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Credit Risk Transfer, Real Sector Productivity, and Financial Deepening

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Abstract

We derive the effects of credit risk transfer (CRT) markets on real sector productivity and on the volume of financial intermediation in a model where banks choose their optimal degree of CRT and monitoring. We find that CRT increases productivity in the up-market real sector but decreases it in the low-end segment. If optimal, CRT unambiguously fosters financial deepening, i.e., it reduces credit-rationing in the economy. These effects rely upon the ability of banks to commit to the optimal CRT at the funding stage. The optimal degree of CRT depends on the combination of moral hazard, general riskiness, and the cost of monitoring in non-monotonic ways.

Keywords: credit risk transfer, delegated monitoring, financial deepening

JEL Classification: D82, G21, G32

1 Introduction

Credit risk transfer (CRT) markets have grown immensely in recent years. Contrary to widespread belief, CRT transactions occur to a large extent *bank-to-bank* and *cross-border*.[1] In this paper, we attempt to shed light on two questions: Why do banks trade risks among them? And what aggregate effects does this have on the financial and the *real* sector?

We assume *two types of credit market incompleteness*: (a) because of information asymmetries the firm population is *credit-rationed* (Stiglitz and Weiss (1981)); (b) because of geographic, regulatory and informational lending barriers (cf. Acharya et al. (2004); Almazan (2002); Winton (2000)) the credit market is *fragmented.* I.e., a bank has a priori access only to a subsample of firms.

Banks grant loans and manage their credit risks through two risk management instruments. *Monitoring* influences firm behavior and thereby mitigates moral hazard (Holmstrom and Tirole (1997); Diamond (1984)). *Credit risk transfers* bridge fragmented markets by giving access to the originator's loans.[2] Each addresses one of the above types of incompleteness. But an important question is how they affect each other's effectiveness.

Several papers have already pointed out that CRT can impair banks' monitoring incentives (Gorton and Penacchi (1995); Duffee and Zhou (2001)).[3] This view is one-sided as one could also ask whether monitoring impedes CRT. Asking how to *optimally combine* the two seems more neutral.

Such an optimum would, to address our second question, also determine the aggregate levels of credit-rationing and market fragmentation. This is important because, for example, there are concerns that CRT-induced monitoring losses could reduce the *supply* of monitored finance.

Interestingly, we find that on the aggregate (real and financial sector) levels the two instruments work not as substitutes but rather as *complements* (necessitating each other). That is, while on the institutional level extensively traded risks are monitored less and intensively monitored risks are traded less, on the aggregate some risks need monitoring to be tradable and some need trading to be "monitorable".

We show that CRT, *if* optimal, unambiguously creates *financial deepening.* Moreover, there is a *segment-shifting effect* in credit markets and a *two-edged productivity effect* in the real sector. In the proposed framework, the optimal degree of CRT is strictly welfare increasing and *completes* credit markets in *both* dimensions.

These positive effects can be obtained because the volume of financial intermediation and firm behavior are ultimately affected only by the *price of credit* which, in turn, is influenced by monitoring and CRT. If CRT can reduce the price in spite of the adverse monitoring effect, it induces the aforementioned effects.

Whether and, if so, to what extent CRT is part of the *price-minimal* risk management strategy depends on three factors in possibly non-monotonic ways: the severity of *moral hazard*, the *general riskiness* of the loan, and the *cost of monitoring.*

Finally, the optimal strategy is implementable only if banks can *commit* to it vis-à-vis their depositors. We find that such a commitment is not feasible, *if* CRT is optimal *and* reduces monitoring. We suggest that this creates room for regulation.

[1] Fitch (2004) estimated the end-2003 market size at $3 trillion worth of contracts outstanding. The British Bankers Association (2004) presumes this number will reach $8.2 trillion by 2006. Fitch and Standard and Poor's (2003) find that risks are largely shifted within the banking sector. According to the ECB (2004), the bulk of European deals are bank-to-bank (80% in Germany) and 80% of all deals are cross-border. Some banks both buy and sell protection.

[2] Banks have stated that their overarching motif for CRT is to diversify credit risk by acquiring claims *not* accessible through regular client acquisition (ECB (2004), p.6).

[3] A notable exception is Arping (2004) who finds the opposite in a hold-up framework.

Except for the substitution effect between CRT and monitoring, all these results are novel. Our contribution to the existing literature is therefore that this work complements and, in part, contradicts related works on this topic.

To our knowledge, two other papers explicitly analyze the effects of CRT on aggregate financial and real variables. Morrison (2003) argues that CRT can cause *disintermediation* and reduce productivity in the real sector, while Marsh and Wagner (2004) analyze how CRT affects banking sector *stability*.

Both of them focus on the relationship between firms, bank and *bondholders* and the *certification* effect which bank monitoring has on bond finance. They analyze how the firm's optimal choice between bank credit and bonds is affected by CRT. In Morrison (2003), for example, it reduces *credit demand*. In contrast, we explicitly analyze the effect of CRT on the relationship between firms, banks and their *depositors* and on banks' *credit supply*, while bonds are absent.

This difference in approach leads to results which, in some important points, run counter to those of Morrison and of Marsh and Wagner. Moreover, we derive a result which highlights an implicit but crucial time consistency assumption in their models. For example, while bondholders are concerned about too *much* CRT, depositors fear too *little*. For the most part, we believe that the results point to various consequences of CRT the importance of which varies according to given real-world circumstances.

The main idea underlying our model is that CRT tightens the bank's *monitoring incentive* constraint but can relax its *participation* constraint. Because CRT represents insurance (although for convenience we model it as a loan pool), it can lower monitoring. However, CRT also reduces the bank's *funding cost function*, i.e., the deposit rate it faces for each given level of monitoring.

The sum of its funding and monitoring costs determine a bank's participation constraint, i.e., what it requires to break even. As the *monitoring cost function* is unaffected by CRT, the participation constraint is relaxed. As long as this effect outweighs the monitoring loss, CRT is beneficial. In essence, the bank looks for its optimal *cost-incentive* combination.

The bank therefore charges *lower credit rates* which, in turn, changes the composition and depth of the credit market. Obviously, this affects real investments.

The inherent trade-off between CRT and monitoring is analogous to Admati and Pfleiderer's (1994) conflict between portfolio diversification and large shareholder monitoring in equity markets. The following quote highlights the parallels.

> [W]e look at the potentially conflicting goals of achieving a high rate of monitoring, which is promoted by concentrated ownership, and realizing risk-sharing gains, which usually requires a more diffuse pattern of ownership. In particular, we ask how incentives to monitor are determined when risk-averse investors can trade freely in the market and cannot make prior commitments to monitor firms at any particular level of intensity. In contrast to most financial models of asset pricing in which the payoffs of risky securities are taken to be independent of the allocation of shares, in our analysis the ownership structure affects the payoffs of firms since it affects the amount of monitoring that occurs.[4]

In our case, *markets* are CRT markets, *investors* are banks, and *ownership* refers to debt claims. But while Admati and Pfleiderer focus on free-rider problems in efficient stock trades in *secondary* markets (as in takeovers; cf. Grossmann and

[4] Admati et al. (1994), p. 1098.

Hart (1980)), we turn our attention to the consequences of this trade-off for bank participation in *primary* (credit) markets.

The remainder of the paper is organized as follows. Section 2 presents the model without CRT and derives its equilibrium. Section 3 introduces credit risk swaps to the model. We derive the equilibrium and present the results of some numerical simulations. In Section 4 we analyze a time inconsistency and possible remedies. In Section 5 we discuss external effects and robustness issues. Section 6 concludes.

2 The Model without CRT

2.1 The Real Sector

Imagine a representative, risk-neutral entrepreneur (firm) with a single project. The project requires an initial outlay of 1 and yields R with probability q_e and 0 otherwise. The entrepreneur relies on external funding only and the opportunity cost of capital is 0.

Assume the following firm effort problem (cf. Holmstrom and Tirole (1997)): The entrepreneur expends either a high or low effort $e = \{h, l\}$ with $q_l < q_h$. When $e = l$ (shirking), she enjoys a private benefit B.

2.2 The Financial Sector

Consider a financial intermediary (bank) which raises deposits in order to grant loans to firms. The bank funds the firm and collects a repayment r_B.

Monitoring Concurrently with firm effort, the bank undertakes monitoring M. $M \in (0, 1)$ represents the probability with which the bank can impose $e = h$ on the firm (Carletti (2004)). If the firm chooses $e = l$ and the bank monitors, the project's success probability is $q_M \equiv q_l + \Delta q M$ where $\Delta q \equiv q_h - q_l$. Monitoring costs follow $C(M) = mM^2/2$. The convex shape reflects, among other things, the increasing marginal cost of gathering more information. The coefficient m captures the diseconomies of scale and denotes monitoring quality. If m is large, the technology is poor, i.e., expensive.

Deposits Depositors deposit money in the bank and collect a repayment r_D. Deposits are pure discount debt and no Diamond-Dybvig-like demand deposits (Diamond and Dybvig (1983)). We assume two types of moral hazard due to *bank agency*. First, dispersed depositors cannot observe the *monitoring effort*. Second, they cannot verify the date-T *project state*, which allows banks to give false reports (cf. Diamond (1984); Gale and Hellwig (1985)). We neglect state verification in the case of *firm agency* arguing that a large bank can easily do so.

Depositors, by choice of contract, want to mitigate these problems. We *assume* they enhance deposits with a non-pecuniary bankruptcy penalty ϕ of the following form (Diamond (1984)): $\phi(r_D, z) = \max(r_D - z, 0)$ where z denotes the actual deposit repayment.[5] Under this contract, the bank will report loan returns truthfully and choose a non-negative amount of monitoring. The drawbacks are that the penalty is a deadweight loss when exercised and that monitoring may still

[5] There are two well-known weaknesses in Diamond's model: (a) the assumption of a finely attuned penalty function is unrealistic and (b) there is a lack of explicit game-theoretic analysis involving, say, the question whether the punishment is subgame-perfect. All we need for our purpose is that the bank's funding costs are risk-sensitive so that the bank becomes quasi-risk averse. An economically more sound, but technically more complicated, argument for banks' risk-sensitive capital constraint is the one in Froot and Stein (1998).

deviate from first-best. The monitoring misalignment and the expected penalty, $E\phi = (1-q)r_D$, therefore comprise the *bank agency costs* in this model.

