

Credible commitments, contract enforcement problems and banks: Intermediation as credibility assurance

Arnoud W.A. Boot*

J.L. Kellogg Graduate School of Management, Department of Finance, Northwestern University, Evanston, IL 60208, USA

Anjan V. Thakor

School of Business, Indiana University, Bloomington, IN 47405, USA

Gregory F. Udell

Graduate School of Business Administration, New York University, New York, NY 1006, USA

Received December 1989. final version received January 1991

We consider **contract enforceability** problems in **credit transactions** and justify a bank as an organizational solution to market breakdown due to **unenforceable contracts**. Specifically, we explain: (i) why **loan commitments exist**, and (ii) why banks **exist** to **sell** such **commitments**. A loan **commitment resolves** moral **hazard more efficiently than any combination** of inside equity and **spot credit**. However, the market **breaks** down if **commitment sellers** are **individuals**, because their **promises** to honor contracts **are** not credible. With a **large** bank, a **perfect sequential** equilibrium is obtained in which credibility is **restored**.

1. Introduction

Why do individuals buy insurance from insurance companies and rarely from other individuals? Why are individuals willing to pay **up-front** fees to firms or organizations for the future delivery of products or **services (e.g. health clubs, professional organizations, hotels, etc.)** but not to other individuals? Why is it that a person who pays an established commercial

*Author to whom **all correspondence should be addressed**. We thank Mark **Flannery**, George **Kanatas**, Steve **Raymar** as well as anonymous referees and the editor of **this journal**, **Giorgio Szégo**, for **helpful** comments. **Earlier versions** of this paper were **presented at** the **TIMS-ORSA meeting** in Washington, D.C., in April 1988 and at the **Western Finance Association** meeting in **Napa, California** in June 1988. The **usual disclaimer applies**.

airline his full airfare weeks in advance of the flight is unlikely to behave similarly with an individual pilot offering to fly him in a private aircraft? Why is it that loan commitments are sold by banks and not by individuals?

We suggest the same answer to all these questions. Firms can credibly commit to supply a product or service in the future in exchange for current compensation. Individuals often cannot. More specifically, we show that the ability to credibly offer loan commitments – instruments that enable the borrower to pay an initial fee in exchange for the option to borrow up to a certain amount in the future at predetermined terms – in the presence of an inherent incentive to renege may in part be the *raison d'être* for banks. We also show that in the case of a **sufficiently** large bank that can make credible commitments, a bank loan commitment is better for the customer than an exchange-based option. In our model, as in Boot, Thakor and Udell (1987, BTU), loan commitments improve **efficiency** because they reduce moral hazard-related losses created by random interest rates. That paper, as well as numerous other papers that explain loan commitments, ignore the issue of contract enforceability, the central focus of this paper. We do not assume **a priori** that the bank will honor loan commitments. The bank may have an incentive to renege, since the borrower will exercise the commitment when **the** committed rate is below the spot market rate.

Beginning with Campbell (1978), numerous papers have attempted to explain why loan commitments exist. However, until **recently**, most have relied on either risk aversion [Thakor and Udell (1987), Melnick and Plaut (1986)] or transactions costs [Mason (1979)]. Some recent papers have assumed risk neutral settings. **Examples** are Berkovitch and Greenbaum (1989), Kanatas (1987), Boot, Thakor and Udell (1987), and Thakor (1989). Apart from the contract enforceability issue, a key difference between these papers and ours is that we endogenously explain why the bank issuing the commitment exists, whereas they take the bank as **being** exogenously given.

An important feature of our paper is that the (commitment) seller's incentive to honor its contract can be guaranteed neither through explicit legal remedies – as in Shavell (1980, 1984), Rogerson (1984), Konakayama, Mitsui and Watanabe (1986) and Schweizer (1989) – nor through implicit, market-based **reward/punishment** mechanisms, as in Klein and Leffler (1981). This is not to say that these effects are not important, but we take this scenario as our starting point and show that an organizational solution to the contract enforcement problem works precisely when a non-organizational solution fails. **The** idea is that it is more costly for an organization to not honor its contractual commitments than it is for an individual, even when both individual and organization are subject to the same structure of penalties for refusing to honor contracts. The potential market failure, when

'In these papers a prespecified 'damage rule' provides contract enforcement.

individuals will not honor contracts, is prevented by the emergence of organizations. Thus, our approach seems capable of more generally explaining why firms exist [Williamson (1975)]; the focus on financial **intermediaries** is for specificity. **There** are two key differences **between** our **research** and the recent literature on financial intermediary existence [e.g. Boyd and Prescott (1986). Diamond (1984). Millon and Thakor (1985) and Ramakrishnan and Thakor (1984)]. First, this literature *assumes* that contracts will be honored and rationalizes intermediary existence on the grounds that it reduces expected contracting costs by more **efficiently** resolving information-related problems. Second, the intermediaries in these papers function only in spot credit markets and hence do not permit an understanding of the role of institutions in the creation and sale of credit options. We consider these instruments important because over 80 percent of all commercial lending in the U.S. is currently done under loan commitments, the aggregate volume of which is over half a trillion dollars.

The paper is organized as follows. Section 2 presents the basic model and the full-information equilibrium. Section 3 introduces moral hazard and rationalizes loan commitments under the assumption that commitments will always be honored. In section 4, contract enforcement problems are introduced and a rationale for the existence of banks as an organizational solution is provided. Section 5 concludes with some thoughts on a borrower's choice between a bank loan commitment and the purchase of a put option directly through an options exchange. Appendix A gives some details of **derivations** in the text and Appendix B contains all the proofs.

2. The model and the full **information** solution

Consider a perfectly competitive, two-period credit market populated by three types of agents: investors, bankers and borrowers. Investors have an endowment which can be lent to borrowers. Borrowers are endowed with projects which must be funded at the beginning of the second period. Bankers are endowed with illiquid wealth in the form of a **project** which requires no funding and which matures at the end of the second period. Bankers serve no role in the credit market until issues of contract enforcement are considered; so we will ignore them until section 4. All agents have linear preferences over non-negative wealth. Non-pecuniary **penalties** are disallowed and limited liability is assumed, so that consumption is bounded from below by **zero**.² Consequently, credit contracts in a competitive

²One reason for bounding consumption from below by zero is that an arbitrarily large penalty (e.g., hanging!) can resolve any incentive or contract enforceability problems trivially. In our context, we do not consider such a harsh and unrealistic environment as a useful starting point to reach any meaningful conclusions. Our assumptions imply that the borrower's utility over wealth is linear over non-negative wealth levels but concave over the entire real line $(-\infty, \infty)$ [see Rockafeller (1972)].

