and the FOC for Y (equations 10 and 12), showing that γ has no impact on the equilibrium choice of Y.

The direct impact of the reduction in γ on stability is positive. It raises the liquidation value of the bank and thus lowers the minimum asset shock $\widehat{\varepsilon}$ that ensures that depositors do not run on the bank (equation 16). However, there is an offsetting effect because an increased liquidation value means that a bank run is less costly for the bank (the MC in 15 fall) and the bank therefore increases its retained risk Z. Proposition 2 shows that Z is even increased by such an amount that the initial beneficial impact on stability is outweighed.

Proposition 2 *An increase in crisis liquidity increases retained risk Z and reduces banking stability.*

Proof. *See Appendix.* ■

To understand the intuition for this perhaps surprising result, consider a (hypothetical) increase in retained risk that exactly offsets the impact of the reduction in γ on the minimum asset shock $\widehat{\varepsilon}$. Denoting with Z_1 the new level of retained risk and with $\widehat{\varepsilon}_0$ the equilibrium minimum asset shock before the reduction in γ, the MB and MC would be

$$MB_1 = \int_{\widehat{\varepsilon}_0}^{1} (\mu + \varepsilon - 1)\, d\varepsilon \tag{20}$$

$$MC_1 = \gamma_1(\mu + \widehat{\varepsilon}_0) Z_1 (\partial\widehat{\varepsilon}/\partial Z)_1 \tag{21}$$

From (20) we have then $MB_1 = MB_0$, i.e., the marginal benefits from retaining risk are the same as before the change in γ. From (21) we have that the reduction in γ reduces the cost of liquidation for a given amount of assets that have to be liquidated and thus the MC_1 is lowered relative to MC_0. There are additional effects on the MC because changes in Z, γ and i (remember that interest rates may change if depositors' expectations about their expected losses change) affect $Z(\partial\widehat{\varepsilon}/\partial Z)$. However, from (18) it can be seen that the overall impact of these latter effects on the MC is negative. Hence we have $MC_1 < MC_0$.

Thus, if, following a reduction in γ, the bank would increase its risk such that it reaches the old $\widehat{\varepsilon}_0$, the marginal benefits from retaining risk would still exceed the marginal costs. The bank will therefore choose an amount of retained risk that exceeds Z_1. Hence, the $\widehat{\varepsilon}$ in the new equilibrium is higher and the stability of the representative bank is reduced. Proposition 3 shows next that the reduction in γ also leads to a higher LGD.

Proposition 3 *An increase in crisis liquidity increases the LGD.*

Proof. *See Appendix.* ■

The intuition for this result can be easily understood by again considering an increase in Z that offsets the initial impact of γ on $\widehat{\varepsilon}$. We have then

$$LGD_1 = \frac{\int_{-1}^{\widehat{\varepsilon}_0}(\widehat{\varepsilon}_0 - \varepsilon)(1-\gamma_1)Z_1 d\varepsilon}{\widehat{\varepsilon}_0 + 1} \tag{22}$$

From (22) it can be seen that this increases the LGD because of the lower γ and the increase in Z. The reason for this is that both the lower γ and the higher Z make the liquidation value more sensitive to shocks, in the sense that a shock below the minimum shock $\widehat{\varepsilon}$ (for which there is no loss) leads now to higher losses for depositors. The equilibrium LGD will be larger than LGD_1 since the bank chooses an amount of retained risk that exceeds the one that offsets the initial impact on stability (as Proposition 2 has shown).

We turn now to the analysis of increased liquidity in the secondary market, represented through a reduction in the risk transfer costs β. A reduction in β has a direct positive impact on stability by increasing bank's profits from risk transfer ($A(Y)$ in 12), which increases bank's equity at $t = 2$ and thus reduces the minimum asset shock $\widehat{\varepsilon}$. The lower β also encourages risk transfer in the secondary market but this does not affect stability since Y only enters in the FOC for Z via $A(Y)$. Overall, stability does not change because the bank offsets the impact of increased profits on stability by increasing Z.

Proposition 4 *An increase in liquidity in normal times increases retained risk Z but does not affect banking stability.*

Proof. *See Appendix.* ■

This result can be readily understood by noting that if the bank restores the old $\widehat{\varepsilon}$ by increasing retained risk, neither the marginal benefits MB (equation 14) nor the marginal costs MC (equation 19) have been affected by the reduction in β.