Competition Credit and deposit markets exhibit perfect *upstream* competition. In equilibrium, only the firm can have a non-negative expected profit.

2.3 Information and Contracts

Only actual project return and efforts are private knowledge. All other parameters, including the *fixed* properties of the firm (R, q_h, q_l, and B), are common knowledge. The model is based purely on moral hazard.

The model features only pure discount debt contracts. The deposit contract is supplemented by a penalty function as an incentive device. The loan contract involves monitoring as a control device. We do *not* derive the (constrained) optimality of these contractual designs. As in other banking models, they are given.

2.4 Equilibrium without CRT

Some proofs are relegated to the Appendix.

The sequence of events is as follows: First, the bank is funded by the depositors and r_D is set. Then, the bank *can* grant a loan to the firm and set r_B. During the life of the loan, the bank and the firm simultaneously choose M and e. Finally, all payments (and penalties) are realized.

The model is solved backward. The equilibrium conditions are that (a) effort and monitoring must be in a Nash equilibrium and (b,c) bank and depositors' expected profits must equal 0.

If the firm chooses $e = h$, its expected profit[6] is given by $\Pi_F^h = q_h(R - r_B)$. If it chooses $e = l$, its profit will be the weighted sum of Π_F^h and its pay-off from successful shirking. Thus, $\Pi_F^h \geq \Pi_F^l$, if and only if $q_h(R - r_B) \geq q_l(R - r_B) + B$. That is, the firm's choice is independent of M. Denote

$$\theta \equiv B/\Delta q + r_B^h. \tag{1}$$

For $R \geq \theta$, the firm's dominant strategy is $e = h$. Otherwise, it is $e = l$. We speak of h-firms and l-firms respectively. By assumption, the bank can discern the firm's type and offer the proper contract.

2.4.1 The Case of an h-firm

Suppose the bank is approached by an h-firm. It will obviously choose $M = 0$ as firm effort cannot be further improved. This provided, bank and depositor profits are $\Pi_B^h = q_h r_B - r_D$ and $\Pi_D^h = q_h r_D - 1$. Because of the zero-profit condition

$$r_B^h = 1/q_h^2 \quad \text{and} \quad r_D^h = 1/q_h. \tag{2}$$

Note that r_B^h determines the level of θ.

2.4.2 The Case of an l-firm

Now suppose an l-firm demands credit. The bank and the depositors will then expect $\Pi_B^l = q_M r_B - r_D - mM^2/2$ and $\Pi_D^h = q_M r_D - 1$. We present the solution in the following proposition.

[6] We will, henceforth, suppress "expected".

Proposition 1 *The l-equilibrium without CRT is*

$$M^* = \begin{cases} 1 & \text{if } m < \bar{m} \\ \frac{-mq_1 + \sqrt{(mq_1)^2 + 2m\Delta^2 q r_D^l}}{m\Delta q} & \text{otherwise.} \end{cases} \quad (3)$$

$$r_B^l = \begin{cases} 1/q_h^2 + \frac{m}{2q_h} & \text{if } m < \bar{m} \\ \frac{-mq_1 + \sqrt{(mq_1)^2 + 2m\Delta^2 q r_D^l}}{\Delta^2 q} & \text{otherwise.} \end{cases} \quad (4)$$

$$r_D^l = \begin{cases} 1/q_h & \text{if } m < \bar{m} \\ 1/q_{M^*} & \text{otherwise.} \end{cases} \quad (5)$$

$$\text{with} \quad \bar{m} = \frac{2\Delta q}{q_h(q_h + q_l)}$$

There is an interior and a corner solution. For sufficiently low m, monitoring is so efficient that the bank chooses the maximum intensity $M^* = 1$. Once m rises above a certain threshold, $\bar{m}$, the optimal monitoring intensity is interior. As $m \to \infty$, M^* approaches zero.

In the corner solution, project success is as likely as in an h-firm. Therefore, the deposit's face value is identical. But the credit rate is higher for l-firms. The premium amounts to $m/2q_h$ which in expectation, times q_h, compensates the bank for the incurred monitoring cost of $m/2$.

The bank's premium in the interior solution is harder to trace but the intuition is simple. The equilibrium must satisfy the zero-profit participation constraints of the bank and depositors which can be expressed through the function

$$\text{PC}: \quad r_B^l(M) = 1/q_M^2 + mM^2/2q_M, \quad (6)$$

plus the monitoring incentive-compatibility constraint of the bank which can also be expressed in terms of M,

$$\text{MIC}: \quad r_B^l(M) = mM/\Delta q. \quad (7)$$

(6) is a convex function (with hyperbolic and parabolic features and) with a positive intercept, whereas (7) is linearly increasing. Their intersection yields the *incentive-compatible (credit rate) minimum.* If they intersect within $M \in (0, 1)$, the solution is interior. Otherwise, we obtain the corner solution (see Figure 1)

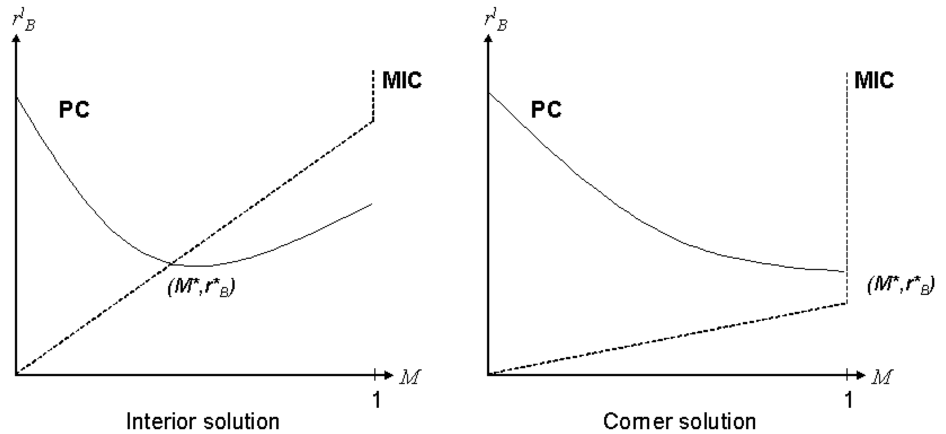

Figure 1: The bank's optimization problem

For a given M, (6) computes the credit rate required by the bank to break even. Therein are two cost components which the bank trades off against each other. It can reduce the likelihood of bankruptcy and, thus, its *funding costs* by increasing its total *monitoring costs*. Both funding and monitoring cost are differentiable in M, $r_D^l = 1/q_M$ and $C(M)$, the former decreasing and the latter increasing in M. The *unconstrained minimum* would solve the first-order condition of (6) which can also be expressed as $[(r_D^l(M) + C(M))/q_M]' = 0$. The constraint on our equilibrium, (7), results from the bank's profit maximization at date 3.

Two conditions must hold in order for the l-contract to be feasible. First, the firm must be eligible: $R \geq r_B^l$. Second, the eligibility threshold for the l-loan must be lower than for the h-loan: $r_B^l < \theta$. This entails the following corollary.

Corollary 1 *For a given m, the l-contract is feasible if and only if $r_B^l(m) \leq R < \theta$. The bank segments the market in h-firms ($R \geq \theta$) and l-firms ($r_B^l(m) \leq R < \theta$). All other firms ($0 < R < r_B^l(m)$) are not financed.*

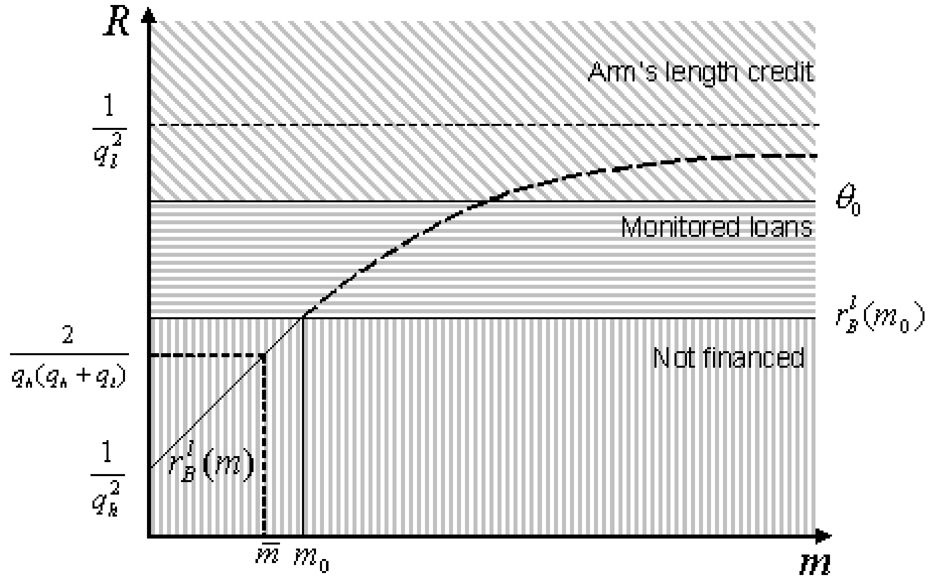

Figure 2: Market segmentation

Figure 2 illustrates the corollary (the shape of $r_B^l(m)$ is derived in the Appendix).

Consider the arbitrary values m_0 and θ_0. The figure depicts a situation where $\theta_0 > r_B^l(m_0)$ so that a market for l-contracts exists. However, one can easily see when this is not the case. Larger B (via θ) enlarge the market for monitored finance. Higher m (via r_B^l) achieve the opposite (cf. Morrison (2003), p. 9).

The economic interpretation is straightforward. In this model, the bank observes firm type and chooses the proper loan contract. Provided $\theta > r_B^l(m)$, there are three market segments. The h-contract resembles an "arm's length" credit and is given to the up-market segment. The l-contract is a "relationship" loan and granted to the low-end segment. The worst firms are not financed. In a world with symmetric information, all firms with $R \geq 1/q_h$ would be financed.