project. Let $k \in \{G, B\}$, where G indicates 'good' quality and B indicates 'bad' quality; k is a summary statistic representing market demand conditions, production costs, etc., that the borrower was unaware of initially but learns prior to investing capital in the project.⁵ Viewed at $t=0$, all agents have homogeneous beliefs about k , as represented by the probabilities: $\Pr(k=G)=\Psi$ and $\Pr(k=B)=1-\Psi$, $\Psi \in (0, 1)$. The realization of k is independent across borrowers. The second observation the borrower makes is of the spot **riskless** rate. Conditional on the single period spot **riskless** interest factor of R_f at $t=0$, the single spot **riskless** interest factor, R , at $t=1$ can take one of two possible values, R , or R_h . We assume $1 < R_l < R_h < \infty$. Viewed at $t=0$, all agents have homogeneous beliefs about R , as represented by the probabilities: $\Pr(R=R_l)=\theta \in (0, 1)$, and $\Pr(R=R_h)=1-\theta$. We assume that $\theta R_l + (1-\theta)R_h = R_f$. We will refer to R as the random variable representing the spot **riskless** factor at $t=1$ and $R_j \in \{R_l, R_h\}$ as its realization. For any borrower, k and R are independent random variables and their realizations at $t=1$ are common knowledge. Thus, at $t=0$ we should use R_f as the single period discount factor, and at $t=1$ we should use either R_l or R_h as the single period discount factor, depending on which state has been realized. Payoffs to be realized at $t=2$ are discounted back to $t=0$ at $(R'_f)^2$, i.e., the annualized two-period discount factor is R'_f . This discount factor satisfies $(1/(R'_f)^2) = (1-\theta)(R_f R_h)^{-1} + \theta(R_f R_l)^{-1}$, which can be shown to hold by using the usual arbitrage arguments.⁶ With this, $R'_f < R_f$.⁷

Having observed k at $t=1$, the borrower knows the **cash** flow distribution of its investment opportunity, the only remaining uncertainty is the actual cash flow that will be realized at $t=2$. Specifically, the cash flow will be $X(a_i, k)$ with probability (w.p.) $p(a_i)$ and zero w.p. $1-p(a_i)$, with $X(a_1, k) > X(a_2, k) \forall k \in \{G, B\}$ and $X(a_i, G) > X(a_i, B) \forall a_i \in \{a_1, a_2\}$. For any two borrowers with the same a , and the same k , the project cash flows are identically and independently distributed (i.i.d.) random variables. With its observations of k and R_j in hand, the borrower now makes its investment and credit utilization decisions.

Under full **information**, the lender can **costlessly** observe both the borrower's action choice and its return in the successful state. If the borrower self-finances, its incremental expected utility, relative to investing in a **riskless** asset, is

$$\{p(a_i)(\Psi X(a_i, G) + \{1-\Psi\}X(a_i, B))\}(R'_f)^{-2} - V(a_i) - R_f^{-1}. \quad (1)$$

⁵For instance, 'bad' quality means that the combination of market demand conditions (low demand) and production costs (high) is adverse.

⁶For a proof, see Appendix A.

⁷The observation that $R'_f < R_f$ corrects an error in our earlier paper [Boot, Thakor and Udell (1987)] where we had assumed $R'_f = R_f$.

We assume that the borrower's first best action choice is a_1 , implying

$$\begin{aligned} & \{p(a_1)(\Psi X(a_1, G) + \{1 - \Psi\}X(a_1, B))\}(R_f')^{-2} - V(a_1) \\ & > \{p(a_2)(\Psi X(a_2, G) + \{1 - \Psi\}X(a_2, B))\}(R_f')^{-2} - V(a_2). \end{aligned} \quad (\text{PR-I})$$

The borrower's liquidity, L , is **insufficient** to permit complete self-financing. An amount $1 - LR_f > 0$ must be borrowed at $t = 1$. The borrower's expected utility can now be written as

$$\begin{aligned} E U(a_i) &= \{p(a_i)(\Psi X(a_i, G) + \{1 - \Psi\}X(a_i, B))\}(R_f')^2 \\ & \quad - p(a_i)\lambda_1 - V(a_i) - LR_f R_f^{-1}, \end{aligned} \quad (2)$$

where

$$\lambda_1 \equiv (1 - LR_f)(\theta r(a_i | R_l)(R_f R_l)^{-1} + (1 - \theta)r(a_i | R_h)(R_f R_h)^{-1}).$$

In (2), λ_1 is the borrower's (discounted) expected repayment obligation to the bank where $r(a_i | R_j)$ is the loan interest factor charged by the lender' and $LR_f R_f^{-1} = L$ is the present value of the liquidity (equity) the borrower relinquishes by investing in the project. The borrower's decision problem is to **choose** its optimal action a_i to satisfy

$$a_i^* \in \underset{a_i \in \{a_1, a_2\}}{\operatorname{argmax}} E U(a_i).$$

It is straightforward to verify that a_i^* is chosen to yield the borrower the same expected utility it enjoys when it has **sufficient** liquidity to completely self-finance, **i.e.**, the first best. To see this, note that lenders **price** their spot loans to earn zero expected profits in a competitive market. Thus,

$$r(a_i | R_j) = R_f(p(a_i))^{-1} \quad \forall a_i \in \{a_1, a_2\}, R_j \in \{R_l, R_h\}. \quad (4)$$

Using (4) and a little algebra, we obtain

$$E U(a_i) = \{p(a_i)(\Psi X(a_i, G) + \{1 - \Psi\}X(a_i, B))\}(R_f')^{-2} - V(a_i) - R_f^{-1},$$

which is the same as its expected utility with complete self-financing **expressed** in (1). Thus, $a_i^* = a_1$, and the first best is attained.

We assume that **the return** in the **successful state**, regardless of the **chosen action**, always **exceeds the repayment** obligation.

3. Moral hazard and a rationale for loan commitments (no ex post contract enforcement problems)

We have just seen that the absence of moral hazard permits spot credit to be used without welfare depletion. We now assume that the borrower's action choice as well as cash flow realization is unobservable to the lender; the lender can observe success or failure of the project? Initially, we consider a (fulfilled expectations) competitive Nash equilibrium (N.E.) when borrowing is limited to only spot market contracting. However, when forward contracting is permitted, we show that borrowing under a loan commitment, in the absence of credibility issues, dominates the spot-market solution. We first specify a set of parametric restrictions that will narrow down the set of potential Nash equilibria, enabling sharper focus on intuition. Assume for now that a borrower takes a \$1 loan at $t=1$, i.e., it does not use its initial liquidity, which we may assume is consumed immediately after $t=0$.

3.1. Additional features of the model and parametric restrictions

We start out with conditions specifying the profitability of projects.

- (i) $X(a_j, k) - r(a_i | R_l) > 0 \quad \forall a_i, a_j \in \{a_1, a_2\} \quad \forall k \in \{G, B\}$,
- (ii) $X(a_2, k) - r(a_i | R_b) < 0 \quad \forall a_i \in \{a_1, a_2\} \quad \forall k \in \{G, B\}$,
 $X(a_1, B) - r(a_i | R_b) < 0 \quad \forall a_i \in \{a_1, a_2\}$,
- (iii) $X(a_1, G) - r(a_i | R_b) > 0 \quad \forall a_i \in \{a_1, a_2\}$.