Proposition 4 modifies previous results obtained by Instefjord (2004), who analyzes the impact of a improved hedging effectiveness through credit derivatives on bank's riskiness. An increase in the hedging effectiveness in his paper is comparable to the reduction in β in the present paper. Although there is no explicit solution for the net effect on retained risk in Instefjord's paper, it is conjectured that if the loan elasticity is sufficiently large, the effect of additional risk taking could outweigh the reduction in risk through increased risk transfer. Our analysis confirms that retained risk increases for a high loan elasticity (which is in fact infinity in our model) but in deviation to Instefjord our results show that banking stability is unaffected. This is because the bank's motive for increasing its retained risk is precisely to offset the initial positive stability impact.

Proposition 5 shows next that although an increase in liquidity in normal times does not affect stability, it leads to a higher LGD. This is because the increased liquidity causes the bank to retain more risk, asset shocks below the minimum asset shock $\widehat{\varepsilon}$ lead to higher losses for depositors (equation 9).

Proposition 5 *An increase in liquidity in normal times increases the LGD.*

Proof. *Follows directly from (9) since we have from Proposition 4 that $d\widehat{\varepsilon}/d\beta = 0$ and $dZ/d\beta < 0$.* ■

4.1 The Influence of the Capital Structure

Generally, improvements in asset liquidity may have an impact on the bank's optimal capital structure, which may modify our stability results. However, this is not the case in our model. This can be seen by noting that a change in D does neither affect the MB nor the MC for a given level of $\widehat{\varepsilon}$ (from equations 14 and 19). Hence, any potential impact arising from a changed capital structure on stability will be undone by the bank through an adjustment of retained risk.[6]

5 Regulation

In this section we extend our analysis to an economy in which deposits are fully insured by a (fairly priced) deposit insurance fund and where the regulator imposes Basel-style minimum capital requirements. To this end we modify the setup as follows. Since iD is equal to the expected losses to depositors from banking defaults (equation 7), we can reinterpret iD as the payments of the bank to the deposit insurance fund, taking place at $t = 0$. Capital requirements are introduced in a simple fashion by assuming that if the equity of the bank at $t = 2$ falls short of a fraction k of its risky assets, the bank is shut down. To keep the analysis comparable to the previous section, both equity and the risky asset at thereby valued at their liquidation value. When the bank is shut down, its assets are liquidated. Depositors are paid out first and any remaining value is distributed to the shareholders of the bank. If the liquidation value of the bank is not sufficient to cover depositors' claims, depositors will be compensated by the deposit insurance fund.

The condition for no banking closure is thus

$$((1-\gamma)(\mu+\varepsilon)-1)Z + A(Y) + W - iD \geq k(1-\gamma)Z$$

i.e., the liquidation value of the bank net of depositors' claims has to exceed k times the liquidation value of the risky assets. Denoting with $\widehat{\varepsilon}_C$ the minimum asset shock that

[6] The optimal capital structure in our model is in fact indetermined: because iD can be substituted for in the expression for $E[\pi]$ (equation 6, using equation 16 and 7), bank's profits are independent of iD. The reason for this is that depositors are always fully compensated for any losses from default through higher interest rates. It would be straightfoward to extend the model in order to obtain a unique optimal capital structure, for example, by assuming increasing marginal costs of attracting local deposits.

ensures that the bank is not closed we get

$$\widehat{\varepsilon}_C = \frac{1-(W+A-iD)/Z}{1-\gamma} - \mu + k \tag{23}$$

The minimum asset shock $\widehat{\varepsilon}$ that guarantees that the bank's liquidation value is sufficient to pay out depositors is unchanged as in equation (16) and we thus have $\widehat{\varepsilon}_C = \widehat{\varepsilon} + k$.

The bank's expected return consists now of the expected value of its portfolio net of debt if the bank is not closed down (i.e., when $\varepsilon \geq \widehat{\varepsilon}_C$) plus any remaining value that is distributed to shareholders when the bank is closed down (this value is positive for $\varepsilon > \widehat{\varepsilon}$)

$$\begin{aligned} E[\pi] &= \int_{\widehat{\varepsilon}_C}^{1} [(\mu+\varepsilon-1)Z + A(Y) + W - iD]\phi(\varepsilon)d\varepsilon + \\ & \int_{\widehat{\varepsilon}}^{\widehat{\varepsilon}_C} [((1-\gamma)(\mu+\varepsilon)-1)Z + A(Y) + W - iD]\phi(\varepsilon)d\varepsilon \end{aligned} \tag{24}$$

