Solvency regulation and credit risk transfer*

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Abstract

This paper analyzes the optimality of credit risk transfer (CRT) in banking. In a model where banks' main activity is to monitor loans, we show that a combination of CRT instruments, loan sales and credit derivatives, might be optimal to insure banks against shocks and to optimally redeploy capital when new investment opportunities arise, without impairing incentives. We derive implications for the optimal design of capital requirements.

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1 Introduction

In the latest years larger banks are steadily increasing their market share in credit risk transfer activities - credit derivatives and loan sales - as extensively documented by ECB (2004), BIS (2005), Minton et al. (2007) and Duffie (2007), among others. When transferring credit risk for risk management purposes, banks reduce their stake in the return from lending, impairing their incentives to monitor loans. If monitoring is important for bank credit, then credit risk transfer (CRT, hereafter) may reduce the value of intermediation and increase bank instability.

In addition, there is evidence that larger banks engaging in CRT transactions, participate in several markets at the same time (for instance Minton et al.(2007) find evidence that banks engaging in asset securitization are more likely to issue credit derivatives as well), showing that loan sales and credit derivatives are complementary activities, and that banks are on both sides of the market for credit derivatives as either buyers and sellers of protection (as documented by Allen and Carletti (2006) and Duffie (2007) among others).

The aim of this paper is to explore the impact of different CRT activities on bank monitoring incentives in a model where banks are subject to moral hazard and optimal capital regulation is in place. In the model loans' face value may be reduced as a consequence of a shock. Banks are subject to a moral hazard problem: they have to exert unobservable efforts in order to monitor entrepreneurs in order to reduce their opportunism.

CRT activities have two different functions here: loan sales serve to free capital for new lending opportunities when other sources of funds are unavailable; credit derivatives instead provide insurance against loan losses. Given that the regulator's objective is to improve bank solvency and to avoid sub-optimal under-investment, the main result in the paper is that incentive compatible level of lending is achieved by letting banks to use a mix of loan sales and credit derivatives together with optimal capital regulation. More specifically, minimum capital requirements provide incentives, credit derivatives insure against shocks on loans value and loan sales provide ex-post liquidity for new lending opportunities once the bank has extended loans in the first stage up to the limit of capital requirements.

In the model the tension between insurance and incentives is driving the results about optimal solvency regulation and use of CRT: when the insurance motive is dominant because of fear of loan losses, the optimal capital ratio has to be tighter, while banks have to buy protection through credit derivatives; the opposite holds when the incentive motive dominates, namely the capital ratio has to be softer and the bank has to sell credit protection.

The paper is related to the growing literature on CRT (see the survey in Kiff et al.(2002)), while only few papers have considered the impact of the use of CRT instruments on banker's incentives and bank solvency (among those, Wagner (2007) and Wagner and Marsh (2006)).

The paper builds on Holmstrom and Tirole (1997) applied to banks, similarly to Rochet (2004) and Chiesa and Bhattacharya (2007), in that monitoring incentives are provided through capital regulation. Chiesa and Bhattacharya (2007) is the most closely related paper on CRT. Their main result is that CRT improves monitoring incentives whereas debt finance does not. This occurs because monitoring does not increase monotonically the portfolio outcomes in all contingencies. If monitoring is more valuable in bad states, then contingent transfers such as CRT are optimal mechanisms to achieve maximum monitoring. In our model monitoring improves portfolio outcomes in all states; further, loan sales and credit derivatives cohexist to respond to two different objectives: loan sales provide additional interim liquidity to fund new lending opportunities, while credit derivatives insure against future loan losses. The optimal balance of insurance and incentives is achieved through CRT and it is preferred to the alternative of raising deposits at the initial date.

Our focus is on the optimal design of capital ratios. This allows us to analyze the issue of pro-cyclicality of capital regulation. Kashyap and Stein (2004) is related to our paper, although bank's use of CRT instruments together with capital regulation affect the conclusions about the optimality of pro-cyclical capital requirements.

The idea that loan sales provide liquidity when other funds are scarce is in Gorton and Pennacchi (1995), although we depart from them by adding credit derivatives and optimal capital regulation.

Finally, the result in our paper that banks using CRT instruments increase their lending while relaxing capital requirements is in line with the empirical evidence in Goderis et al.(2006) and Cebenoyan and Strahan (2004).