The condition (PR-2) indicates that if the riskless spot rate is low, projects will always be undertaken [see (i)]. If the spot rate is high, projects will only be undertaken if a_1 has been chosen and the project's technological quality is good [see (ii) and (iii)].¹⁰

¹⁰At $t=2$, the borrower observes the Mud realization of its project cash flow. Under asymmetric information, however, the lender only observes whether or not the borrower's project was successful, not the actual cash flow. If the lender extends a loan at a given interest rate, then all it knows - or can agree with the borrower upon - is that the return in the successful state exceeds the promised repayment, and is zero in the unsuccessful state. This means that the ex post information set of the borrower is partitioned finer than the bank's. These assumptions imply that ex post payoff-contingent contracts [Bhattacharya (1980)] are precluded. Moreover, given ex post unobservability, the optimal contract between the bank and the borrower is debt [Gale and Hellwig (1985)]. However, our analysis should be viewed as taking a debt contract as given, since we do not address complications arising from the optimal verification strategy possibly being random [Mookherjee and Png (1989)].

¹⁰Note that $(X(a_i, k) - r(a_i | R_b)) < 0$ for some values $a_i \in \{a_1, a_2\}$ and $k \in \{G, B\}$. This also affects the self-financing case because investing in the riskless asset then strictly dominates investing in the project. In our analysis we work with a modified version of (PR-1) which is stated in Appendix A.

The central aspect of our analysis is moral hazard, which exists **because** if the lender assumes that the borrower has undertaken the (**first** best) action a , at $t=0$ and prices the spot **loan** accordingly, the borrower *anticipates* this and chooses a . The following restriction ensures this:

$$\begin{aligned}
 & p(a_2)\{\theta\Psi(X(a_2, G) - r(a_1|R_i)) + \theta(1 - \Psi)(X(a_2, B) - r(a_1|R_i))\}(R_f R_i)^{-1} - V(a_2) \\
 & > p(a_1)\{\theta\Psi(X(a_1, G) - r(a_1|R_i))\}(R_f R_i)^{-1} \\
 & \quad + \theta(1 - \Psi)(X(a_1, B) - r(a_1|R_i))(R_f R_i)^{-1} \\
 & \quad + \Psi(1 - \theta)(X(a_1, G) - r(a_1|R_h))(R_f R_h)^{-1} - V(a_1). \tag{PR-3}
 \end{aligned}$$

The condition (PR-3) says that moral hazard destroys **the** incentive compatibility of the first best contract. The moral hazard exists because we have *risky* debt and limited liability.

Finally, we have two additional parametric restrictions. One says that if the borrower anticipates at $t=0$ that it can only borrow and undertake the project in the high interest state, it would have no incentive to take any action to develop project. That is,

$$\begin{aligned}
 & \Psi(1 - \theta)p(a_i)(X(a_i, G) - r(a_i|R_h))(R_f R_h)^{-1} - V(a_i) < 0 \\
 & \forall a_i \in \{a_1, a_2\}. \tag{PR-4}
 \end{aligned}$$

The **other** restriction is complementary. If the borrower now anticipates at $t=0$ that it can only borrow and undertake the project in the low interest state, it will have an incentive to take at least action a . The restriction is

$$\begin{aligned}
 & p(a_2)\{\theta\Psi(X(a_2, G) - r(a_2|R_i)) + \theta(1 - \Psi)(X(a_2, B) - r(a_2|R_i))\} \\
 & \times (R_f R_i)^{-1} - V(a_2) > 0. \tag{PR-5}
 \end{aligned}$$

We assume that **(PR-1)** through **(PR-5)** hold throughout. It is easy to verify that the set of parameters for which these restrictions hold is **non-empty**.

3.2. The loan market with only spot credit

In Lemma 1 we summarize the Nash equilibria that are attainable if the borrower has **access** to only spot credit.

Lemma 1. *There exists at least one competitive N.E. in the spot credit market. The N.E. yielding the borrower its highest expected utility involves the*

Table 1
Description of states at $t = 1$ and borrower takedown behavior.^a

State	Probability	Borrower decisions	
		Anion a_1 ,	Anion a_2
$\xi_{gt} \equiv (G, R_t)$	$\Psi\theta$	Invest, no LC take down	Invest, no LC take down
$\xi_{gh} \equiv (G, R_h)$	$\Psi[1 - \theta]$	Invest, take down LC	Invest, take down LC (do not invest without LC)
$\xi_{bt} \equiv (B, R_t)$	$[1 - \Psi]\theta$	Invest, no LC take down	Invest, no LC take down
$\xi_{bh} \equiv (B, R_h)$	$[1 - \Psi][1 - \theta]$	Do not invest; commitment seller can also decline to lend under LC	Do not invest

^aLC means loan commitment'.

borrower choosing a_1 , and the lender charging $r(a_2 | R_t)$ for $R_t \in (R_t, R_h)$. In this equilibrium the borrower's expected utility is lower than first best.

This result is intuitive. The borrower's ex ante perception of the competitive spot borrowing rate (at $t = 1$) affects its expected share of the terminal cash flow, and does not induce a choice of the first best action, a_1 , at $t = 0$. The key observation is that the borrower's marginal return to effort is diminishing in the loan interest rate."

3.3. The loan market with loan commitments

Now consider an environment in which forward contracting is permitted. Investors –endowed with initial liquidity R_t^{-1} – can issue loan commitments at $t = 0$ under which they promise to lend at $t = 1$ up to \$1 at a fixed rate of δ with $\delta \in (R_t(p(a_1))^{-1}, R_h(p(a_1))^{-1})$. While this is a fixed rate loan commitment, our analysis extends to variable rate commitments with some rigidity in the commitment rate relative to the borrower's spot borrowing rate. An example is a prime-plus commitment with a fixed add-on. The investor/commitment seller (c.s. henceforth) receives a commitment fee of g at $t = 0$. If state ξ_{gh} occurs, the borrower can draw down under the commitment at $t = 1$. In states ξ_{gt} , ξ_{bt} and ξ_{bh} , the loan commitment is not taken down. Our results in the next section will verify this. Table 1 summarizes the different states and the borrower's takedown and investment behavior in those states.

Theorem 1. Assuming that the c.s. will always honor its commitment, there exists a loan commitment contract that induces the borrower to choose a first best action and yields the commitment seller zero expected profit. Moreover,

¹¹See also Chan and Thakor (1987).

there exist values of the borrower's initial liquidity, L , for which this loan commitment contract strictly Pareto dominates any spot credit market equilibrium (attainable with partial equity *financing*) and produces a *first best level* of expected utility for the borrower.

(The proof of Theorem 1 is available from the authors upon request.)

This result generalizes the results of BTU. Contracting with a loan commitment achieves *first best*, and *accomplishes* this when equity cannot. *Specifically*, the borrower could either use its initial liquidity as equity in *conjunction* with spot borrowing, or use it to *purchase* a loan commitment at $t=0$ which requires a fee of g . Theorem 1 states *that*, for *sufficiently* low levels of initial liquidity, only the loan commitment achieves *first best*. The intuition is that the loan commitment *reduces* the distortionary *effect* of random interest rates by setting the commitment rate, δ , low enough to ensure a marginal return to *effort* that prompts an action choice of a_1 .