The expression for iD is unchanged (equation 7). Rearranging the FOC for Z (from 24) and using $\widehat{\varepsilon}_C = \widehat{\varepsilon} + k$, we obtain the MB and MC

$$MB = \int_{\widehat{\varepsilon}}^{1} (\mu+\varepsilon-1)\, d\varepsilon - \int_{\widehat{\varepsilon}}^{\widehat{\varepsilon}+k} \gamma(\mu+\varepsilon)d\varepsilon \tag{25}$$

$$MC = \gamma(\mu+\widehat{\varepsilon}+k)Z\partial\widehat{\varepsilon}_C/\partial Z \tag{26}$$

$$= \gamma(\mu+\widehat{\varepsilon}+k)(\frac{1}{1-\gamma} - \mu - \widehat{\varepsilon}) \tag{27}$$

From (25), (26) and (27) we can see that compared to the unregulated economy, both MB and MC are changed because liquidation occurs already at $\widehat{\varepsilon}_C = \widehat{\varepsilon} + k$ rather than at $\widehat{\varepsilon}$. The marginal benefits are reduced because costly liquidation arises now also if $\widehat{\varepsilon} \leq \varepsilon < \widehat{\varepsilon}_C$. The MC is increased because of the higher marginal liquidation shock $\widehat{\varepsilon}_C$ the value of the assets that have to be liquidated is increased.

However, the proofs regarding the impact of asset liquidity on banking stability (stability refers analogous to the previous sections to the probability that the bank's debt exceeds its liquidation value, i.e., $\varepsilon < \widehat{\varepsilon}$) and the LGD can still be readily applied.

Proposition 6 *As in the unregulated economy, (i) an increase in crisis liquidity reduces stability and increases the LGD, (ii) an increase in liquidity in normal times does not affect stability and increases the LGD.*

Proof. *Analogous to Propositions 2 - 5, noting that* $\partial \frac{dE[\pi]}{dZ} / \partial \widehat{\varepsilon}$ *is now* $\partial \frac{dE[\pi]}{dZ} / \partial \widehat{\varepsilon} = -(\mu + \widehat{\varepsilon} - 1) - \gamma k - \gamma(\frac{1}{1-\gamma} - 2\mu - 2\widehat{\varepsilon} - k) = -(2\gamma - 1)(\frac{1}{1-\gamma} - \mu - \widehat{\varepsilon})$. ■

Proposition 7 shows next that the impact of an increase in k on banking stability is positive. Although there is no direct effect of k on $\widehat{\varepsilon}$, the increase in k reduces the MB and increases the MC. Thus the bank reduces its retained risk and stability increases.

Proposition 7 *An increase in capital requirements* k *reduces retained risk* Z *and increases stability.*

Proof. *See Appendix.* ■

Capital requirements can therefore be used to mitigate the impact of increased crisis liquidity. However, they cannot be used to offset any negative stability impact. This is because a banking closure is only an effective threat for banks when it is costly. When γ is low the costs of banking closure are low and, consequently, capital requirements are becoming ineffective.

Proposition 8 *If the risky asset becomes perfectly liquid in times of crisis* ($\gamma \longrightarrow 0$)*, bank stability becomes minimal regardless the size of capital requirements* k.

Proof. *For* $\gamma \to 0$ *we have that* $MC \to 0$ *(from 27 and* $-1 \leq \widehat{\varepsilon} \leq 1$*). From* $MB \to \int_{\widehat{\varepsilon}}^{1} (\mu + \varepsilon - 1)\, d\varepsilon > 0$ *for* $\widehat{\varepsilon} < 1$ *we have hence that* $dE[\pi(Z)]/dZ > 0$ *for* $\widehat{\varepsilon} < 1$*. Thus* $\gamma \to 0$ *implies* $\widehat{\varepsilon} \to 1$. ■

Suppose now that the regulator can change the cost of a banking closure to bank's shareholders. More specifically, assume that the regulator can impose a proportional penalty δ on the value of the bank's risky assets when the bank is closed down. An example for such proportional penalties (or subsidies if $\delta < 0$) are tax deductions granted to financial institutions that acquire assets of a bank that has been closed down by the regulator (as has been common practice in the U.S.). Such tax deductions increase the price at which the financial institutions are prepared to acquire the bank's assets and thus amount to a reduction in δ.[7]