We focus on the problem of non-observability of the monitoring effort of the banker, namely on the moral hazard implication of CRT, while we dis-regard the implications of private information in CRT markets (see among others Duffee and Zhou (2001), Thompson (2006) and Nicolò and Pelizzon (2004)).

The remainder of the paper is organized as follows. Section 2 describes a simple model of prudential regulation; we then extend this model by introducing two additional features: new lending opportunities and a solvency shock. We study the impact of these new features on the optimal capital ratio. In Section 3 we show that this optimal solution can be implemented by a combination of loan sales and credit derivatives together with a solvency regulation. Section 4 discusses the implications for pro-cyclicality of capital ratios and liquidity management. Concluding remarks are in Section 5.

2 A simple model of prudential regulation

Our starting point is the simple prudential regulation model of Rochet (2004). Consider a two-date economy (t=0,1) adapted from Holmstrom and Tirole (1997). At date 0 a bank, with capital E_0, raises deposits D_0 from dispersed investors and extends loans L_0 to some entrepreneurs. Depositors' alternative return per unit invested is 1.

Entrepreneurs rely on banking finance to undertake a risky project : each project requires 1 unit of investment at date 0, and yields a return $R > 1$ at date 1 with probability $p \in [0, 1]$ and 0 otherwise. The success probability of the loan portfolio is affected by the banker's monitoring effort: un-monitored loans' success probability falls to $p - \Delta p > 0$, while the banker saves a private cost $B > 0$ per unit lent. We assume constant return to scale for loan returns and private benefits. Loans' returns are perfectly correlated.

Further, we assume that only monitored finance is viable[1]

$$pR > 1 > (p - \Delta p)R + B \tag{A1}$$

Given that the monitoring effort is non-observable, the bank is subject to moral-hazard. For the banker to monitor the portfolio of loans the following incentive

[1] Given that investors are dispersed, they do not have incentives to monitor. Monitored finance is thus provided by banks.

compatibility condition must be fulfilled

$$p\left(RL_0 - D_0\right) \geq (p - \Delta p)\left(RL_0 - D_0\right) + BL_0$$

which can be rewritten as

$$D_0 \leq \left(R - \frac{B}{\Delta p}\right) L_0. \tag{1}$$

Given that depositors do not observe the monitoring effort while the banker derives a private benefit from not monitoring, he cannot credibly promise to repay depositors an amount greater than the maximum expected pledgeable income defined by the right-hand side in the previous expression.

We further assume that a deposit insurance fund (DIF) is in place: by paying a premium π_0 depositors are fully insured against the risk of bank failure at date 1.

Date 0 bank's balance sheet is defined as

$$L_0 + \pi_0 = E_0 + D_0. \tag{2}$$

The break-even condition for the DIF is that the expected repayment to depositors, when the banker monitors, must not exceed the premium, that is

$$\pi_0 \geq (1 - p) D_0,$$

and substituting from (2)

$$L_0 \leq E_0 + pD_0. \tag{3}$$

In this simple model we derive the optimal prudential regulation as the contract between the DIF and the banker that maximizes expected social surplus.[2]

Proposition 1 *The optimal prudential regulation can be implemented by a combination of a fair premium on deposit insurance,* $\pi_0 = (1-p)D_0$, *and a capital adequacy requirement limiting banks' lending to a certain multiple of their equity, that is*

$$L_0 \leq \frac{E_0}{k_S}$$

where $k_S \equiv 1 - p\left(R - \frac{B}{\Delta p}\right)$ *is the capital ratio.*

[2] The idea is that the regulator acts in the interest of depositors (see Rochet, 2004, for a detailed discussion of the optimal prudential regulation).

Proof. The optimal contract between the DIF and the banker requires choosing the level of loans L_0 and deposits D_0 that maximizes expected social surplus

$$ES = (pR - 1) L_0$$

subject to incentive compatibility constraint (1) and break-even condition (3). The optimal solution is obtained by saturating the two constraints. In particular, setting:

$$D_0 = \left(R - \frac{B}{\Delta p}\right) L_0$$

Substituting into (3), we obtain

$$E_0 \geq \left[1 - p\left(R - \frac{B}{\Delta p}\right)\right] L_{0.}$$

■

Note that we need to assume

$$p\left(R - \frac{B}{\Delta p}\right) < 1 \tag{A2}$$

Assumption 2 implies that banks need capital; if it was not satisfied, banks could be 100% financed by depositors.[3]

From Proposition 1 it follows that banks can expand their lending at a maximum of $1/k_S$ of their equity: the optimal capital ratio k_S is increasing in the severity of the moral hazard, measured by B, while decreasing in the expected return of the project, pR. A greater capital ratio implies tighter credit conditions.