To *see* why a loan commitment yields the borrower its *first best* expected utility, we *proceed* as follows. The *c.s.* will set δ just low enough to ensure that the borrower's marginal return to effort is at least as great as the level needed to ensure a choice of a_1 at $t=0$, thereby eliminating the distortionary effect of the loan interest rate. Of course, at this rate, the *c.s.* *suffers* an expected loss on the loan. To recoup, the *c.s.* charges a commitment fee g at $t=0$. The commitment fee has no inantive effect because it is paid '*up-front*' and represents a 'sunk cost' that does not *affect* the borrower's action choice. Partial (inside) equity *financing* with a spot loan is not as *effective* as a loan commitment. Note that a *fixed* rate loan commitment pegs the interest rate at the same level regardless of the spot rate. Thus, it reduces the customer's repayment obligation by different *percentages* in the low and high interest rate states, providing a greater *percentage* reduction in the high interest rate state in which the distortionary *effect* of the loan interest rate is the most severe with spot credit. Partial equity financing, on the other hand, reduces the borrower's repayment obligation *evenly* across both *the* low and the high interest rate states, which is less *efficient*. That is, equity financing is less *effective* in reducing distortions than a loan commitment.

4 Loan commitments with ex *post* contract enforcement *problems*: A *raison d'être* for banks

We have demonstrated that loan commitments represent a powerful contractual solution to a moral hazard problem in the credit market. In this *section*, however, we establish that the *bilateral* commitment contract discussed in section 3 is untenable when contract *enforceability* is considered and loan commitments are issued by individuals. When loan commitments are issued by bank, on the other hand, we show that credibility problems

can **be** resolved and the first best restored. In our organizational solution, banks are large in the **sense** that they are owned by many bankers, they issue many loan commitments, and they are funded by many investors (who become depositors).

4.1. The **contract** enforcement problem

The option-like feature of a loan commitment **implies** that the **c.s.** provides a subsidized loan when the borrower exercises the commitment.¹² This creates an incentive for the **c.s.** to renege on its promise to lend under the commitment. In practice the **c.s.** docs have some leeway in determining whether or not to honor the commitment. In particular, if it can establish that the borrower's financial condition deteriorated materially between the time of issue of the loan commitment and the time of takedown, then it could invoke the 'material adverse change' (MAC) clause and be legally unencumbered from its obligation. Of course, there must be costs for the **c.s.** if it refuses to honor the commitment, **otherwise**, the commitment would never be honored. These costs could be loss of reputation, explicit legal damages, etc. An exorbitantly high cost for not honoring the commitment will guarantee compliance and **trivialize** the contract enforcement problem. However, arbitrarily high penalties will generally not be feasible. We will shortly discuss 'appropriate' penalties.

Under what circumstances is it reasonable to assume, in the context of our model, that the **c.s.** could **costlessly** not lend under the commitment? One obvious circumstance is the occurrence of state ξ_{bh} . In this state, the borrower's project has a negative expected cash flow even if a , had been chosen at $t=0$.¹³ We assume that if the borrower wants to exercise the commitment and the **c.s.** declines to lend in a state other than ξ_{bh} , then a costly but perfect ex post audit can be conducted by the courts to determine **the** borrower's realized project **payoff**.¹⁴ Because a borrower's type realization at $t=1$ is common knowledge, an audit of **the** realized cash flow, conditional on project **success**, will **permit** an exact inference of the borrower's action choice. If the borrower is found to have chosen a , then the **ca.** must pay damages to the borrower. But if a , is detected, the **c.s.** can keep the commitment fee and pay nothing to the borrower. That is, a borrower that chose a , can be interpreted as having a 'materially deteriorated'

¹²See also Campbell (1978) and Thakor, Hong and Greenbaum (1981).

¹³We view the realization of the states ξ_i , $i \in \{gl, gh, bl, bh\}$ as being **specific** to the bank's loan commitment customer. When the loan commitment customer finds itself in state ξ_{bh} , the SPOT riskless rate for all borrowers is R_p . Note that since the k s are (pairwise) independent across borrowers, they will be borrowers who find themselves in state ξ_{bh} even when our bank's commitment customer finds itself in state ξ_{bh} .

¹⁴It is immaterial who bears the audit cost incurred by the court. Assuming that it is borne by the losing party only adds **mom notation**.

financial condition. Note, however, that if the borrower is unsuccessful, its realized cash flow is zero regardless of its type and action choice. Having observed project failure, an audit of the cash flow would be useless since it is common knowledge that the cash flow is zero and non-informative about the agent's action choice.

In states ξ_{gt} and ξ_{bt} , the borrower optimally decides to let the commitment expire unexercised. Thus, the only state relevant for us is ξ_{gh} . If state ξ_{gh} occurs and the **c.s.** reneges, the borrower has two choices. It can either do nothing or take legal action against the **c.s.** The borrower decides on its legal action at $t=2$ after **observing** its cash flow. A borrower who observes project success but had chosen a , at $t=0$ will optimally decide to do nothing since he is worse **off** by suing. Also, a borrower who observes project failure will not sue. In either case, the **c.s.** can keep its revenues. Of course, a borrower who chose a , at $t=0$ and is successful at $t=2$ will want to sue a **c.s.** that reneges in state ξ_{gh} . In this **case**, there are two questions. What will be the likely outcome? And, if the borrower wins, what will be the penalty imposed on the **c.s.**? As stated earlier, contingent on project **success**, a borrower suing in state ξ_{gh} will win if he chose a . The question of the 'appropriate' penalty is more difficult. Therefore, we will consider the most stringent possible penalty: confiscation of the entire net worth of the **c.s.** Given this legal penalty structure, we now consider the viability of three **different types** of **c.s.**'s.

4.2. A loan commitment as a bilateral credit exchange: The non-bank case

This is the case considered in section 3 in which an investor and a borrower contract directly with each other. The difficulty with this arrangement is that the investor could collect the commitment fee and simply **proceed** to consume its cash endowment of R_f^{-1} at $t=0$. The commitment would then not be honored at $t=1$ and no legal **enforcement** mechanism could **remedy** the situation. Thus, this approach is inefficient.

4.3. A loan commitment as a bilateral exchange: The single banker-single borrower case

An alternative to a bilateral investor–borrower contract is the **case** where a single banker **intermediates** between a single investor (hereafter referred to as a depositor) and a single borrower. The advantage of having a banker **intermediate** between a borrower and a depositor is that it can **acquire** funds from a depositor at $t=0$ and **thus prevent** the depositor from consuming its endowment at $t=0$. **Of course**, incentives must be provided to ensure that the bank honors the commitment. Under this arrangement, the banker (now the **c.s.**) **promises** to lend up to $\$1$ should the borrower wish to take such a

loan at $t=1$. The funds to support this commitment are raised through a two-period **certificate** of deposit (CD) **purchased** by a depositor (our original investor).

We now characterize those agents who can become a bank. Potential bankers may or may not be endowed with projects at $t=0$. 'Endowed' bankers have projects (equity) that do not require investment – either capital or labor – and yield a fixed payoff of $S > 0$ at $t=2$. However, the payoff is completely unobservable to all except the banker who owns the project. Thus, this agent can consume this payoff without detection. This can only be prevented if a court of law takes possession of it.¹⁵ In that case, the court can divert S' to some other agent. We assume that $S' \in (0, S)$, and is very small due to high verification and title transfer costs. In our **formal** analysis we put an upper bound on the payoff of the banker's project endowment. That is,

$$S \in (0, \bar{S}), \quad (\text{PR-6})$$

where \bar{S} is defined in the proof of Theorem 2. Bankers without project endowments are observationally indistinguishable at $t=0$ from endowed bankers. Thus, they could mimic these agents. A verification cost of v could be incurred to perfectly distinguish both types. Initially, however, we will assume that they can be distinguished at a cost of $v=0$. However, note that the verification cost v will prevent trivial solutions in which bankers resolve their credibility problem by joining together and building up **sufficient** equity (despite the upper bound on S) such that a specific number of (credible) loan commitments can be sustained. These issues are discussed later.