For given k, this penalty does neither affect iD, $\widehat{\varepsilon}$ nor $\widehat{\varepsilon}_C$, therefore equations (7), (16) and (23) still apply. The bank's expected return is now

$$E[\pi] = \int_{\widehat{\varepsilon}_C}^{1} [(\mu+\varepsilon-1)Z + ((1-\beta)p-1)Y + W - iD]\phi(\varepsilon)d\varepsilon + \tag{28}$$

$$\int_{\widehat{\varepsilon}}^{\widehat{\varepsilon}_C} [(1-\gamma-\delta))(\mu+\varepsilon-1)Z + ((1-\beta)p-1)Y + W - iD]\phi(\varepsilon) \tag{29}$$

and the expressions for MB and MC become

$$MB = \int_{\widehat{\varepsilon}}^{1} (\mu+\varepsilon-1)\, d\varepsilon - \int_{\widehat{\varepsilon}}^{\widehat{\varepsilon}+k} (\gamma+\delta)(\mu+\varepsilon)d\varepsilon \tag{30}$$

$$MC = (\gamma+\delta)(\mu+\widehat{\varepsilon})Z\partial\widehat{\varepsilon}/\partial Z \tag{31}$$

$$= (\gamma+\delta)(\mu+\widehat{\varepsilon}+k)(\frac{1}{1-\gamma} - \mu - \widehat{\varepsilon}) \tag{32}$$

Thus δ affects the bank's optimization problem by reducing the MB and by raising the MC. As a consequence, an increase in δ leads to a reduction in the bank's choice of retained risk Z and thus $\widehat{\varepsilon}$ falls.

Proposition 9 *An increase in δ reduces retained risk Z and increases stability.*

Proof. *See Appendix.* ■

Proposition 10 shows next that penalties can be used to completely offset any impact of a reduction in γ. From (30) and (32), this is because they can directly eliminate the impact of a change in the liquidation cost γ on the MB and the MC. Penalties are thus a more effective tool than capital requirements for counteracting the negative stability impact of increased crisis liquidity.

Proposition 10 *The stability impact of a change in the liquidation cost $d\gamma$ can be offset by changing the penalty δ by $d\delta = -d\gamma$.*

Proof. *Follows directly from (30) and (32) by noting that $\partial MB/\partial\gamma = \partial MB/\partial\delta$ and $\partial MC/\partial\gamma = \partial MC/\partial\delta$.* ■

[7] Similarly, allowing the acquiring institution to use goodwill on its books can also be interpreted as a reduction in δ.

6 Summary

The various new credit derivative instruments have increased banks' possibilities to manage their loans, which have been traditionally considered as illiquid. What are the consequences for the stability of the banking sector? This paper has shown that the benefits of increased liquidity from facilitating risk transfer in normal times and from enhancing liquidation in a crisis, are counteracted by corresponding increases in banks' risk taking. Overall, stability is reduced because the improved liquidation in a crisis reduce banks' incentives to avoid a crisis. Banks therefore take on an amount of new risk that leads to a higher probability of default.

Regulators wishing to address this stability problem can do this by increasing capital requirements. However, as asset liquidity increases, capital requirements become a less effective instrument for ensuring stability. A preferable means for undoing the impact of increased liquidity on stability is to reduce the liquidation value of the bank.

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Proof of Proposition 1. Solving the integral in the expression for $\partial E[\pi]/\partial Z$ (from 13) gives

$$\partial E[\pi]/\partial Z = \frac{1}{2}(1-\widehat{\varepsilon})(\widehat{\varepsilon}-1+2\mu) - \frac{\gamma}{(1-\gamma)Z}(\mu+\widehat{\varepsilon})(W+A-iD)$$

Substituting $\widehat{\varepsilon}$ (using the definition of $\widehat{\varepsilon}$ and A) yields

$$dE[\pi(Z)]/dZ = \frac{(2\gamma-1)(W+A-iD)^2 - (\gamma^2-\mu^2(1-\gamma)^2)Z^2}{2(1-\gamma)^2Z^2} \tag{33}$$