2.1 A dynamic model with uncertainty

We now introduce two ingredients in the model: new lending opportunities at an interim stage and a negative shock (a credit loss) affecting the expected return on the portfolio of loans.

At date 0 the bank raises $E_0 + D_0$, lends L_0, and pays premium π_0 to the DIF as before.

[3]This assumption rules out the lemon problem that appears, for example, in Chiesa and Bhattacharya (2007).

At date 1/2 an observable shock occurs with probability $q \in [0,1]$: in this event the loan portfolio return in case of success is reduced to $(R-\alpha)$ per unit lent, instead of R. We assume that $0 < \alpha < R$ and that

$$p(R-\alpha) > 1. \tag{A3}$$

This last inequality means that monitored loans still remain profitable even after taking into account the loss of the face value caused by the negative shock.

After date 1/2, a new lending opportunity arises. The bank has the possibility to finance new loans of the same quality of the old ones in proportion to L_0: loans can be increased up to $L_1 = (1+x)L_0$ with $x \in [0,\, \beta]$. This ingredient captures the idea that new valuable projects may become available once the bank has already extended loans, and is constrained by the capital requirement. Since we assume rigidities in the deposit market[4], the banker has to raise money from investors to fund these new projects.[5] This new ingredient requires solving for the optimal injection of new funds, in addition to the optimal lending capacity determined at $t = 0$.

Figure 1 might help to clarify the sequence of events. The upper branch variables (no credit loss) are denoted by a superscript $+$, while the lower branch variables (solvency shock) are denoted by a superscript $-$.

[Insert Figure 1]

For the banker to monitor the loans in both cases, the following incentive compatibility constraints must hold:

$$R_B^+ \geq \frac{B}{\Delta p} L_1^+, \quad R_B^- \geq \frac{B}{\Delta p} L_1^-, \tag{4}$$

where R_B^+ (respectively, R_B^-) defines the revenue in case of loan success in the upper (respectively, lower) branch. $L_1^+ = (1+x^+)L_0$ and $L_1^- = (1+x^-)L_0$ denote respectively total lending in the upper and lower branches.

[4] To increase the volume of deposits requires time since the bank has to open new branches, while financial markets and, as we will see, CRT markets, provide some flexibility for funding at the time when new investment opportunities arise.

[5] One way to implement this is for instance by letting the banker to sell loans originated at date 0, while retaining a portion in his portfolio in order to retain his monitoring incentive (as in Gorton and Pennacchi (1995)) and using this liquidity to extend new loans.

From an ex-ante perspective, investors are willing to commit to inject new funds at date $t = 1/2$ if and only if:

$$\begin{aligned} & p\left\{(1-q)\left[RL_1^+ - D_0 - R_B^+\right] + q\left[(R-\alpha)L_1^- - D_0 - R_B^-\right]\right\} \\ \geq \; & \left[(1-q)\,x^+ + qx^-\right] L_0. \end{aligned} \tag{5}$$

The optimal contract between the DIF and the banker to maximize the expected social surplus is derived in the following Proposition.

Proposition 2 *The optimal prudential regulation can be implemented, as in the static model, by a combination of a fair premium on deposit insurance, $\pi_0 = (1-p)D_0$, and a capital adequacy requirement*

$$L_0 \leq \frac{E_0}{k_0} \tag{6}$$

where $k_0 = k_S[1+\beta(1-q)] + qp\alpha$ denotes the modified capital ratio.