A **deposit** contract must **be** designed to support the bilateral loan commitment contract between the banker and the borrower. The deposit contract must provide an expected two-period return to the depositor of $(R_f')^2 - 1$. It must also take into account the possibility of the bank renege. **Since** the depositor is not party to the **c.s.** decision to renege, the courts are unlikely to take away as a penalty assets **that** support the depositor's claim. We assume that the depositor's funds are protected by legally binding '**me-first**' rules.

For an individual banker who issues a loan commitment at $t=0$, the deposit contract is as follows. The **c.s.** issues a two-period CD at $t=0$ and raises R_f^{-1} . At $t=0$, the **c.s.** invests in the **riskless** asset, so that it has **\$1** in loanable funds available at $t=1$. At $t=1$, the **c.s.** lends **\$1** under the loan commitment if state ξ_{gh} **occurs** for the borrower. At $t=2$, depositors can only

¹⁵As in costly state verification models [e.g., Gale and Hellwig (1985)], we assume that some assets have values that are difficult to verify. Examples in our context are relatively illiquid assets such as certain types of inventories, some types of office furniture, tangible executive privileges like art objects and plush carpets in offices, etc.

Table 2

Payoffs of depositors, commitment seller and borrower for different states (except ξ_{gh}), all payoffs discounted to $t=0$ (assume borrower chooses a_1).

State	Depositor's payoff	Commitment seller's (c.s.) payoff	Borrower's payoff to m spot borrowing
At $t=1$			
ξ_{ai} At: -2 Project succeeds	$g + [R_f]^{-1}$	$[R_f R_i]^{-1} S$	$\{X(a_1, G) - R_i [p(a_1)]^{-1}\} [R_f R_i]^{-1} - V(a_1) - g$
Project fails			$-V(a_1) - g$
ξ_{bi} Project succeeds	$g + [R_f]^{-1}$	$[R_f R_i]^{-1} S$	$\{X(a_1, B) - R_i [p(a_1)]^{-1}\} [R_f R_i]^{-1} - V(a_1) - g$
Project fails			$-V(a_1) - g$
ξ_{bh} Project succeeds			$-V(a_1) - g$
Project fails	$g + [R_f]^{-1}$	$[R_f R_h]^{-1} S$	$-V(a_1) - g$

be paid $gR_f R_h$ if the project fails. Note that since the commitment fee is invested in the riskless asset at $t=0$, $gR_f R_h$ is its compounded value at $t=2$ if state ξ_{gh} occurs. If states ξ_{gi} , ξ_{bi} or ξ_{bh} occur, or if ξ_{gh} occurs and the c.s. reneges, the loan commitment is not taken down and the c.s. invests its \$1 in the riskless asset at $t=1$.¹⁶ In states ξ_{gi} and ξ_{bi} , the c.s. pays $gR_f R_i + R_i$ to the depositor, whereas in state ξ_{bh} , the c.s. pays $gR_f R_h + R_h$ to the depositor. In state ξ_{gh} , when the c.s. reneges, the c.s. pays the depositor $gR_f R_h + p(a_1)\delta$ in accordance with 'me first' rules. Table 2 summarizes the payoffs to the c.s., the borrower and the depositor at $t=2$ in states ξ_{gi} , ξ_{bi} and ξ_{bh} , and for the different strategies the c.s. could pursue. Table 2a presents this information for state ξ_{gh} . These payoffs are for $a=a_1$; those for $a=a_2$ can be written analogously. In the tables all cash flows are discounted to $t=0$ values.

Having formalized the nature of the bilateral single banker-single borrower loan commitment, we can now analyze equilibrium in the game between the c.s., the borrower and the depositor. In this game the informed agent - the borrower - moves first. We characterize a sequential equilibrium which survives the Grossman and Perry (1986) perfect sequential equilibrium (PSE) refinement. We will call this a competitive PSE with a loan commitment (CPSEL). The interested reader is referred to figs. B.1 and B.2 for descriptions of the extensive form. We now state the following result.

Theorem 2. *With a bilateral loan commitment contract between an individual c.s. and a borrower, the c.s. will renege. Thus, the only CPSEL involves the borrower not accepting the contract at my positive price.*

¹⁶Allowing the c.s. to invest in risky spot loans at $t=1$ does not materially change the results.

Table 2a

Payoffs of depositors, commitment seller and borrower for state $\xi_{g,h}$ and different strategies (all payoffs discounted to $t=0$).

States at $t=2$	Payoff to depositors of commitment seller		Commitment seller's payoff	
Commitment holder	C.s. honors LC	C.s. reneges	C.s. honors LC	C.s. reneges
Project succeeds	$g + \delta [R_f R_h]^{-1}$	$g + p(a_1) \delta [R_f R_h]^{-1}$	$S [R_f R_h]^{-1}$	0
Project fails	g	$g + p(a_1) \delta [R_f R_h]^{-1}$	$S [R_f R_h]^{-1}$	$\{R_h - p(a_1) \delta + S\} [R_f R_h]^{-1}$
States at $t=2$	Commitment holder's payoff			
Commitment holder	C.s. honors LC	C.s. reneges		
Project succeeds	$\{X(a_1, G) - \delta\} \times [R_f R_h]^{-1} - V(a_1) - g$	$\{X(a_1, G) + R_h - R_h [p(a_1)]^{-1} + S' - p(a_1) \delta\} \times [R_f R_h]^{-1} - g - V(a_1)$		
Project fails	$-V(a_1) - g$	$-V(a_1) - g$		

The market with bilateral credit exchange breaks down because **the c.s.** is unable to make a credible promise to lend under the commitment in states in which the borrower wishes to take it down. This happens despite the availability of legal recourse to the borrower and **the** possible penalizing of the **c.s.** for unjustifiable failure to perform. Legal recourse is **ineffective** because the maximum legal penalty is less than the gain to the **c.s.** from reneging. To see why, note that the commitment fee is set at $t=0$ to equal the expected present value of the subsidy to the borrower under the commitment. Thus, once the borrower is in **the** state in which **takedown** is profitable (state $\xi_{g,h}$), the subsidy on the loan **exceeds** the commitment fee. By not **honoring** the commitment – and investing in the **riskless** asset instead – the **c.s.** can gain even if **successful** legal action by the borrower forces it to relinquish all of its wealth. Of course, this rests on S not being too high. We will show that even when S is not high enough to ensure contract enforceability with an individual **c.s.**, it can do so with a bank.

4.4. Loan commitments issued by a bank

The simplest resolution of the contract enforceability problem is for the **c.s.**

to be a bank with N (≥ 2) equityholders (investors), 1 borrower and 1 depositor. With N **sufficiently** large, the bank will honor **its** commitment **since** the value of its lost projects will exceed the gain from renegeing. However, if $v > 0$, this resolution is **inefficient** relative to an alternative we will discuss shortly. The reason is that verification costs – required to distinguish endowed bankers from those not endowed – are borne by the borrower in equilibrium, and having many equityholders per borrower increases the per capita incidence of verification costs.