2.4.3 Bank Agency Costs

All agency costs in this model, even the bank agency costs, are in a sense ultimately rooted in the firm effort problem. In order to assess, however, those costs which distinctively arise from the informational frictions between the bank and its depositors, we can use two yardsticks: (a) a *fully self-financed* bank or (b) a deposit-financed bank which can *commit to monitoring.*

Corollary 2 *The optimal monitoring intensity of a fully self-financed bank is lower. In comparison, we thus have relative overmonitoring.*

This results from the fact that the *real* marginal monitoring benefits and costs are not equated in equilibrium, as the penalty function creates an *artificial* benefit of monitoring. From the opposite angle, bankruptcies are costlier to the bank under deposit finance. So, less monitoring becomes costlier. This type of overmonitoring is different than the one noted by Carletti (2004). Carletti focuses on the fact that banks do not internalize entrepreneurial benefits, which is also the case here.[7]

Corollary 3 *The optimal monitoring intensity of a deposit-bank which can commit to monitoring is higher. In comparison, we thus have relative undermonitoring.*

If the monitoring incentive-compatibility constraint were absent, a competitive bank would choose the unconstrained minimum. Part of its monitoring would reduce depositors' required face values. Thus, once these are set, the bank would ex post have an incentive to choose a lower monitoring intensity. Therein precisely lies the issue of incentive-compatibility. With commitment, this problem vanishes.

3 The Model with CRT

3.1 Introducing a Credit Risk Swap

Consider the previous model a region and replicate it. The only difference between the twin regions shall be that their projects are uncorrelated. Suppose cross-border loans are not possible but the banks can swap claims. Importantly, assume symmetric information within the swap transaction. I.e., we disregard the adverse selection issue in CRT transactions in order to focus on their *intra-region* effects.

CRT adds another event to our timeline. At any time during the credit period, the two banks can swap a share $1-\alpha$ of their loans with $\alpha \in (0,1)$. A crucial issue is whether banks can credibly *commit* to any α at the funding stage. Throughout this section we assume they can. In Section 4 we address time consistency.

3.2 Equilibrium with CRT

Our construction paves the way for a *symmetric* solution by assuming (a) *twin* regions, (b) *proportional* swaps of (c) *homogeneous* claims only. Thanks to our one-bank-one-firm setup we also rule out *domestic* diversification. We capitalize on such effects only via CRT. Our results should be robust to these assumptions.

The equilibrium with CRT is subject to the same conditions as the one without but it features an additional variable, α. Thus, without an extra condition we obtain a degree of freedom, i.e., an equilibrium for any given α. In competitive markets, however, banks are forced to minimize their credit rate. Therefore, in equilibrium, the credit rate with CRT, r_{B1}, should be *minimal* subject to the other constraints.

Given the symmetric solution, we can focus on region 1. Region 2 is simply its spitting image. When convenient, we omit the regional subscript.

[7] To complete the picture: without penalties, increasing self-finance will have monitoring approach first-best from 0; with penalties, it will have monitoring approach first-best from above.

3.2.1 The Case of an h-swap

Since $M = 0$ and $e = h$ strictly for h-firms, α is irrelevant for the effort choices. However, α can influence r^h_{B1} and thereby θ (see (1)).The lower r^h_{B1}, the more firms comply with θ.

Assuming the symmetric solution ($r_{B1} = r_{B2}$), the bank's profit function for h-contracts reduces to $\Pi^h_B = q_h r^h_{B1} - r^h_{D1}$. This shows that α has no *direct* bearing on the bank. The zero-profit condition leads to $r^h_{B1} = r^h_{D1}/q_h$ (as in Section 2.4).

Suppose the banks swap $(1-\alpha)$ under the symmetric solution. Then the pay-offs to bank 1 and its depositors are shown in the following table.

State	S_{12}	S_{10}	S_{02}	S_{00}
Default event	None	Credit 2 only	Credit 1 only	Both
Probability	q_h^2	$q_h(1-q_h)$	$q_h(1-q_h)$	$(1-q_h)^2$
Bank revenue	r^h_{B1}	αr^h_{B1}	$(1-\alpha)r^h_{B1}$	0
Deposit repayment	r^h_{D1}	$\min(r^h_{D1}, \alpha r^h_{B1})$	$\min(r^h_{D1}, (1-\alpha)r^h_{B1})$	0

By varying α, money is transferred between the states S_{10} and S_{02}. Such transfers should not matter to risk-neutral depositors *unless* the money is not taken from the depositors' share in S_{10} but from the bank's. We can derive the following lemma.

Lemma 1 *Let α^h denote a retention rate which maximizes the return to depositors under the h-contract. The set of α^h is given by*

$$\min(q_h, 1-q_h) \leq \alpha^h \leq \max(q_h, 1-q_h) \tag{8}$$

The range converges to $\alpha^h = 1/2$ for $q_h = 1/2$. For a given q_h, every α^h leads to the same deposit rate. Therefore, without loss of generality, assume $\alpha = q_h$. Then

$$r^h_{D1} = \max\left(\frac{1}{1-q_h(1-q_h)}, \frac{1}{q_h(2-q_h)}\right) \tag{9}$$

For $q_h = 1/2$, $r^h_{D1} = 1.\bar{3}$.[8] Simple calculations show that $r^h_{D1} \leq r^h_D$ strictly. Since $r^h_{B1} = r^h_{D1}/q_h$, note that $r^h_{D1} \leq r^h_D \Leftrightarrow r^h_{B1} \leq r^h_B \Leftrightarrow \theta_1 \leq \theta$. The equalities hold only trivially for q_h either 0 or 1. We summarize our findings in the following proposition.

Proposition 2 *For $0 < q_h < 1$, CRT reduces the price of arm's length credit via funding costs (price effect). This relaxes the incentive-compatibility constraint for firms and increases the number of h-firms eligible for arm's length credit (segment-shifting effect). This, in turn, raises real sector productivity in the upper segment, while society also saves on monitoring costs (productivity$^+$ effect).*

The *price effect* replicates Diamond (1984). This is no surprise as in the setting of the h-swap both firm and bank effort problems are effectively absent. In contrast to Diamond's world, however, the *latent* existence of the firm effort problem produces the additional *segment-shifting* and *productivity$^+$ effects* insofar as diversification eliminates the moral hazard for a wider subset of firms.

This is not a mere redistribution of rents. Real output increases plus the economy saves on monitoring costs. But why do more firms opt for high effort? For an h-firm, a firm's proceeds ensure incentive-compatibility for the firm *and* participation of the bank. In l-firms, at least one constraint is always violated. CRT can lower banks' "production" costs, hence, their required pay-off (the price) falls. Thus, while firms' *pledgeable income* is unchanged, more can now satisfy their incentive-compatibility constraint *and* the bank's (*relaxed*) participation constraint.

[8] I.e., 1 divided by the probability that at least one credit will pay, $q_h^2 + 2q_h(1-q_h) = 3/4$, because $q_h = 1/2 \Rightarrow r^h_{B1} = 2r^h_{D1}$ implies that depositors lose money only if both credits fail.

3.2.2 The Case of an l-swap

$R < \theta_1$ defines the new set of l-firms. To better understand how CRT impacts the bank's decision, it is helpful to derive the following lemma.

Lemma 2 *Under the symmetric solution, the bank's profit function is*

$$\Pi_B^l = q_{M_1^*} r_{B1}^l - r_{D1}^l - mM_1^{*2}/2. \tag{10}$$

As in the h-swap, α has no *direct* bearing on the bank's profit. There are two *indirect* effects through which CRT changes the bank's rationale: through (a) monitoring incentives M_1^* and (b) funding costs r_{D1}^l. The (b)-effect is the same as in the h-swap. As we will see, this diversification benefit is traded off against a loss in monitoring. We now state our main result in proposition 3.

Proposition 3 *For every admissible α, there exists an l-equilibrium with CRT:*

$$M_1^* = \begin{cases} 1 & \text{for} \quad m < \bar{m}_1 \\ \frac{-mq_1 + \sqrt{(mq_1)^2 + 2m\alpha(2-\alpha)\Delta^2 q r_{D1}^l}}{m(2-\alpha)\Delta q} & \text{otherwise.} \end{cases} \tag{11}$$

$$r_{B1}^l = \begin{cases} \frac{r_{D1}^l + \frac{m}{2}}{q_h} & \text{for} \quad m < \bar{m}_1 \\ \frac{-mq_1 + \sqrt{(mq_1)^2 + 2m\alpha(2-\alpha)\Delta^2 q r_{D1}^l}}{\alpha(2-\alpha)\Delta^2 q} & \text{otherwise.} \end{cases} \tag{12}$$

$$r_{D1}^l = \begin{cases} \frac{1 - q_h(1-q_h)(1-\alpha) r_{B1}^l}{q_h} & \text{for} \quad m < \bar{m}_1 \\ \frac{1 - q_{M_1^*}(1-q_{M_1^*})(1-\alpha) r_{B1}^l}{q_{M_1^*}} & \text{otherwise.} \end{cases} \tag{13}$$

$$\text{with} \quad \bar{m}_1 = \frac{2\alpha\Delta q r_D^l}{(2-\alpha)q_h + \alpha q_l}$$

It can be shown from this proposition that CRT invokes less monitoring: *Assume* more CRT lead to an *in*crease in monitoring. Depositors would benefit from diversification *and* more monitoring. This would strictly decrease r_D^l (see (13)). However, lower α *and* r_D^l would imply a lower M_1^* (see (11)) contradicting the assumption that more CRT increases monitoring. This argument applies equally to $\bar{m}_1$.

Corollary 4 *$dM_1^*/d\alpha > 0$; $\bar{m}_1^*/d\alpha > 0$; $\bar{m}_1 = \bar{m}$ and $M_1^* = M^*$ for $\alpha = 1$. Thus, CRT decreases monitoring incentives and thereby possibly productivity in the low-end segment of the real sector (productivity$^-$ effect).*

The shedding of credit risk diminishes the bank's monitoring incentive because, while still fully bearing the costs, it shares the benefits. The swap creates a virtual loan pool and a joint production problem with it.[9]

The *productivity$^-$ effect* implies that with CRT the low-end real sector becomes riskier and less productive. Ironically, banks may improve in terms of efficiency and stability. This happens precisely when CRT reduces funding costs (which reflect *bank* risk).

So what is the price effect? A comparison with the previous results shows the identity of Proposition 1 and 3 for $\alpha = 1$, and that for *corner solutions* $r_{D1}^l = r_{D1}^h$ and $r_{B1}^l = r_{B1}^h + C(1)$. Since $r_{B1}^h \leq r_B^h$, if anything, CRT lowers prices.