Proof. The optimal contract between the DIF and the banker requires choosing the level of loans L_0, deposits D_0 and a rate of growth of loans in both states $0 \leq x^-, x^+ \leq \beta$, that maximize expected social surplus

$$ES = (1-q)\,[pR-1]\,(1+x^+)L_0 + q\,[p(R-\alpha)-1]\,(1+x^-)L_0 \tag{7}$$

under the incentive compatibility constraints (4) and the break-even conditions (3) and (5). The optimal solution is obtained by choosing $x^- = 0, x^+ = \beta$ and saturating the other constraints. In particular (5) becomes:

$$pD_0 \leq \left\{(1-q)\left[p\left(R - \frac{B}{\Delta p}\right)(1+\beta)\right] + q\left[p\left(R-\alpha-\frac{B}{\Delta p}\right)\right]\right\} L_0 - (1-q)\beta L_0$$

and substituting it into (3), we obtain

$$E_0 \geq [1+\beta(1-q)]\left[1 - p\left(R - \frac{B}{\Delta p}\right)\right] L_0 + pq\alpha L_0.$$

■

The capital ratio is greater compared to that in the static model, implying tighter credit conditions: the maximum pledgeable income is in fact reduced by expected loan losses and each unit lent is valued more due to lending expansion for a given capital level.

3 Optimal prudential regulation and CRT

We now show that there is an optimal mix of CRT instruments (loan sales and credit derivatives) and prudential regulation that implements the optimal solution characterized above. Define k_0 to be the capital ratio at date 0, implying that loans L_0 have to be at most a multiple $1/k_0$ of the bank's capital E_0 (minimum capital requirement). The DIF premium is set, as before, to $\pi_0 = (1-p)D_0$, since the probability of default of the bank is unchanged.

At date 1/2 in state + the banker has to raise new funds βL_0 by selling a fraction y of its old loans. The unit price of a loan in state + is

$$P = p\left(R - \frac{B}{\Delta p}\right).$$

Therefore y can be obtained by dividing β by P:

$$y = \frac{\beta}{p\left(R - \frac{B}{\Delta p}\right)} > \beta.$$

Note that, due to assumption (A2), the bank has to sell more loans than it grants new ones, in order to maintain its incentives, that is $yL_0 > \beta L_0$. Since the maximum pledgeable income to investors is smaller than L_0, $PL_0 < L_0$, the bank can undertake new lending opportunities β only at the cost of selling a greater fraction of old loans, that is $y > \beta$. If state + prevails, the banker receives $\frac{B}{\Delta p}L_0(1+\beta)$ in case of success at $t = 1$ to maintain his incentives to monitor all the loans in its portfolio. By contrast, if state $-$ prevails, the payment to the banker in case of success is only $\frac{B}{\Delta p}L_0$, as in the static model.

In order to balance its budget in each of the two situations, the bank has to pay investors contingent transfers S^+ and S^- defined by:

$$S^- = (R-\alpha)L_0 - D_0 - \frac{B}{\Delta p}L_0,$$

and

$$S^+ = RL_0[1+\beta-y] - D_0 - \frac{B}{\Delta p}L_0(1+\beta-y).$$

Note that the capital ratio k_0 is designed so that these transfers are actuarially fair:

$$qS^- + (1-q)S^+ = 0.$$

After easy computations, we find indeed that the expressions of S^- and S^+ can be simplified into:

$$S^- = -(1-q)\left[\alpha - \frac{\beta k_S}{p}\right] L_0,$$

and

$$S^+ = q\left[\alpha - \frac{\beta k_S}{p}\right] L_0.$$

We can state the following result.

Proposition 3 *The optimal prudential regulation can be implemented by the following capital ratio*

$$k_0 = k_S[1+\beta(1-q)] + qp\alpha = (1+\beta)k_S + pqW \tag{8}$$

selling a fraction

$$y = \frac{\beta}{p\left(R - \frac{B}{\Delta p}\right)} \tag{9}$$

of loans at date $1/2$ *in state* $+$ *and using contingent transfers (CDS)*

$$S^+ = qWL_0, \quad S^- = -(1-q)WL_0 \tag{10}$$

with $W \equiv \left[\alpha - \frac{\beta k_S}{p}\right]$.

We comment the result in the Proposition starting from the case without loan losses and without new lending opportunities, that is $\alpha = \beta = 0$. In this case the optimal capital ratio is the static capital ratio k_S and there is not a role for credit risk transfer, neither loan sales nor contingent transfers at date $1/2$ as

$$y = S^+ = S^- = 0.$$

When $\alpha > 0$, but $\beta = 0$ (no new lending opportunity at $t = 1/2$), the bank does not sell loans, $y = 0$, while uses contingent transfers insuring for credit losses αL_0 through a Credit Default Swap. The capital ratio is augmented relatively to the static model by $qp\alpha$ since the maximum pledgeable income for depositors is reduced in state $-$: in order to mantain the incentives to monitor, the capital ratio is increased in state $-$ by the amount of the credit losses $p\alpha$ multiplied by the probability that this event occurs, q. However depositors are insured against this event by a CDS fully repaying the losses.