Consider now a **large bank** that sells commitments to a countable infinity of borrowers. This bank has exactly as many depositors and equityholders as it has borrowers. Thus, the per capita incidence of verification costs will now only be v . Assume, for simplicity, that $v = 0$. **All** borrowers start out being identical at $t = 0$, with each assessing a probability of Ψ of realizing $k = G$. As in Boyd and Prescott (1986), our bank is 'large' in that it has a countable infinity of equityholders, depositors and borrowers, and 'small' in that it has no monopoly power. The latter is achieved by assuming that the fraction of all agents that deals with any bank is **zero**.

When a bank deals with multiple commitment buyers at $t = 0$, the deposit contract negotiated at $t = 0$ must **be** modified to reflect this multiplicity. To ensure comparability with the non-bank case, we keep the spirit of the deposit contract unchanged. That is, it is again a claim to a risky **payoff**. To understand the deposit contract, note that it is no longer convenient to refer to depositors' payoffs in states $\xi_{g,t}$ through $\xi_{\delta,h}$; these states are **borrower-specific** and we have many borrowers. We will, therefore, refer to depositors' payoffs in the high and the low spot rate states. At $t = 1$, if $R = R_t$, **no** borrower takes down its commitment. The bank thus invests all of its deposit funds in the **riskless** asset at R_t . Similar to the non-bank case, depositors are promised a per capita payoff of $gR_f R_t + R_t$. At $t = 1$, if $R = R_h$, borrowers with $k = G$ will take down their **commitments**; the fraction of such borrowers is Ψ . The remaining borrowers let their commitments expire unexercised. The deposit funds made available by such borrowers are **invested** in the **riskless** asset yielding R_h per dollar invested. Thus, if the bank honors all of its exercised commitments, depositors get $\delta + gR_f R_h$ on every commitment borrower whose project is successful and $gR_f R_h$ on **every** commitment borrower whose project fails. On the remaining funds, depositors get $R_h + gR_f R_h$. On a per capita basis, therefore, the depositors' (expected) payoff is $gR_f R_h + p(a_1)\Psi\delta + \{1 - \Psi\}R_h$, conditional on $R = R_h$, whereas the bank's per capita expected payoff is S .

At $t = 0$ then, the expected present value of the payoff to depositors is

$$\theta\{gR_f R_t + R_t\}(R_t R_f)^{-1} + (1 - \theta)\{gR_f R_h + p(a_1)\Psi\delta + (1 - \Psi)R_h\}(R_h R_f)^{-1}.$$

The terms in parentheses with negative exponents are discount factors. We can simplify the above expression and re-write it as

$$g + \theta R_f^{-1} + (1 - \theta) \{ R_h - \Psi(R_h - p(a_1)\delta) \} (R_h R_f)^{-1}.$$

In a competitive loan commitment market, if one assumes that the bank will honor its commitment when the customer **takes** it down, then the usual **no**-arbitrage considerations dictate that the commitment should be priced to satisfy

$$g = \Psi(1 - \theta)p(a_1)(r(a_1 | R_h) - \delta)(R_f R_h)^{-1},$$

where $r(a_1 | R_h) = R_h(p(a_1))^{-1}$. Substituting (6) into (5) and simplifying, we can now see that the depositors' expected payoff at $t=0$ is R_f^{-1} , the amount of deposits raised by the bank.

Before formalizing banks, we will sketch the intuition behind why a bank can help to **restore** credibility. Let N be the number of loan commitment sellers (**equityholders**) in the coalition we call a bank. Let N_r be the number of commitments taken down and $N_r \leq N$, the number of commitments on which the bank reneges. Let u' be the incremental **per** capita gain to the bank from renegeing as opposed to not renegeing. assuming the borrower has chosen a_1 . We can now write

$$u' = \xi_1 - S, \quad \text{where } \xi_1 \equiv \{ (1 - p(a_1))^{N_r} \} N_r N^{-1} (R_h - \delta p(a_1) + S).$$

To understand ξ_1 , note that if the bank **reneges** and escapes legal punishment (this occurs with probability $1 - h(a_1)$, which is the probability that the borrower's project fails), then its contractual obligation to depositors is $\delta p(a_1)$, whereas its gross payoff is $R_h + S$. The probability that no borrower's project will succeed is $(1 - p(a_1))^{N_r}$ and the total expected payoff over the renegeed commitments is $N_r (1 - p(a_1))^{N_r} (R_h - p(a_1)\delta + S)$. Per loan commitment issued then, this expected payoff is given by ξ_1 . If the bank does **renege** on any commitment, its **payoff** is S . Thus, u' gives the per capita difference between the payoffs from renegeing and not renegeing. Now, if the bank is very large ($N \rightarrow \infty$) and reneges on all its commitments, $\lim_{N_r} [1 - p(a_1)]^{N_r} = 0$. Thus, $\lim_{N_r \rightarrow \infty} \xi_1 = 0$, implying $u' = -S$. On the other hand, if it reneges on only one commitment, then $N_r N^{-1} = N^{-1}$, and thus $\lim_{N_r \rightarrow \infty} \xi_1 = 0$. **Once** again, $u' = -S$. This means that, when there is a finite number of renegeed commitments, there is a nonzero probability that the bank will **escape** legal punishment. But, the per capita gains from renegeing **vanish** with increasing bank size. Although for any **finite** N , there will generally **be** an optimal N , we assume that, if the bank reneges, it will renege on all its commitments. This does not **sacrifice** much **since** we focus on an **infinitely** large bank for which the optimal N , is shown later to be zero (**see** Theorem 3). Note, however, that an infinitely large bank is **unnecessary** to establish **credibility**; generally $u' < 0$ for a finite N .

Table 3

Payoffs of depositors, (infinitely large) bank **and** borrower in **different** states and **strategies** (payoffs discounted to $t=0$ for each spot rate **realization**, $R_t \in \{R_l, R_h\}$, with **expectation** taken **across** **success** and failure states at $t=2$, borrower **chooses** a_1).

State	Depositors' per capita expected payoff		Bank's per capita expected payoff	
	At $t=1$	Bank honors LC	Bank reneges	Bank honors LC
$R=R_l$	$[R_l]^{-1} + g$	$[R_l]^{-1} + g$	$S[R_l R_l]^{-1}$	$S[R_l R_l]^{-1}$
$R=R_h$	$g + p(a_1)\Psi\delta$ $\times [R_l R_h]^{-1}$ $+ [1 - \Psi][R_l]^{-1}$	$g + p(a_1)\Psi\delta$ $\times [R_l R_h]^{-1}$ $+ [1 - \Psi][R_l]^{-1}$	$S[R_l R_h]^{-1}$	0
State	Borrower's expected payoff			
		$k = G$		$k - B$
At $t=1$	Bank honors LC	Bank reneges		
$R=R_l$	U_1^1	U_1^1		U_3^1
$R=R_h$	U_1^1 $+ \Psi[R_h - p(a_1)\delta]$	$U_1^1 + (S$ $\times [R_l R_h]^{-1}$		U_4^1

Now suppose $R=R_h$ at $t=1$ and the bank refuses to honor any of the commitments taken down. Consequently, it will lose all of its equity, including the commitment fee revenue, if any commitment holder **successfully** sues. As in the non-bank case, we want depositors to obtain the same (expected) payoff as in the case in which the bank honors its commitments. Thus, the deposit contract stipulates that depositors get a **per** capita payoff of $gR_l R_h + p(a_1)\Psi\delta + \{1 - \Psi\}R_h$ when there is no lending under commitments and $R=R_h$. If a commitment holder successfully sues, this amount must first be paid to depositors with the rest going to the commitment holders.