[9]Cf. Gintschel and Hackethal (2004). The same problem arises in models of multiple bank relationships (Carletti (2004)). In the case of many banks, this converges to the free-riding problem of dispersed shareholders. However, the most common interpretation would be insurance. As for all insurance, the incentive to avoid the damage event is reduced.

The interior solution is not so straightforward. For any α, the bank still chooses its incentive-compatible minimum (see 2.4.2) equating the participation constraint with its monitoring-incentive constraint. These are now functions of M *and* α:

$$\text{PC}: \quad r^l_{B1}(M,\alpha) = r^l_B(M) \cdot \tfrac{q_M}{1-\alpha(1-q_M)} \tag{14}$$

$$\text{MIC}: \quad r^l_{B1}(M,\alpha) = r^l_B(M)/\alpha \tag{15}$$

with $r^l_B(M)$ being the respective RHS of (6) and (7). CRT (lower α) relaxes the participation constraint but tightens the incentive-compatibility constraint, i.e., it reduces the bank's cost pressure but worsens its monitoring incentives. The composite effect is ambiguous (see Figure 3).

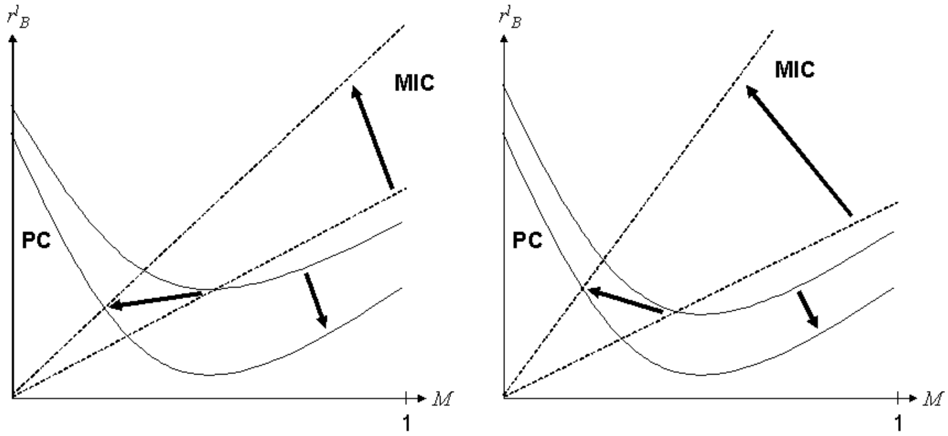

Figure 3: The impact of α on the bank's PC and MIC

Why is the participation constraint relaxed? The monitoring cost function $C(M)$ is not affected by α. Funding costs, on the other hand, are:

$$r^l_{D1}(M,\alpha) = r^l_D(M) - q_M(1-q_M)(1-\alpha)r^l_{B1}. \tag{16}$$

with r^l_D from Proposition 1. While (16) collapses to $r^l_D = 1/q_M$ for $\alpha = 1$, it is clearly different otherwise. In other words, each α represents another *funding cost function*. Under our competitive assumptions, the bank chooses that function which, in interaction with (15), generates the *global* incentive-compatible minimum.

In fact, we may claim that the bank opts to produce the most price-competitive loan even though (12) does not give us any explicit solution. This also minimizes the eligibility threshold for l-contracts.

Proposition 4 *A competitive credit market will force the bank to adopt that α^* which leads to the globally minimal $r^l_{B1}(\alpha^*, M^*)$ (price effect). If $\alpha^* < 1$, then a positive amount of CRT is optimal. If CRT is optimal, a wider range of firms will be eligible for l-contracts compared to the case without CRT (financial deepening effect).*

If optimal, CRT *deepens* credit supply. Contrary to fears that *monitoring* disincentives imperil the market for *monitored finance*, we find that even though banks are inclined to monitor l-firms less, they are willing to finance *more* of them. Although, owing to bank agency, some credit-rationing will remain ($r^l_B \geq r^h_B > 1/q_h$), external financing and economic activity will draw nearer to first-best.

Monitoring and CRT are distinct risk management instruments. They are *substitutes*: CRT reduces a bank's funding costs but also its marginal return from monitoring. Considering the costs and benefits, banks can strike the optimal balance. But they are also *complements*: While obviously l-firm risks need monitoring to be transferable, the deepening result shows that some actually need CRT to be monitorable. Markets are completed domestically as well as across borders.[10]

3.2.3 Bank Agency Costs

In Section 2.4.3, we argued that bank agency costs comprise expected penalty and monitoring misalignment. Clearly, if optimal, CRT reduces expected penalty costs as banks become safer. With respect to monitoring, the conclusion depends on the benchmark. Compared to a deposit-bank which can commit to monitoring, CRT would aggravate *under*monitoring. In this view, monitoring losses are clearly bad. But compared to a fully self-financed bank, CRT would mitigate *over*monitoring. More precisely, "free-riding" would counterbalance "over-incentivization" and monitoring, drawn between two evils, would near first-best. Overall, CRT would reduce penalty costs and the monitoring misalignment "killing two birds with one stone".

3.3 Numerical Simulation

This subsection provides some numerical simulations in order to more clearly assess the effects that our model parameters have on the CRT equilibrium. We simulated the system in Proposition 3 and examined the effect of q_h, q_l, and m on the optimal M^*-α^*-combination. In particular, we varied $m = (0.1, 6)$ and $(q_h, q_l) = \{(0.9, 0.1), (0.9, 0.7), (0.7, 0.3), (0.5, 0.3), (0.6, 0.5)\}$.

Lacking explicit solutions, we first computed equilibria by gradually increasing α from 0.1 to 1. We then searched the resultant subset of admissible α for the one with the lowest associated credit rate. The result is shown in Figures 4 and 5.

Optimal monitoring M^* is positively related to the degree of moral hazard and negatively to the cost of monitoring. However, α^* behaves non-monotonically due to the interplay of two effects.

The effect of riskiness in general Consider the extremes $m = 0$ and $m \gg 0$.

In the first case, the bank chooses $M = 1$ always so that $r_D^l = 1/q_h$ and $r_B^l = 1/q_h^2 + m/2 \approx 1/q_h^2$. Since monitoring is unaffected by CRT, the bank will maximally exploit diversification and choose its *minimum* admissible α, i.e., $\alpha^* = \underline{\alpha} = \max(r_D/r_B, 1 - r_D/r_B)$ (see Lemma 7 in the proof of Proposition 3) which translates into $\alpha^* = \max(q_h, 1 - q_h)$.

In the second case, the bank chooses $M \approx 0$ so that $r_D^l = 1/q_l$ and $r_B^l = 1/q_l^2 + mM^2/2 \approx 1/q_l^2$. Monitoring is nearly insensitive to CRT. The bank will therefore choose $\alpha^* = \max(q_l, 1 - q_l)$ in the limit.

That is, at the poles, the optimal degrees of CRT are *independent* of moral hazard as monitoring grows insensitive to CRT. Instead they depend on the level of q_h and q_l, or the respective *general riskiness* of the firm.

Denote $\alpha_f^*(m)$ for two loans $f = 1, 2$. Whenever $\alpha_1^*(0) > \alpha_2^*(0)$ and $\alpha_1^*(\infty) < \alpha_2^*(\infty)$, their curves in Figure 5 will cross. Consider, e.g., $(0.6, 0.5)$ and $(0.5, 0.3)$.

Every curve will travel from $\max(q_h, 1-q_h)$ to $\max(q_l, 1-q_l)$. For $(0.9, 0.1)$, this journey both starts and ends at 0.9. However, in the process its $\underline{\alpha}$ falls and rises again so that (absent other effects) its curve is V-shaped. It would, for example, cross with $(0.7, 0.3)$ *even though* its α^* is higher at both ends. Some curves would even cross twice, e.g., $(0.9, 0.1)$ and $(0.8, 0.7)$ (not depicted).

[10] By *subdividing* risks CRT leads to an *adding* of risks to the bank sector. As the bank sector grows its *aggregate* risk could rise (Diamond (1984); Samuelson (1963)). Some would argue that this is destabilizing (cf. Marsh and Wagner (2004)). However, we prefer to view it as efficient.

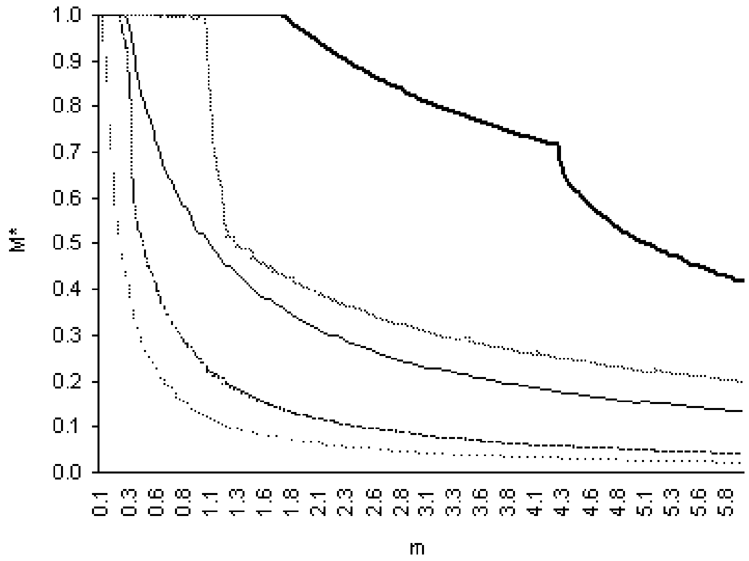

Figure 4: M^*

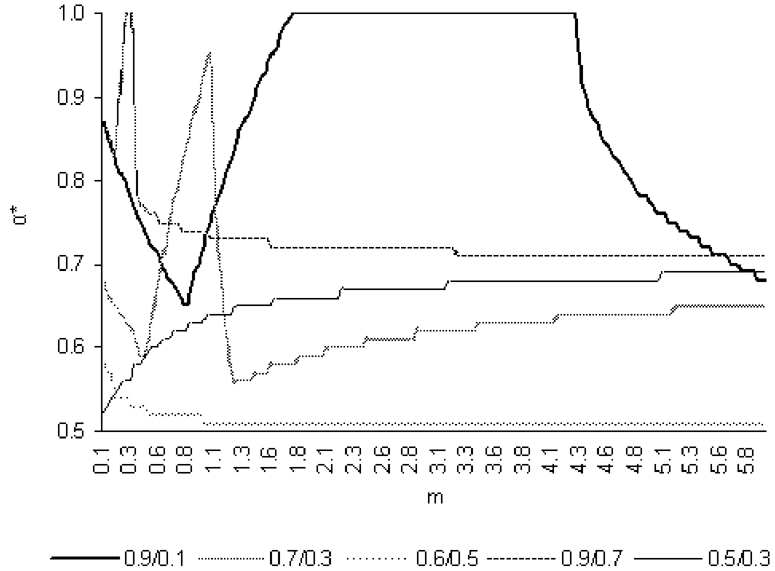

Figure 5: α^*

These intricate effects owe themselves to the effect of general riskiness and the admissibility restriction on α (cf. *first* and *second limit* in Lemma 7). They are not easily visible in Figure 5 as they are distorted by the second effect.