Setting to zero and solving for Z, noting that $\gamma^2-\mu^2(1-\gamma)^2>0$ because of $\mu<\gamma/(1-\gamma)$, gives

$$Z^* = (W+A-iD)\sqrt{\frac{2\gamma-1}{\gamma^2-\mu^2(1-\gamma)^2}}$$

Since $\gamma^2-\mu^2(1-\gamma)^2>0$, $W+A-iD>0$ and $\gamma>1/2$ it follows that $Z^*\in(0,\infty)$. Differentiating (33) wrt. Z gives

$$\partial E^2[\pi(Z)]/\partial^2 Z = -(W+A-iD)^2\frac{2\gamma-1}{(1-\gamma)^2Z^3}$$

hence, because of $\gamma>1/2$, we have $\partial E^2[\pi(Z)]/\partial^2 Z<0$ and therefore Z^* is a maximum and unique. ■

Proof of Proposition 2. We show first $d\widehat{\varepsilon}/d\gamma<0$ and then $dZ/d\gamma<0$. $d\widehat{\varepsilon}/d\gamma<0$: From $E[\pi]=MB-MC$ and using (14) and (19), the total differential of $dE[\pi(Z)]/dZ=0$ wrt. γ is

$$\frac{d\frac{dE[\pi]}{dZ}}{d\gamma} = \frac{\partial\frac{dE[\pi]}{dZ}}{\partial\gamma} + \frac{\partial\frac{dE[\pi]}{dZ}}{\partial\widehat{\varepsilon}}(d\widehat{\varepsilon}/d\gamma) = 0$$

From $\partial\frac{dE[\pi]}{dZ}/\partial\gamma<0$ and $\partial\frac{dE[\pi]}{dZ}/\partial\widehat{\varepsilon} = -(\mu+\widehat{\varepsilon}-1)-\gamma(\frac{1}{1-\gamma}-2\mu-2\widehat{\varepsilon}) = -(2\gamma-1)(\frac{1}{1-\gamma}-\mu-\widehat{\varepsilon})<0$ (because of the conditions for interior solutions $\gamma>1/2$ and $\mu<\gamma/(1-\gamma)$ and because of $\widehat{\varepsilon}\leq 1$) it follows that $d\widehat{\varepsilon}/d\gamma<0$. $dZ/d\gamma<0$: Using (7) to substitute iD in (16) gives

$$\widehat{\varepsilon} = \frac{1-(W+A)/Z}{1-\gamma} + \int_{-1}^{\widehat{\varepsilon}}(\widehat{\varepsilon}-\varepsilon)\phi(\varepsilon)d\varepsilon - \mu$$

Totally differentiating wrt. γ gives

$$d\widehat{\varepsilon}/d\gamma = \frac{1-(W+A)/Z}{(1-\gamma)^2} + \frac{(W+A)/Z^2}{1-\gamma}dZ/d\gamma + \int_{-1}^{\widehat{\varepsilon}} d\widehat{\varepsilon}/d\gamma\phi(\varepsilon)d\varepsilon$$

Solving the integral and rearranging gives

$$d\widehat{\varepsilon}/d\gamma(\frac{1-\widehat{\varepsilon}}{2}) = \frac{1-(W+A)/Z}{(1-\gamma)^2} + \frac{(W+A)/Z^2}{1-\gamma}dZ/d\gamma$$

Since $d\widehat{\varepsilon}/d\gamma < 0$ and $1-(W+A)/Z \geq 0$ (from 16 with $\mu + \widehat{\varepsilon} \geq 0$ and $iD \geq 0$) it follows that $dZ/d\gamma < 0$. ■

Proof of Proposition 3. From (9) we have that

$$\begin{aligned} dLGD/d\gamma &= \frac{\left(\begin{array}{c} \int_{-1}^{\widehat{\varepsilon}} \left[(1-\gamma)Zd\widehat{\varepsilon}/d\gamma + (\widehat{\varepsilon}-\varepsilon)(-Z+(1-\gamma)dZ/d\gamma\right]\phi(\varepsilon)d\varepsilon(\widehat{\varepsilon}+1) \\ -\int_{-1}^{\widehat{\varepsilon}}(\widehat{\varepsilon}-\varepsilon)(1-\gamma)Z\phi(\varepsilon)d\varepsilon d\widehat{\varepsilon}/d\gamma \end{array}\right)}{(\widehat{\varepsilon}+1)^2} \\ &= \frac{\left(\begin{array}{c} \int_{-1}^{\widehat{\varepsilon}} \left[(\widehat{\varepsilon}-\varepsilon)(-Z+(1-\gamma)dZ/d\gamma\right]\phi(\varepsilon)d\widehat{\varepsilon}(\widehat{\varepsilon}+1) \\ +\int_{-1}^{\widehat{\varepsilon}}(1+\varepsilon)(1-\gamma)Z\phi(\varepsilon)d\varepsilon d\widehat{\varepsilon}/d\gamma \end{array}\right)}{(\widehat{\varepsilon}+1)^2} < 0 \end{aligned}$$