Thus, the deposit contracts in the bank and the non-bank cases are similar. Table 3 lists the depositors' and the bank's payoffs in different states for alternative bank strategies.

Theorem 3. *There exists a CPSELIC involving banks, each dealing with a countable infinity of borrowers, such that each borrower purchases a loan commitment at $t=0$ and chooses a , and each bank honors every commitment at $t=1$.*

This theorem implies two key points. First, a (large) bank can resolve the contract **enforceability** problem that plagues the bilateral credit transactions.

This is despite the fact that a borrower has the **same** legal recourse when dealing with a bank as it does when dealing with an individual lender. In both cases, the maximum penalty imposed on the lender is the loss of all of its terminal equity. The **difference** between the two **cases** lies in the **effectiveness** of the legal punishment mechanism. The effectiveness increases with the size of the **c.s.** and attains its maximum for an infinitely large bank.

Second, we have a novel economic rationale for a bank. Because bilateral contracts are not credible and the legal system is ineffective in **restoring** appropriate incentives, a **non-organizational**, market-mediated equilibrium fails to exist. This market failure creates an impetus for the emergence of organizations (banks) to intermediate between individual borrowers and lenders (depositors) in a manner that assures credibility.

5. Concluding thoughts

We have taken a close look at **c.s.** incentives to honor its loan commitments. Although contract enforceability **hazard** has been acknowledged in the loan commitments literature, ours is the first paper to analyze its implications. Our principal findings are listed below.

- (i) Loan commitments serve an economic function in an environment characterized by linear preferences and **takedown** uncertainty; in addition they dominate inside equity in resolving moral hazard.
- (ii) A loan commitment can be economically valuable even when its seller's incentive to renege is explicitly allowed for.
- (iii) A new economic rationale is provided for the existence of a bank; an organization like a bank can make credible promises to honor its loan commitments, while an individual lender cannot.

A callous observer might question the centrality of contract **enforceability** because banks renege infrequently. This misses the point, however. Perhaps loan commitments are generally honored **because** they are issued by **banks**.

Since the loan commitment is a put option, an interesting question is whether the borrower could buy a put option directly from a securities exchange.¹¹ Since we could assume that the exchange would never decline to honor its obligation to buy the customer's debt when the latter chose to exercise its option, is it possible to do better with this approach?

Although we have formally analyzed this case and shown that a loan commitment solution dominates that attainable with an exchange-based put

¹¹We thank a referee for suggesting this comparison. The referee also suggested that we could explicitly model the credit quality insurance aspect of a bank loan commitment. Indeed, if the bank is a monitoring specialist whose monitoring affects the probability distribution of k , then $\Pr(k = B)$ would be lower with a bank than with an exchange, strengthening the case for a bank loan commitment.

option, we will only outline the intuition here. We can assume that the exchange-based put option permits the buyer of the option to sell its debt (a promise to repay the exchange at $t=2$) to the exchange at a fixed price of \$1. The face value of this debt can be set to ensure that the option buyer chooses the **first** best action as with the bank loan commitment contract. Now, the intuition is that the willingness of the exchange to always honor its contract with the option buyer allows the buyer to put its debt to the exchange even in the state in which the buyer's project has negative NPV, given the high interest rate realization. In this state the bank is able to renege with impunity by invoking the MAC clause in its contract. Since the exchange is compensated ex ante by the option buyer for the dissipation involved in investing in the negative NPV state, it is the option buyer who is worse off.

The basic point is that an exchange-based solution can dominate a bank solution if the credibility of the bank in honoring its contract is suspect. However, when the credibility problem is resolved, the greater flexibility of a bank loan commitment (provided by the MAC clause) means that the bank solution dominates the exchange-based solution.

Banks in our model lend through loan commitments and also directly in the spot market. Moreover, they borrow long and lend both long and short, suggesting that an augmented version of the model could potentially address maturity mismatching and asset-liability mix issues. Hence, these 'conventional' issues could be analyzed in a framework in which contracts may not be honored and there is an endogenous reason for the bank to **exist**.¹⁸

Appendix A Derivation of no-arbitrage term **structure relationship**

Consider two **different** investment strategies that yield identical payoffs with identical risk. The first strategy involves investing \$1 at $t=0$ in a **two-year pure discount** bond with price P_0^2 . The payoff at $t=2$ will be $(R'_f)^2$. The second strategy involves buying two **securities** at $t=0$. One is a **one-year pure discount** bond that pays \$1 at $t=1$; we buy $(R'_f)^2/R_h$ units of this bond. This purchase will cost $((R'_f)^2/R_h)R_f^{-1}$ at $t=0$. The other security we buy is a call option. This option entitles us to buy $(R'_f)^2$ units of a one-year pure discount bond at $t=1$ with each unit of this bond paying \$1 at $t=2$; the exercise price of this option is $(R'_f)^2/R_h$. Because investors are risk neutral and the option will be exercised at $t=1$ only if $R=R_f$, the price of this call option at $t=0$ should be

$$P_0^c = (\theta/R_f)((R'_f)^2 R_f^{-1} - (R'_f)^2 R_h^{-1}).$$

¹⁸We could also model **seller reputation in contract enforcement**, in which case banks may be shown to value **reputation** more than an individual c.s.

It can be seen that **both** investment strategies yield sure payoffs of $(R'_f)^2$ at $t=2$ and hence, to prevent arbitrage, they should cost the same at $t=0$. Equating the investment in the first strategy (\$1) to that in the **second** strategy $(P_0^e + (R'_f)^2(R_h R_f)^{-1})$ gives us the desired **term** structure relationship.