Saving monitoring incentives According to the first effect, gradually decreasing M should take the firm's success probability from q_h to q_l. For $q_h > q_l \geq 0.5$, $\alpha^*(m)$ should be monotonically decreasing; for $q_h > 0.5 > q_l$, V-shaped; and for $0.5 \geq q_h > q_l$, monotonically increasing. Although $(0.9, 0.1)$, $(0.7, 0.3)$, and $(0.9, 0.7)$ obey this course at the ends, they feature a *hump* in-between.

Consider, for example, $(0.9, 0.1)$ where $\alpha^*(m) = 1$ for approximately $1.8 < m < 4.6$. This indicates that the bank is *not* making maximum use of diversification everywhere. In fact, here, it makes no use of it.

Quite simply, it prefers to *save its monitoring incentive.* As would be expected from the first effect, $(0.9, 0.1)$ initially decreases from 0.9. But at around $\alpha^*(0.8) \approx 0.65$, it turns around and starts to rise again. All the while, Figure 4 tells us, the bank retains $M^* = 1$. That is, now that m is so high that the bank must make a trade-off between monitoring and CRT, monitoring is so valuable that the bank would rather forego some CRT.

As m increases further, the comparative advantage of monitoring declines. At $m \approx 4.6$, the marginal net value created by monitoring falls below the marginal value of CRT. So, α^* begins to fall again. As M^* continually decreases with m, the first effect will eventually kick in and $\alpha^*(m)$ will make a final turn towards 0.9.

Where there is a hump, monitoring "undermines CRT incentives".

When monitoring is important, there is less CRT. Since the value of monitoring increases with the severity of moral hazard, the model predicts less CRT origination (a) in high moral hazard loans and (b) by banks with mainly relationship-intensive loans on their books.

If one sees publicly listed companies, often externally rated and forced to comply with high transparency standards, as low moral hazard (i.e. bank monitoring is less crucial) and small and medium-sized enterprizes (SME) as high moral hazard loans, then recent empirical findings support our predictions. According to S&P (2003), up to 90% of CRT involve large listed companies (low moral hazard loans), while CRT for SME (high moral hazard) loans is rarer. Moreover, the ECB (2004) finds that specialized banks with a narrow customer base tend to sell rather than buy protection. A third study on international CRT markets by Fitch (2003) confirms that protection selling is mainly concentrated among smaller regional banks, while protection buying is predominant among larger banks. What emerges seems to be a structure where larger banks with low moral hazard loans act as originators and market makers for peripheral banks with more relationship-intensive loans.

The model also predicts more protection buying in environments where banks are either very efficient[11] or hardly involved in corporate governance (the first effect). Conversely, mediocre monitoring technologies are less conducive to CRT.

4 Time Consistency

4.1 The Commitment Problem

CRT benefits come from changes in the funding cost function of the bank, i.e., the cost of deposits. A question that therefore arises is whether the bank, once funded, has an incentive to deviate from the CRT promise made to depositors. Proposition 5 answers this question.

[11] According to ECB (2004), CRT may help banks establish relationships without excessive cluster risks. Along the same lines: "Increasingly, these credit derivatives allow banks to maintain value-added relationships without necessarily acting as 'buy and hold' lenders" (Fitch (2003), p.6); "[CRT can] divorce the client relationship from the risk decision" (S&P (2003), p.7). This is precisely our result for small m. Cf. also the benchmark solution in Marsh and Wagner (2004).

Proposition 5 $\alpha = 1$ *is ex post dominant whenever* $M_1^* < 1$*. The promise of* α^* *is time inconsistent whenever* $\alpha^* < 1$ *and* $M_1^* < 1$*. Forward-looking depositors will foreclose CRT in these cases.*

Intuitively, assume depositors are *naive.* When making loans the bank, if anything, would already have reaped any benefits from CRT via lower funding costs. This provided, CRT incentives vanish. Indeed, the bank would, on the contrary, rather *abstain* from CRT to avoid eroding its monitoring incentives. This would increase its expected profit. In competitive credit markets, it must forfeit this rent by lowering its credit rates even further. In fact, it would be *pressured* to dilute its deposits.

This moral hazard is quite in the spirit of the *asset substitution problem*[12]: the debtor (the bank) has ex post incentives to opt for a riskier strategy. In asset substitution models, the debtors' rationale for making cash-flows riskier depends on their being residual claimants and on *limited liability.* Here, owing to the penalty the bank is, from its own perspective, fully liable.

In our case, the bank is not concerned with transferring money from shortfall to solvent states. Its goal is to increase the *probability* of the solvent state by preserving its incentive to monitor. This is achieved by *not* conducting CRT.

Given our previous results, the foreclosure of CRT is a welfare loss. Apparently, the penalty function does not preclude this type of opportunism.

4.2 Ex Ante Measures

Bank equity Consider a bank funding β of its capital from its own pocket:

$$\Pi_B^l = q_M r_B^l - r_D^l + \beta(r_D^l - 1) - mM^2/2. \tag{17}$$

β achieves the same as α, namely a fall in funding costs, only without hampering monitoring incentives. The reduction is $\beta(r_D^l - 1)$ where $(r_D - 1)$ is the *external funding premium.* Obviously, for $\beta = 1$ bank agency costs are zero.

Bank equity substitutes and gradually reduces the *need* for CRT. But it cannot prevent foreclosure when CRT is still beneficial. It also neglects wealth constraints.

Credit market power Consider a bank with some credit market power so that it has some leeway in setting r_B^l. Ceteris paribus, this reinforces monitoring incentives, as can be seen from the incentive constraint $M_1^* = \alpha \Delta q r_{B1}^l / m$.

This has three effects: First, there are more corner solutions $M_1^* = 1$, which are not subject to the time inconsistency. Second, more monitoring reduces r_D^l. Third, rising r_B^l and falling r_D^l imply changes in the range of admissible α.

That is, credit market power *can* reduce the need and range of CRT plus eliminate the commitment problem for a larger subset of firms. But the lower firms' pledgeable income, the weaker the effects. When constraints bind ($R = r_B^l$), there are none. The effects thus dwindle as we approach the credit market frontier.

4.3 Ex Post Measures

Reputation We ask whether the deterrence effect of ex post punishment can overcome the problem. For instance, what if in a repeated game banks would lose future deposits by violating past promises? Put differently, could the bank build up a reputation for good risk management, i.e., stability?

Not surprisingly, such a reputation mechanism can exist for appropriate parameters for, say, the expected value of continuation (see Appendix for a discussion).

[12] Often also referred to as *risk-shifting* or *excessive risk-taking.* See also, closely related to our setup, Hellwig (1998).

One can virtually calibrate the preferred equilibrium. Notwithstanding this, reputational mechanisms between small depositors and banks seem not out of place.

However, the reputation argument relies on the assumption that depositors can observe α. In reality, CRT and, more generally, risk management are rather *opaque* (cf. Morrison (2003)). Moreover, one can argue that depositors lack sophistication or that such surveillance is costly and akin to monitoring (to avoid which they went to the bank). Alternatively, inferences from the bank's ex post performance suffer from noise leading to unwarranted punishment and the forgiveness problem.

Also, if α were observable it is unclear why depositors would not take measures before their deposits drown. In other words, the reputation argument seems to imply that α is indeed observable but *unverifiable* or, at least, costly to verify.

A market response to these criticisms seems to be that banks, which frequently tap markets for funding, face shorter maturities on their liability side and through rating agencies disclose their ex ante bank risks.

Risk-Sensitive Capital Regulation Consider a *public* agency P which, on behalf of depositors, monitors (supervises) banks. Assume it is (a) sufficiently sophisticated, (b) can coordinate the costs of supervision, and (c) due to its public nature verifies what it observes.

Let it provide deposit insurance, supervise the bank, and ask a capital requirement K from the bank to cover potential damages. Upon insolvency, P becomes the bank's creditor and the depositors' insurer. Let s denote expected deposit shortfall and t additional costs incurred by P including expected *bankruptcy costs* such as administrative costs from bankruptcy proceedings or political costs. P's expected pay-off is given by $\Pi_P = K - s(\alpha) - t(\alpha)$.[13]

Let $\alpha^* = \arg\min_\alpha r_B$ subject to participation and incentive constraints. Suppose P is *benevolent* and wants to break even, $K(\alpha) = s(\alpha) + t(\alpha)$. The bank's profit is then $\Pi_B = q_{M(\alpha)} r_B - 1 - t(\alpha) - C(\alpha)$.

Apart from t, funding costs are 1 as for a fully self-financed bank. Here t represents the external funding premium.

Proposition 6 *Suppose a public agency insures deposits, supervises banks, and requires prudent capital equal to its total expected bankruptcy costs $K(\alpha) = s(\alpha) + t(\alpha)$. If $K(\alpha)$ is ex interim risk-sensitive, banks will stick to $K(\alpha^*)$.*

This is not surprising. Since K more or less represents funding costs, to let P adjust K is equivalent to having depositors change *post*-CRT deposit rates. In a sense, K replaces r_D^l with the difference that, by assumption, P can use K to discipline banks.