When $\alpha, \beta > 0$ things are a little bit more complicated: the bank does not want to commit to pay $q\alpha L_0$ in state $+$ because of its new lending opportunity. This is why it only insures a fraction $1 - \frac{\beta k_S}{\alpha p}$ of its loan losses. It may even happen that the bank actually wants to "sell" protection against its loan losses because it actually needs more funds in state $+$, due to the new lending opportunities (this occurs when $\beta k_S > \alpha p$). Further the dynamic capital ratio is augmented compared to the static model because total loans growth in state $+$ and there are credit losses in state $-$: with probability $(1-q)$ there are no losses and loans grow at rate $(1+\beta)$, with probability q there are expected loan losses of $p\alpha$. Summing up, the optimal capital ratio should be

$$(1-q)(1+\beta)\,k_S + q\,[k_S + p\alpha]$$

which, once simplified, gives the capital ratio in Proposition 3.

The sign of the term W captures two contrasting effects on the optimal capital ratio: on the one hand the capital ratio is greater (tighter capital requirements) to compensate depositors for the fact that the maximum expected pledgeable income is reduced by loan losses ("insurance" motive); on the other hand, the capital ratio is smaller in the lower branch to improve incentives ("incentive" motive). The relative importance of these two contrasting effects is captured by the sign of W : if $W > 0$ the "insurance" motive dominates, while if $W < 0$ the "incentive" motive is driving the results. The usual contrast between insurance and incentives applies here: the regulator would like to insure depositors against loan losses, but this dilutes the banker's effort worsening his incentives.

Finally, the result in Proposition 3 has implications also for the use of CRT: according to the sign of W the model says that the banker buys protection in the CRT market if $W > 0$, while sells protection when $W < 0$. The following observation may help to understand this result: CDS insures against the event of a negative shock; for each unit of premium $qW > 0$ the banker receives a refund of $W > 0$ in the downturn. When the sign is negative it implies that the banker receives the premium qW in both states in exchange of a payment $W < 0$ when the negative event occurs.

To conclude, the mix of CRT instruments together with capital regulation is explained by the need to solve for the optimal balance of insurance and incentive motives. Given that the probability of facing loan losses in the downturn is exogenous, it is optimal to insure for this event. However, since the banker has to be provided with incentives to monitor, it is not optimal to give him full insurance. The incentive motive requires the optimal regulation to punish the banker when the solvency shock occurs. Depending on the relative importance of the two motives, solvency regulation should be more or less soft (soft vs. hard-budget constraint). When the insurance motive is important, capital requirements are tighter (greater capital ratio than in the static model) and insurance is provided through credit derivatives; when the incentive motive dominates, capital requirements are softer and there is a transfer of resources from the bad state to the good one through credit derivatives which works in the opposite direction.

We now derive the following result on the effect of changes in the parameters on the optimal capital ratio.

Proposition 4 *The optimal capital ratio increases with α and β. The effect of an increase in the probability of a shock q on the capital ratio is positive (resp. negative) when $W > 0$ (resp., $W < 0$).*

Proof. It is easy to derive from the optimal capital ratio in (8) the following results:

$$\begin{aligned}
\frac{\partial k_0}{\partial \alpha} &= qp > 0; \\
\frac{\partial k_0}{\partial \beta} &= (1-q)k_S > 0; \\
\frac{\partial k_0}{\partial q} &= pW.
\end{aligned}$$

■

Capital requirements must be tighter the larger loan losses and the greater the growth of new opportunities of lending. As already explained, the expression of W captures the importance of loan losses relative to incentives. An increase in loan losses, rise in α requires tighter capital requirements when optimal CRT is feasible. Finally, when the probability of a negative shock increases, larger q, the effect on the optimal capital ratio depends on the relative strength of the two opposite motives, that is upon the sign of W.