since $dZ/d\gamma, d\widehat{\varepsilon}/d\gamma < 0$. ■

Proof of Proposition 4. The total differential of $dE[\pi(Z)]/dZ = 0$ wrt. β is

$$\frac{d\frac{dE[\pi]}{dZ}}{d\beta} = \frac{\partial\frac{dE[\pi]}{dZ}}{\partial\widehat{\varepsilon}}(d\widehat{\varepsilon}/d\beta) = 0$$

hence $d\widehat{\varepsilon}/d\beta = 0$ because of $\partial\frac{dE[\pi]}{dZ}/\partial\widehat{\varepsilon} < 0$ (which has already been shown in the Proof of Proposition 2). $dZ/d\beta < 0:$ Using (7) to substitute iD in (16) gives

$$\widehat{\varepsilon} = \frac{1-(W+A)/Z}{1-\gamma} + \int_{-1}^{\widehat{\varepsilon}}(\widehat{\varepsilon}-\varepsilon)\phi(\varepsilon)d\varepsilon - \mu$$

Totally differentiating wrt. β gives

$$d\widehat{\varepsilon}/d\beta = \frac{(W+A)/Z^2}{1-\gamma}dZ/d\beta - \frac{1/Z}{1-\gamma}dA/d\beta + \int_{-1}^{\widehat{\varepsilon}}(d\widehat{\varepsilon}/d\beta)\phi(\varepsilon)d\varepsilon$$

Since $d\widehat{\varepsilon}/d\beta = 0$ and $dA/d\beta = \partial A/\partial\beta + (dA/dY)dY/d\beta = \partial A/\partial\beta < 0$, it follows that $dZ/d\beta < 0$. ■

Proof of Proposition 7. From (25), (27) we have that

$$\frac{d\frac{dE[\pi]}{dZ}}{dk} = \frac{\partial\frac{dE[\pi]}{dZ}}{\partial k} + \frac{\partial\frac{dE[\pi]}{dZ}}{\partial\widehat{\varepsilon}} d\widehat{\varepsilon}/dk = 0$$

Since $\partial\frac{dE[\pi]}{dZ}/\partial k < 0$ and $\partial\frac{dE[\pi]}{dZ}/\partial\widehat{\varepsilon} < 0$ (see Proposition 6) we have $d\widehat{\varepsilon}/dk < 0$. From $d\widehat{\varepsilon}/dk = (\partial\widehat{\varepsilon}/\partial Z)dZ/dk < 0$ and $\partial\widehat{\varepsilon}/\partial Z > 0$ it follows then $dZ/dk < 0$. ■

Proof of Proposition 9. From (30),(32) we have that

$$\frac{d\frac{dE[\pi(Z)]}{dZ}}{d\delta} = \frac{\partial\frac{dE[\pi(Z)]}{dZ}}{\partial\delta} + \frac{\partial\frac{dE[\pi(Z)]}{dZ}}{\partial\widehat{\varepsilon}} d\widehat{\varepsilon}/d\delta = 0$$

Since $\partial\frac{dE[\pi]}{dZ}/\partial\delta < 0$ we have $(\partial\frac{dE[\pi]}{dZ}/\partial\widehat{\varepsilon})d\widehat{\varepsilon}/d\delta > 0$. Since $\partial\frac{dE[\pi]}{dZ}/\partial\widehat{\varepsilon} = -(\mu+\widehat{\varepsilon}-1)-(\gamma+\delta)k-(\gamma+\delta)(\frac{1}{1-\gamma}-2\mu-2\widehat{\varepsilon}-k) = -(2\gamma+2\delta-1)(\frac{1}{1-\gamma}-\mu-\widehat{\varepsilon})+\frac{\delta}{1-\gamma} < 0$ (because of the conditions for interior solutions $\gamma > 1/2$ and $\mu < \gamma/(1-\gamma)$), it follows that $d\widehat{\varepsilon}/d\delta < 0$. From $d\widehat{\varepsilon}/d\delta = (\partial\widehat{\varepsilon}/\partial Z)dZ/d\delta < 0$ and $(\partial\widehat{\varepsilon}/\partial Z) > 0$ (from 16) it follows then $dZ/d\delta < 0$.

■

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