In reality, such ex post measures are apparently performed by public authorities and rating agencies who hold banks accountable for risk management. Regulations make capital requirements increasingly risk-sensitive. Internal credit ratings performed by banks gained importance, as have external ratings, in the context of which the new capital adequacy rules (Basel II) played a key role. Finally, investors seem to react by adjusting funding rates, exchanging management, or coercing the sale of excessive risks. The question is whether CRT effects are properly treated.

This finding is not unexpected. If risk-sensitive capital requirements are intended to let banks internalize the costs of excessive risk-taking, logically, they also work against *in*sufficient risk-shedding. One is simply the mirror image of the other.

[13] Of course, P only has a non-negative expectancy provided that it gets to keep the capital even in the case of solvency. Although real-world capital requirements would be returned, if a bank quit its operations for other reasons than bankruptcy, this is hardly ever observed. Rather, banks stay in business as long as they do not go entirely bankrupt, while required capital - albeit varying - stays with the regulator all along. That is, in practice, the capital is "owned" by the regulator, unless the event for which it was provisioned actually materializes.

5 Model Discussion

External effects We have drawn a fairly positive picture of what we consider to be the *direct* effects of CRT. A word of caution is warranted, however, with regard to any welfare predictions, for there could be important indirect or *external effects.*

At the heart of Morrison (2003) and Marsh and Wagner (2004) is an *informational spill-over* from banks to bondholders. For the latter, bank monitoring *certifies* the firm quality. Banks do not internalize these benefits and care little if, due to CRT, this function suffers. According to Morrison, for example, this may lead to welfare-decreasing *disintermediation.*

Other stakeholders may benefit from banks' presence in corporate governance. For example, Perotti and von Thadden (2004) argue that employees have similar risk preferences regarding firm investments. In fact, they propose society might politically delegate corporate control to banks. In this view, a loss in bank monitoring would harm labor interests.

Another issue could be non-internalized "social" costs of bank failures (Marsh and Wagner (2004)). These could arise, e.g., from a breakdown of payment systems, counterparty risks or, more generally, systemic risks. If aggregate or systemic bank sector risks rose due to CRT, these dangers could grow.

It should be emphasized that, in all three models, banking sector risk refers to the risk of a portfolio of *independent* banks and not *systemic* risks, e.g., due to financial contagion among connected banks. This is important because CRT might have effects on the latter. Intuitively, the structure of liabilities in CRT markets is reminiscent of interbank markets in Allen and Gale (2000).

Such and other *potential* external effects certainly warrant more attention.

Diversification We have neglected other means of diversification apart from direct lending or CRT. For example, banks could simply buy shares or give interbank market loans to other banks. In fact, in our one-bank-one-loan model, this would be identical to CRT. In reality, however, this would not allow banks to trade specific loan risks.[14] CRT, on the contrary, allows to isolate specific credit risks, also from other *types* of risk. Furthermore, CRT unbundles cash-flow and control rights.

Banks could also simply merge and thus unite their credit markets. A "cross-border" merger (or acquisition) would achieve diversification without monitoring losses. However, empirical evidence on bank mergers points to potential drawbacks. For example, mergers typically entail immense integration costs; bigger banks could also worsen internal incentives (Cerasi and Daltung (2000)); there could be *specialization advantages* so that, conversely, merging would involve *diseconomies of scope.*

Finally, depositors themselves could split their deposits among different banks. This would be futile. Recall the risk-neutral assumption: diversification per se has no value. Bank diversification is beneficial because banks plunder their own state-contingent surplus to stuff depositors' shortfall states. "Split" depositors would demand proportional repayments from each bank. Without trading in state-contingent claims, the banks face the same funding costs as before. This effect is also obtained when investors spread their savings directly among firms in Diamond (1984).

Competition We assumed that banks are Bertrand competitors on credit markets but hold complete bargaining power in deposit markets, and not *double Bertrand competition*(DBC) where banks are price-competitors in both.[15] In the same way in

[14]The ECB (2004) study cites as one of the main motifs for CRT transactions the reduction of risks related to *single entities.* Also, the surveys by Fitch (2003,2004; p. 8 and p. 4 respectively) and by the BBA (2004), p. 2) point out that *single-name* credit default swaps make up the lion's share of trade in CRT markets. They are by far the most popular product.

[15]Cf. Yanelle (1997) and Freixas and Rochet (1997).

which DBC aggravates asset substitution (Hellmann et al. (2000)), it could foreclose CRT: competing for deposits could provoke ex post risk-taking by banks. Facing higher deposit rates banks might have to avoid monitoring erosion and abstain from CRT to preserve a no-loss.

Another alternative is to give banks more credit market power. We have already hinted at some consequences. More generally, banks could reap diversification gains but continue to price loans on a stand-alone basis. They would bear less risk than compensated for.

Collusion Unlike in Morrison (2003), there is no collusion between banks and firms. The bank has an isolated moral hazard incentive. Firms could side with banks, but also with depositors as more monitoring lowers their own pay-off. They might even want to bribe the bank to conduct CRT.

If it were (a) possible and (b) lucrative for the firm to bribe the bank and (c) the bank could, in return, commit to conduct CRT, *then* optimal CRT could be saved. However, firms could also bribe banks to reduce monitoring per se *without* recourse to CRT. For neither banks nor firms have any direct ex post benefit from CRT, only from monitoring.

Bribing for less monitoring resembles junk bond finance (cf. Morrison (2003)). To allow this, we would need assume that banks can commit *not* to monitor contradicting our assumption that monitoring is not contractible. Without bondholders, by assumption, *unable* to monitor, the "bribe market" would not work properly.

Other robustness issues Neither a *linear* monitoring cost function[16] nor a *continuous* firm effort change the thrust of our results.

The same holds true for employing a *perfect* hedge or an *asymmetric* swap. All that is needed is simply a trade in different state-contingent claims.

Needless to say, our common knowledge assumptions are important. Adverse selection would clearly complicate matters. A discussion of these issues relating to CRT markets can be found in Duffee and Zhou (2001) and Plantin (2003).

6 Conclusion

We have analyzed the effects of credit risk transfer (CRT) on aggregate financial intermediation and the real sector. We showed that CRT alters a bank's participation and monitoring incentive constraints. In competitive markets, the bank chooses the optimal combination of CRT and monitoring. *If* optimal, positive CRT creates financial deepening. It also increases productivity in the up-market and lowers it in the low-end segment of the real sector. Welfare effects are overall positive and are obtained when banks can be committed to the optimal level of CRT. The latter depends on the severity of moral hazard, the general riskiness of the loan, and the cost of monitoring in non-monotonic ways.

Based on these findings, banks should be encouraged to undertake CRT - not only to shift risks to other, presumably less fragile sectors but also within the banking sector - as neither the real sector nor the banking sector seem to suffer from CRT. A critical issue that still prevails is the opacity of CRT markets. We have shown that banks have an incentive for moral hazard and might thus abstain from undertaking beneficial CRT transactions. To reduce the opacity, it seems essential that regulatory authorities force banks to disclose their CRT deals.

[16]Cf. Carletti's (2004) discussion of how a linear monitoring cost technology affects results. In fact, the basic setup of our model would converge to Morrison's (2003) discrete monitoring variable setup. Banks would either monitor fully or not at all. Our basic results would remain the same.

A word of caution is warranted, however. We consider our findings to be the first-order effects of CRT. Still, we believe that a final welfare assessment additionally warrants the analysis of external effects omitted in this paper. This would seem to be a natural starting point for future research.

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A Appendix

A.1 Proof of Proposition 1

The bank's profit function is

$$\Pi_B^l = q_M r_B^l - r_D - mM^2/2 \tag{18}$$

Monitoring: The bank will choose $M^* = \arg\max_M \Pi_B^l$ the solution of which is $M^* = \min(\Delta q r_B/m, 1)$ where the corner solution is obtained for $m < \bar{m} \equiv \Delta q r_B$.

Credit rate: Plug the monitoring solution back into (18), set it equal to zero, and solve for r_B^l. Plug the solution back into $M^* = \min(\Delta q r_B/m, 1)$ and $\bar{m}$. The expressions thus obtained for r_B^l and M^* are shown in the proposition.

Deposit rate: Depositors require $r_D^l(M) = 1/q_M$. As $M \in [0,1]$, note that $r_D \in [1/q_l, 1/q_h]$.

We have the functions $M = \psi(r_D^l)$ and $r_D^l = \varphi(M)$ and are looking for fix points of $\psi(\varphi(M))$, i.e., where M^* and r_D^l are mutually best responses.

Corner solution: If $m < \bar{m}$, then $M^* = 1$ which implies $q_{M^*} = q_h$. Suppose depositors choose $r_D^l = 1/q_h$. Plugging this back into $\bar{m}$ yields $m < q_h^{-1} 2\Delta q/(q_h + q_l)$ which is exhibited in the proposition. I.e., for l-firms whose q_h and q_l satisfy this condition, the corner solution exists.

Interior solution: For $m > q_h^{-1} 2\Delta q/(q_h + q_l)$, we get the interior solution of $M^*(r_D^l)$ and $r_D^l(M) = 1/q_M$. Plug $r_D^l(M)$ into $M^*(r_D^l)$ and bring everything on the LHS. Denote the *cubic* term on the LHS as $f(M^*)$.

$$f(M^*) = m\Delta q^2 M^{*3} + 3mq_l \Delta q M^{*2} + 2mq_l^2 M^* - 2\Delta q \tag{19}$$

We look for M^* such that $f(M^*) = 0$.

Lemma 3 $\lim_{+\infty} f(M^*) = +\infty$ *and* $\lim_{-\infty} f(M^*) = -\infty$.

Lemma 4 *The local maximum is left of the origin.*

Proof: The first-order condition yields

$$M_{1,2}^{opt} = -\frac{q_l}{\Delta q} \pm \sqrt{\frac{q_l^2}{3\Delta^2 q}}.$$

Strictly, $M_2^{opt} < 0$. Because of Lemma 3 this must be the maximum. □

Lemma 5 *At least one* M *in* $(0,1)$ *solves* $f(M^*) = 0$.

Proof: $f(0) = -2\Delta q < 0$. The condition for $f(1) > 0$ turns out to be $m > q_h^{-1} 2\Delta q/(q_h + q_l) = \bar{m}$, our condition for interior solutions. Thus, for $m > \bar{m}$, there exists at least one interior solution. □

Lemma 6 *There is exactly one* M *in* $(0,1)$ *which solves* $f(M^*) = 0$.