4 Discussion

The solution in the model has several implications for capital regulation and liquidity management. In particular we discuss the implications for pro-cyclicality of capital ratios when banks have access to CRT markets and the alternative to CRT instruments of liquidity hoarding.

4.1 Pro-cyclicality of capital ratios

This section examines how capital ratios vary in the different states at $t = 1/2$ ($+$ and $-$). This question is simple if one looks at the book value of equity, as we have done so far. Indeed, the book value of assets does not change in state $-$ (it remains equal to L_0) while it decreases in state $+$ (it becomes $(1 + \beta - y)L_0 < L_0$). Thus by using accounting identities, in particular the definition of capital ratio at date 0 $E_0 = k_0 L_0$ we see that the capital ratio (measured in accounting values) decreases in state $+$ compared to state $-$, hence exhibits some procyclicality.

As a matter of fact the capital ratio in state $-$ is

$$\frac{E_0}{L^-_{1/2}} = \frac{k_0 L_0}{L_0} = k_0$$

while in state $+$ it is

$$\frac{E_0}{L^+_{1/2}} = \frac{k_0 L_0}{(1 + \beta - y)L_0} = \frac{k_0}{(1 + \beta - y)}$$

and from the condition $(\beta - y) < 0$ we derive that the capital ratio in state $+$ is smaller than in state $-$.

If one uses fair value accounting the story is a little more complex. [To be developed]

4.2 Liquidity hoarding

We now turn to the question of what is the alternative to the use of CRT instruments. One possibility is for the bank to hoard liquidity at time $t = 0$ to save funds in case of loan losses at time $t = 1/2$. We show that this alternative is dominated by the solution with CRT instruments. The intuition is that liquidity hoarding requires the bank to save a fixed amount of liquidity at an earlier date compared to the date when the shock occurs. At this stage not all information is available. The ex-ante optimal level of liquidity to hold at time $t = 0$ is therefore different from the ex-post optimal level of liquidity and this impairs banker's incentives. To mitigate this ex-ante incentive problem, capital ratio adjusts to a higher level, reducing lending in the first stage. On the contrary CRT markets provide a more flexible solution by supplying liquidity at $t = 1/2$, that is when uncertainty about the shock is resolved.

Assume that the bank raises $E_0 + D_0$ and lends L_0, pays the premium to the DIF as before and hoards $\widetilde{L}_0$ as liquidity to be used at date $t = 1/2$. From date 0 bank's balance sheet, we have:

$$L_0 + \pi_0 + \widetilde{L}_0 = E_0 + D_0.$$

At date $t = 1/2$ when new lending opportunities βL_0 arise, the banker can invest up to xL_0 of his hoarded liquidity $\widetilde{L}_0$. Notice that this amount cannot be made conditional upon the realization of the shock, since there is no credible commitment not to employ it at time $t = 1/2$. Regardless of the state of the economy the banker funds new loans up to βL_0 in both states. It is easy to derive that β is the optimal growth rate: the constraint is now $x^+ = x^-$ since there is a unique level of liquidity hoarded at date 0. Given that the expected surplus in (7) is increasing in the unique level of liquidity, the optimal rate of growth is β.

Given the (fair) DIF premium, date 0 balance's sheet becomes

$$(1 + \beta) L_0 = E_0 + pD_0 \tag{11}$$

The banker's expected return at $t = 1$ is thus

$$\begin{aligned} R_B^+ &= R(1 + \beta)L_0 - D_0 \\ R_B^- &= (R - \alpha)(1 + \beta)L_0 - D_0 \end{aligned} \tag{12}$$

At date 1/2 for the banker to monitor the following incentive constraints must hold:

$$R_B^+ > R_B^- \geq \frac{B}{\Delta p} L_1$$

from which $R_B^- = \frac{B}{\Delta p} L_1$. This sets an upper limit to the amount of deposits the bank can raise, that is

$$D_0 = \left[R - \alpha - \frac{B}{\Delta p} \right] (1 + \beta) L_0 \tag{13}$$

Substituting (13) into the balance sheet in (11) we derive the capital adequacy requirement

$$E_0 \geq \widetilde{k}_0 L_0$$

where $\widetilde{k}_0 = (1+\beta)[k_S + p\alpha]$. It is easy to check that

$$\widetilde{k}_0 > k_0$$

that is capital ratio is greater (tighter credit conditions), to compensate for the soft-budget constraint given by the liquidity hoarded at time 0.

We can state the following result:

Proposition 5 *The solution with liquidity hoarding is sub-optimal compared to the solution with CRT markets.*

Proof. We can compare the expected surplus in the two cases. From expression (7) substituting the optimal capital ratio and the two optimal levels $x^+ = \beta, x^- = 0$ we derive

$$ES^* = \frac{E_0}{k_0}\{(pR-1)(1+\beta) - qp\alpha\}$$

While computing the expected surplus in the liquidity hoarding solution, we have

$$ES^{LH} = \frac{E_0}{\widetilde{k}_0}\{(pR-1)(1+\beta) - qp\alpha(1+\beta)\}$$

Given that $\widetilde{k}_0 > k_0$ and that the term in brackets is smaller in the expression below we conclude that $ES^* > ES^{LH}$. ■

For a given level of capital the banker will lend less in this case, and therefore liquidity hoarding implies a sub-optimal solution compared to the case with CRT markets.

5 Conclusions

In a model where bank's monitoring is important but un-observable we have shown that CRT instruments improve incentives, provided that the capital ratio is adjusted accordingly. The model has implications for solvency regulation, in particular for pro-cyclicality of capital ratios and for liquidity management.

In the model banks are homogenous with regard to their moral hazard costs and exposure to shocks. We leave for future research the task of exploring optimal solvency regulation in a setting where banks are heterogeneous with regard to the size of loan losses or private benefits. For instance Rochet (2004) explores optimal closure rules and capital regulation when banks are hit differently by the same macroeconomic shock.

In the model we do not discuss the lemon problem associated with informational asymmetries between CRT sellers and buyers, in particular in the market of loan sales. In our model when banks sell loans, they preserve monitoring incentives by retaining a portion of the loan sold. This eliminates the problem of asymmetries of information between the bank and investors who acquire a portion of the loan. Furthermore, this assumption eliminates any cost due to the cohexistence of credit derivatives and loan sales, as explored in Duffee and Zhou (2001) and Thompson (2006), where the introduction of credit derivatives may cause a break-down in the market of loan sales.

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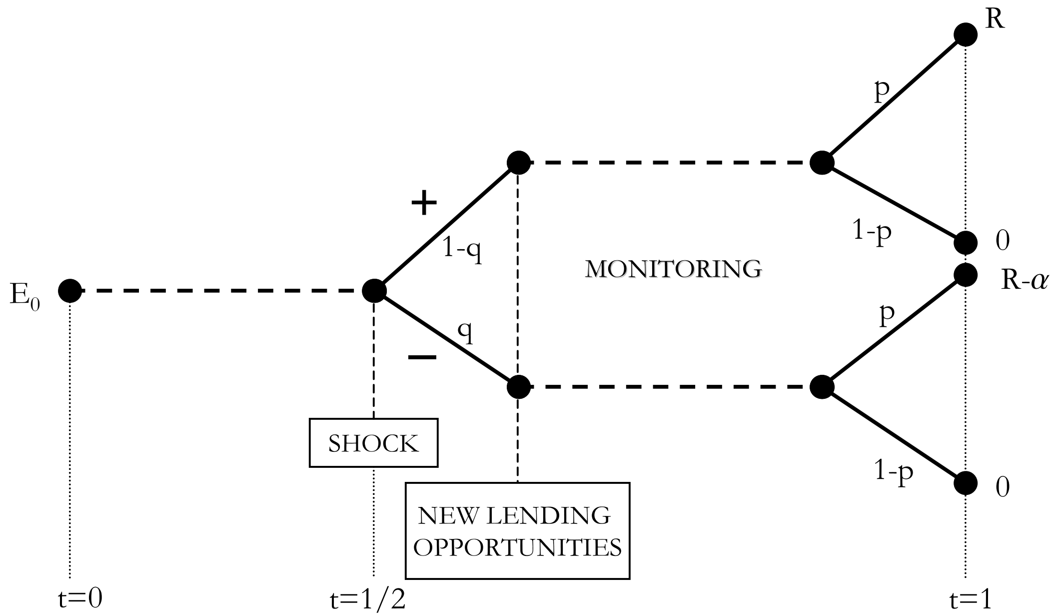

Figure 1 - Timing and events