Proof: Follows from Lemmas 4 and 5. □

A.2 Shape of $r_B^l(m)$ in Figure 2

To derive the properties of $r_B^l(m)$ in Figure 2, plug (4) into $R \geq r_B^l$:

$$R \geq \frac{1}{q_h^2} + \frac{m}{2q_h} \quad if \quad m \leq \bar{m}, \tag{20}$$

$$R \geq \frac{-mq_1 + \sqrt{(mq_1)^2 + 2m\Delta^2 q r_D^l}}{\Delta^2 q} \quad if \quad m > \bar{m}. \tag{21}$$

Note that (a) for $m = \bar{m} \Rightarrow r_D^l = 1/q_h$, (20) and (21) collapse to $2q_h^{-1}/(q_h + q_l)$; (b) for $m = 0$, (21) cannot apply and (20) collapses to $r_B^l = 1/q_h^2$; (c) for $0 \leq m \leq \bar{m}$, (20) holds and it is linear in m with slope $2^{-1}/q_h$; (d) for $m > \bar{m}$ the slope of $r_B^l(m)$ is smaller than $2^{-1}/q_h$. If the bank were to *continue* maximum monitoring, the slope would remain $2^{-1}/q_h$. However, the bank reduces monitoring as the marginal cost thereof grows larger than the marginal benefit. Since no change in M would have r_B^l rise linearly with $2^{-1}/q_h$ in m, an optimal change (here, reduction) in M implies that r_B^l's slope is *less* than $2^{-1}/q_h$. In fact, as M falls further, the slope must gradually decrease; (e) $\lim_{m\to\infty} r_B^l(m) = 1/q_l^2$ because $\lim_{m\to\infty} M^* = 0$ and $M^* = 0 \Rightarrow r_B^l = 1/q_l^2$.

For any given m, $r_B^l(m)$ is the bank's required minimum credit rate for l-firms. If this threshold is greater than θ, any firm which is eligible for the l-contract is also eligible for the h-contract. Needless to say, any firm would prefer the latter.

A.3 Proof of Corollary 2

A self-financed bank offers an h-firm $r_{SFB}^h = 1/q_h < 1/q_h^2$. Therefore, $\theta_{SFB} < \theta$. I.e., fewer firms are monitored.

It offers the following to an l-firm (repeat the steps from A.1 with $r_D = 1$):

$$M_{SFB}^* = \begin{cases} 1 & \text{for } m < \bar{m}_{SFB} \\ \frac{-mq_1 + \sqrt{(mq_1)^2 + 2m\Delta^2 q}}{m\Delta q} & \text{otherwise.} \end{cases} \tag{22}$$

$$r_{SFB}^l = \begin{cases} 1/q_h + \frac{m}{2q_h} & \text{for } m < \bar{m}_{SFB} \\ \frac{-mq_1 + \sqrt{(mq_1)^2 + 2m\Delta^2 q}}{\Delta^2 q} & \text{otherwise.} \end{cases} \tag{23}$$

with $\bar{m}_{SFB} = \frac{2\Delta q}{2q_h + q_l}$

Clearly, $\bar{m}_{SFB} < \bar{m}$ and $M_{SFB}^* < M^*$ for $m > \bar{m}_{SFB}$. As a result, $M_{SFB}^* = M^* = 1$ for $m < \bar{m}_{SFB}$, while $M_{SFB}^* < M^*$ otherwise.

A.4 Proof of Corollary 3

Take the depositors' zero-profit condition, $r_D^l = 1/q_M$, and plug it into the bank's zero-profit condition: $q_M r_B^l - 1/q_M - mM^2/2 = 0$. Solve for r_B^l. Form the first-order condition $\partial r_B/\partial M = 0$. This will yield *unconstrained cost-minimal* M and r_B^l. We receive a cubic equation $g(M)$ analogous to $f(M)$ in (19).

$$g(M) = 1/2(m\Delta^2 qM^3 + 3mq_l\Delta qM^2 + 2mq_l^2 M) - 2\Delta q \tag{24}$$
$$f(M) = m\Delta^2 qM^3 + 3mq_l\Delta qM^2 + 2mq_l^2 M - 2\Delta q \tag{25}$$

One can check that f and g always have one intersection at $M = 0$ and none for $M > 0$. Since, obviously, $\lim_{M\to\infty} f > \lim_{M\to\infty} g$, this means that for any $M^* > 0$ and $M^+ > 0$ for which $f(M^*) = g(M^+) = 0$, it must hold that $M^* < M^+$.

A.5 Proof of Lemma 1

Figure 6 is a simple graphic proof. Suppose $r_{B1}^h < 2r_{D1}^h$. Since $r_{B1}^h = r_{D1}^h/q_h$, this is equivalent to $q_h > 1/2$. The state pay-offs in S_{10} and S_{02} (the other states are irrelevant) can then be represented by Figure 6(a). By inspection, as long as both bins do not exceed the cut-off point r_{D1}^h, expected deposit return is maximal. The condition for this, $\alpha r_{B1}^h \leq r_{D1}^h \wedge (1-\alpha) r_{B1}^h \leq r_{D1}^h$, can be transformed to

$$q_h \leq \alpha \leq 1 - q_h. \tag{26}$$

Now suppose $r^h_{B1} > 2r^h_{D1}$ which is equivalent to $q_h < 1/2$ (and illustrated in Figure 6(b)). Here, deposit return is maximal if no bin is smaller than the cut-off point. The respective condition, $\alpha r^h_{B1} \geq r^h_{D1} \wedge (1-\alpha) r^h_{B1} \geq r^h_{D1}$, can be transformed to

$$q_h \geq \alpha \geq 1 - q_h. \tag{27}$$

Finally, suppose $r^h_{B1} = 2r^h_{D1}$, i.e. $q_h = 1/2$. Clearly, maximum deposit return is only achieved by equalizing both bins to the cut-off point (Figure 6(c)).

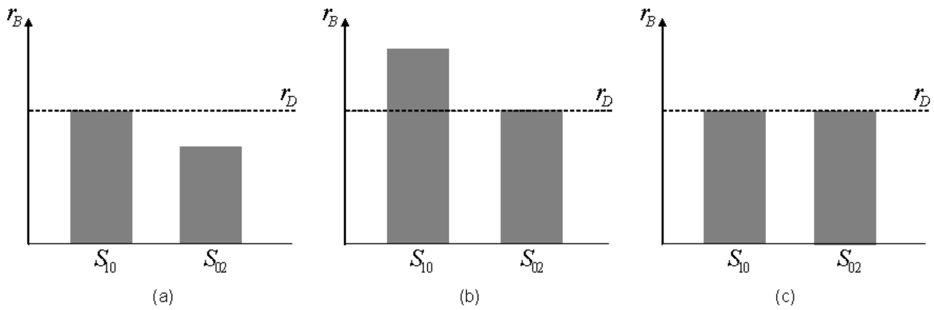

Figure 6: Proof of Lemma 2

A.6 Proof of Lemma 2

When bank 1 faces an l-firm, its profit is given by

$$\Pi^l_{B1} = q_{M1} q_{M2} [\alpha r^l_{B1} + (1-\alpha) r^l_{B2}] + q_{M1}(1 - q_{M2}) \alpha r^l_{B1} + q_{M2}(1 - q_{M1})(1-\alpha) r^l_{B2} - r^l_{D1} - m M_1^2/2. \tag{28}$$

We assume the *symmetric* solution for the entire game, i.e., we assume $r_{D1} = r_{D2}$ and $r_{B1} = r_{B2}$. Plugging these into (28) yields

$$\Pi^l_B = q_{M1} \alpha r^l_{B1} + q_{M2}(1-\alpha) r^l_{B1} - r^l_{D1} - m M_1^2/2. \tag{29}$$

The first-order condition with respect to M_1 gives $M_1^*(r^l_{B1}, \alpha) = \min(1, \alpha \Delta q r^l_{B1}/m)$ where the corner solution is obtained for $m < \bar{m}_1 \equiv \alpha \Delta q r_{B1}$. The solution for bank 2 is analogous so that $M_1^* = M_2^*$. Plugging this identity into (29) yields

$$\Pi^l_B = q_{M_1^*} r^l_{B1} - r^l_{D1} - m M_1^{*2}/2. \tag{30}$$

A.7 Proof of Proposition 3

Monitoring: A.6. **Credit rate**: Plug $M_1^*(r^l_{B1}, \alpha) = \min(1, \alpha \Delta q r^l_{B1}/m)$ into (30), set equal to zero, and solve for r^l_{B1}. Re-substitute the solution into $M_1^*(r^l_{B1}, \alpha) = \min(1, \alpha \Delta q r^l_{B1}/m)$. Both solutions are shown in the proposition. **Deposit rate**: To determine r^l_{D1}, we introduce a reasonable restriction on α.

Lemma 7 *Any admissible α must satisfy the following condition:*

$$\alpha \geq \max(r^l_{D1}/r^l_{B1}, 1 - r^l_{D1}/r^l_{B1}). \tag{31}$$

Proof: The restriction is equivalent to Lemma 1. The "diversification" is the same for all α^h. Since smaller α lead to higher monitoring losses (see Proposition 4), it is only rational to choose the *maximal* α_h.

The following just restates what we just said. Consider, again, what the swap achieves. First, look at the case without risk transfer, $\alpha = 1$, from the perspective of the depositors of Bank 1.

State	S_{12}	S_{10}	S_{02}	S_{00}
Default	None	Credit 2 only	Credit 1 only	Both
Prob	$q_{M^*}^2$	$q_{M^*}(1-q_{M^*})$	$q_{M^*}(1-q_{M^*})$	$(1-q_{M^*})^2$
Credit	r_{B1}^l	r_{B1}^l	0	0
Deposit	r_{D1}^l	r_{D1}^l	0	0

Since $r_B^l - r_D^l > 0$, what the swap achieves is to transfer some of the bank's surplus in S_{10} to S_{02}. Doing so increases the depositors' expected repayment, since the money is taken from *the bank*.

St.	S_{12}	S_{10}	S_{02}	S_{00}
Def.	None	Credit 2 only	Credit 1 only	Both
Prob	$q_{M^*}^2$	$q_{M^*}(1-q_{M^*})$	$q_{M^*}(1-q_{M^*})$	$(1-q_{M^*})^2$
Cr.	r_{B1}^l	αr_{B1}^l	$(1-\alpha)r_{B1}^l$	0
Dep.	r_{D1}^l	$\min(r_{D1}^l, \alpha r_{B1}^l)$	$\min(r_{D1}^l, (1-\alpha)r_{B1}^l)$	0

Thus, it is good for the depositors to shift credit returns from S_{10} to S_{02} *as long as* the money is taken from the bank's surplus. The bank should stop (a) when money begins to be taken from depositors in S_{10}, i.e., when $\alpha = r_{D1}^l / r_{B1}^l$, or (b) when it starts to transfer to itself in S_{02}, i.e., when $(1-\alpha)r_{B1}^l = r_{D1}^l$. Call (a) the *first* and (b) the *second limit.*

Given that no more diversification is achieved if α falls below of any of these limits but monitoring continues to be reduced, the larger of the limits represents the *minimum* rationally admissible α. □

Lemma 7 allows us to represent the depositors' zero-profit condition as

$$q_{M_1^*}^2 r_{D1}^l + q_{M_1^*}(1-q_{M_1^*})r_{D1}^l + q_{M_1^*}(1-q_{M_1^*})(1-\alpha)r_{B1}^l = 1$$

where the LHS is the expected deposit repayment if the *first* limit applies. Solving this equation for r_{D1}^l yields the expression shown in the proposition. It includes the *second* limit case. For $\alpha = 1 - r_{D1}^l / r_{B1}^l$ and $r_{B1}^l \geq 2r_{D1}^l$, this expression turns into $r_{D1}^l = [q_{M^*}(2-q_{M^*})]^{-1}$ which is the analogous solution if the second limit *binds* before the first one. Note also that $q_{M^*} = q_h$ for $m < \bar{m}_\alpha$.

A.8 Proof of Proposition 5

The promise of α is time *inconsistent* if the bank has an incentive to deviate from it ex post. Assume (a) that the bank has promised α^* at date 0 and (b) that the depositors, in good faith, have chosen to demand the face value $r_{D1}^l(\alpha^*)$, and (c) that the bank granted an l-loan at $r_{B1}^l(\alpha^*)$. Thus, after the loan approval the profit function of the bank is as follows (cf. Appendix A.6):

$$\Pi_B^l = q_{M_1(\alpha)} r_B^l(\alpha^*) - r_D^l(\alpha^*) - mM_1(\alpha)^2/2. \tag{32}$$

Note that $\alpha \neq \alpha^*$ is possible. α is the actual variable still to be chosen, whereas $r_B^l(\alpha^*)$ and $r_D^l(\alpha^*)$ are *constants* fixed on the basis of a previously given *promise* α^*. Let the bank maximize Π_B^l with respect to α. For this, we must first substitute $M_1^*(r_{B1}^l, \alpha) = \min(1, \alpha\Delta q r_{B1}^l/m)$ (see A.6) into (32). Thus, we have to distinguish the two cases. For $M_1^*(\alpha^*) < 1$, the first-order condition turns out to be

$$\frac{(r_B^l \Delta q)^2}{m} - \frac{(r_B^l \Delta q)^2}{m} \cdot \alpha = 0 \Leftrightarrow \alpha = 1.$$

For $M_1^*(\alpha^*) \geq 1$, on the other hand, (32) is completely independent of α so that $\partial \Pi_B^l / \partial \alpha = 0$. The bank might just as well stick to α^*.

A.9 A Repeated Game Setup

Suppose there are two players $i = D, B$. Depositors (D) choose between two actions: either *trust* (t) the bank and set $r_{D1}^l(\alpha) = r_{D1}^l(\alpha^*)$ or *distrust* (d) it and set $r_{D1}^l(\alpha) = r_{D1}^l(1)$. The bank ($B$) either *keeps* ($k$) its promise and chooses $\alpha = \alpha^*$ or *breaches* (b) it and chooses $\alpha = 1$. We neglect intermediate values because, if going for b, the bank's dominant choice is $\alpha = 1$. Therefore, depositors' best responses are t and d. Denote this the stage game G. G is sequential, depositors lead and the bank follows. Thus, the former cannot cheat on the latter, i.e., (d, k) will never be played.

Let there be a probability δ that this stage game G will be repeated at the next stage and denote the repeated game by $G(\delta)$. Suppose that δ is close to 1 and let $\tau = 0, 1, ..., \infty$ index the (potential) stages of the game. In addition, assume that the bank gets a non-monetary utility ϵ from continuation.

Finally, consider the following simple trigger strategy: The two parties play (t, k) in G_τ unless the bank has played b in $G_{\tau-1}$. In the latter case, they play (d, b) forever after (or possibly end the game). In other words, new depositors trust the bank only if it has had a good record in the past (reputation). A once unfaithful bank is stigmatized, depositors will not trust it again.

If depositors distrust the bank and play d, the bank is no longer competitive in credit markets, i.e., $\Pi_B^{db} = 0$. Thus, once a bank has played b, it goes out of business.

From the solutions of the extensive version of our stage game, we know that $\Pi_B^{tk} = \Pi_D^{tk} = 0$, whereas $\Pi_B^{tb} > 0$ and $\Pi_D^{tb} < 0$. These are date τ profits.

If (t, k) is played, though its monetary profit is zero, the bank's pay-off is $\epsilon(1 - \delta)^{-1}$ which is its expected continuation value.

If (t, b) is played, the bank makes a one-time profit, $\Pi_B^{tb} = q_{M(1)} r_B(\alpha^*) - r_D(\alpha^*) - mM(1)^2/2$ (cf. 5), but forfeits its continuation value.

We now draw down the strategic form representation of G_τ.

		Bank	
		k ($\alpha = \alpha^*$)	b ($\alpha = 1$)
Depositors	t ($r_D(\alpha^*)$)	$0, \epsilon(1-\delta)^{-1}$	Π_D^{tb}, Π_B^{tb}
	d ($r_D(1)$)	-	$0, 0$

Figure 7: Strategic Form Representation of G_τ

The bank remains honest only if $\epsilon(1-\delta)^{-1} \geq \Pi_B^{tb}$. We rewrite Π_B^{tb} by subtracting $\Pi_B^{tb} = q_{M(\alpha^*)} r_B(\alpha^*) - r_D(\alpha^*) - mM(\alpha^*)^2/2$ the value of which is zero. Then plug in $M_1^*(r_{B1}^l, \alpha) = \min(1, \alpha \Delta q r_{B1}^l / m)$ (see A.6) and rearrange.

Proposition 7 *(t,k) is a reputational equilibrium if and only if*

$$m^{-1}(1 - \alpha^*)^2 \cdot r_B^l(\alpha^*)^2 \cdot \Delta^2 q / 2 \geq \epsilon(1 - \delta)^{-1}. \tag{33}$$

The LHS represents the profit from breaching Π_B^{tb}. Due to the endogeneity of α^* and r_B^l, the comparative statics are not obvious. We have therefore simulated it. Figure 8 shows the result. The curves represent the thresholds which the expected value of continuation must surpass for given m, q_h, and q_l. In a sense, their magnitude signals how "dubious" a bank's promise is.

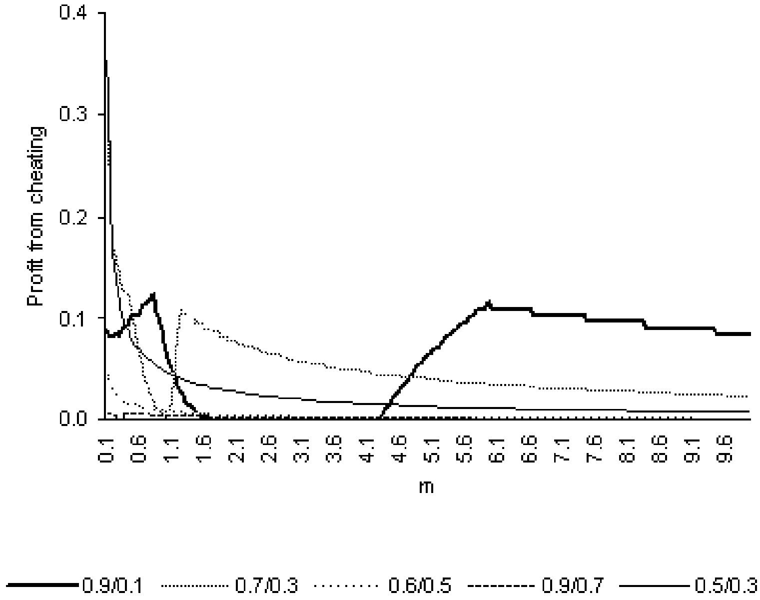

Figure 8: The bank's profit from playing (t, b)

The ranges where the profit from cheating is zero are the ones where $M^* = 1$ so that there really is no commitment problem. The profit from breaching is high where the trade-off or tension between monitoring and CRT is the strongest, i.e., where monitoring is substantially reduced *due to CRT* (and is not generally low because of m). In contrast, e.g., for very high m, $0 < M \ll 1$ even if $\alpha = 1$, i.e., breaching is not so valuable as it increases monitoring intensity only by a whisker.

A.10 Proof of Proposition 6

The proof is very simple. P sets K as to make $K(\alpha^*) = s(\alpha^*) + t(\alpha^*)$ so that it breaks even. Assume $\alpha^* = \arg\min r_B = \arg\min_\alpha K(\alpha^*)$ so that $K(\alpha^*) < K(\alpha)$ for all $\alpha \neq \alpha^*$. I.e., α^* and M^* are the *price-minimal* strategy. Denote $r_B^* \equiv \min r_B$.

Suppose the bank deviated from α^* to $\alpha = 1$ after it has set $r_B = r_B^*$, and P would intervene. To break even, P would increase the capital requirement to $K(1) > K(\alpha^*)$. The bank would monitor with $M(1) > M(\alpha^*)$. But this no longer represents the price-minimal strategy. The *zero-profit* equilibrium would require $r_B > r_B^*$. I.e., at least one party is making a loss. Since, by assumption, depositors always get 1 and P has intervened and raised K precisely to break even, it must be the bank. Thus, it will not deviate.

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