Modified version of (PR-1)

$$\begin{aligned}
 & p(a_1)\{\theta\Psi(X(a_1, G) - r(a_1|R_l))(R_f R_l)^{-1} + \theta(1 - \Psi) \\
 & \quad \times (X(a_1|B) - r(a_1|R_l))(R_f R_l)^{-1} \\
 & \quad + (1 - \theta)\Psi(X(a_1, G) - r(a_1|R_h))(R_f R_h)^{-1}\} - V(a_1) \\
 & > p(a_2)\{\theta\Psi(X(a_2, G) - r(a_2|R_l)) + \theta(1 - \Psi) \\
 & \quad \times (X(a_2|B) - r(a_2|R_l))(R_f R_l)^{-1} - V(a_2). \tag{PR-1'}
 \end{aligned}$$

Appendix B. Proofs of the results

Proof of Lemma 1. We will first prove that the allocation described in the lemma is indeed a **N.E.** A necessary condition for a **N.E.** is

$$\begin{aligned}
 & p(a_2) \sum_{\xi_i \in \Xi} \Pr(\xi = \xi_i)(X(a_2, k(\xi_i)) - r(a_2|R(\xi_i))) - V(a_2) \\
 & \geq p(a_1) \sum_{\xi_i \in \Xi} \Pr(\xi = \xi_i)(X(a_1, k(\xi_i)) - r(a_2|R(\xi_i))) - V(a_1) \tag{B.1}
 \end{aligned}$$

where $k(\xi_i)$ is the realization of k corresponding to the realization ξ_i and $R(\xi_i)$ is the realization of R corresponding to the realization ξ_i ; $r(a_1|R_f)$ is defined in (4). Comparing (B.1) with (PR-2) now reveals (B.1) to be weaker. Thus, this equilibrium is **supported** by the bank believing the borrower has **chosen** a , and the borrower believing that the bank will extend **credit** at $r(a_2|R_l)$ if $R=R_l$ and at $r(a_2|R_h)$ if $R=R_h$. Both beliefs are **rationalized** in equilibrium. Moreover, the bank earns zero expected profit and, **with these** beliefs, no other contract makes the borrower strictly better off. All that remains to be shown is that the borrower's expected utility is non-negative. Using (PR-3), the borrower's expected utility is

$$\begin{aligned}
 & p(a_2)\{\theta\Psi(X(a_2, G) - r(a_2|R_l)) + \theta(1 - \Psi)(X(a_2, B) - r(a_2|R_l))\} \\
 & \quad \times (R_f R_l)^{-1} - V(a_2). \tag{B.2}
 \end{aligned}$$

From (PR-5). (B.2) is strictly positive. Thus, this is a N.E. From (PR-1') it follows that this is a lower expected utility than first best.

Note that any N.E. involving the bank lending at $r(a_2|R_j)$ if $R=R_j$ for $j \in \{h, l\}$ and rationing otherwise is strictly Pareto dominated by the N.E. above. Thus, we need not consider those N.E. Also, 'mixed action' contracts, involving $r(a_i|R_l)$ if $R=R_l$ and $r(a_j|R_h)$ if $R=R_h$, with $a_i \neq a_j$, can never be N.E. Thus, the only candidates for N.E. that we **need** to examine are those involving (i) the bank charging $r(a_1|R_l)$ if $R=R_l$ and rationing otherwise and (ii) the bank charging $r(a_1|R_h)$ if $R=R_h$ and rationing otherwise. The reason why these are the only two remaining candidates is twofold. First, (PR-2) precludes a N.E. in which the bank charges $r(a_1|R_l)$ if $R=R_l$ and $r(a_1|R_h)$ if $R=R_h$. And second, an allocation involving the bank charging $r(a_1|R_l)$ if $R=R_h$ or $r(a_1|R_h)$ if $R=R_l$ can never be a N.E. in the spot credit market because it would entail the bank making either a positive expected profit or a negative expected profit. Now suppose the bank charges $r(a_1|R_l)$ if $R=R_l$ and rations otherwise. **Since** the borrower correctly anticipates this in equilibrium, it will assess its expected utility from choosing a , as

$$p(a_1)\{\theta\Psi(X(a_1, G) - r(a_1|R_l)) + \theta(1 - \Psi)(X(a_1, B) - r(a_1|R_l))\} \\ \times (R_l R_l)^{-1} - V(a_1), \quad (\text{B.3})$$

and its expected utility from choosing a , as

$$p(a_2)\{\theta\Psi(X(a_2, G) - r(a_1|R_l)) + \theta(1 - \Psi)(X(a_2, B) - r(a_1|R_l))\} \\ \times (R_l R_l)^{-1} - V(a_2). \quad (\text{B.4})$$

Note now that (PR-3) implies that $X(a_2, G) - r(a_1|R_h) < 0$, whereas $X(a_1, G) - r(a_1|R_h) > 0$. Moreover,

$$X(a_1, B) - r(a_1|R_h) > X(a_2, B) - r(a_1|R_h).$$

Using these observations with (PR-2) implies that (B.4) strictly **exceeds** (B.3). **Thus**, the bank's belief about the borrower's action choice is not **rationalized** and this is not a N.E. Next suppose the bank charges $r(a_1|R_h)$ if $R=R_h$ and rations **otherwise**. The borrower's **expected** utility from choosing a , is

$$p(a_1)\{(1 - \theta)\Psi(X(a_1, G) - r(a_1|R_h)) + (1 - \theta)(1 - \Psi)(X(a_1, B) - r(a_1|R_h))\} \\ \times [R_l R_h]^{-1} - V(a_1). \quad (\text{B.5})$$

But from (PR-3), $X(a_1, B) - r(a_1 | R_h) < 0$. Now from (PR-4), it follows that the expression in (B.5) is strictly negative. Hence, this is not a **N.E.** either. \square

Proof of Theorem 2. We first define $\bar{S} \equiv (1 - p(a_1))(r(a_1 | R_h) - \delta)$, where δ follows from (PR-3) if substituted for $r(a_1 | R_h)$ and solved as an equality (see the proof of Theorem 1),

$$\delta \equiv \{\lambda_2 - [V(a_1) - V(a_2)]R_f\}[\Psi\{1 - \theta\}\{p(a_1) - p(a_2)\}[R_h]^{-1}]^{-1}$$

and

$$\begin{aligned} \lambda_2 \equiv & p(a_1)\{\Psi\theta X(a_1, G)[R_l]^{-1} + \Psi[1 - \theta]X(a_1, G)[R_h]^{-1} \\ & + \theta[1 - \Psi]X(a_1, B)[R_l]^{-1}\} \\ & - [p(a_1) - p(a_2)]\theta r(a_1 | R_l)[R_l]^{-1} \\ & - p(a_2)\{\Psi\theta X(a_2, G)[R_l]^{-1} + \Psi[1 - \theta]X(a_2, G)[R_h]^{-1} \\ & + \theta[1 - \Psi]X(a_2, B)[R_l]^{-1}\}. \end{aligned}$$

In this and subsequent proofs, we **utilize** the extensive **form** of the commitment game (see figs. B.1 and B.2). We now analyze the depositors. **Because** the CD contract makes their **payoff** independent of the bank's strategy, they do not care about the **bank's** strategy. The only important factor is the depositor's belief about the borrower's action choice. Suppose $\Pr(a = a_1) = \mu_d$, $\Pr(a = a_2) = 1 - \mu_d$. That is, μ_d is the probability depositors attach to a choice of a , and $1 - \mu_d$ is the probability attached to a . We will return to these beliefs later on in the **proof**.

C.S.'s **metastrategy** (conditional on borrower buying **loan commitment**)

This is relevant only when a borrower comes for a loan commitment. The probability that the borrower will accept the loan commitment is irrelevant for the commitment seller. The commitment seller's beliefs about the borrower's action are $\Pr(a = a_1) = \mu_c$, $\Pr(a = a_2) = 1 - \mu_c$. Since the commitment seller is the last to move, its **perfect** metastrategy, m , is

$$m = \begin{cases} h & \text{if } \mu_c > D_3, \\ n \text{ or } h & \text{if } \mu_c = D_3, \\ n & \text{if } \mu_c < D_3, \end{cases} \tag{B.6}$$

when

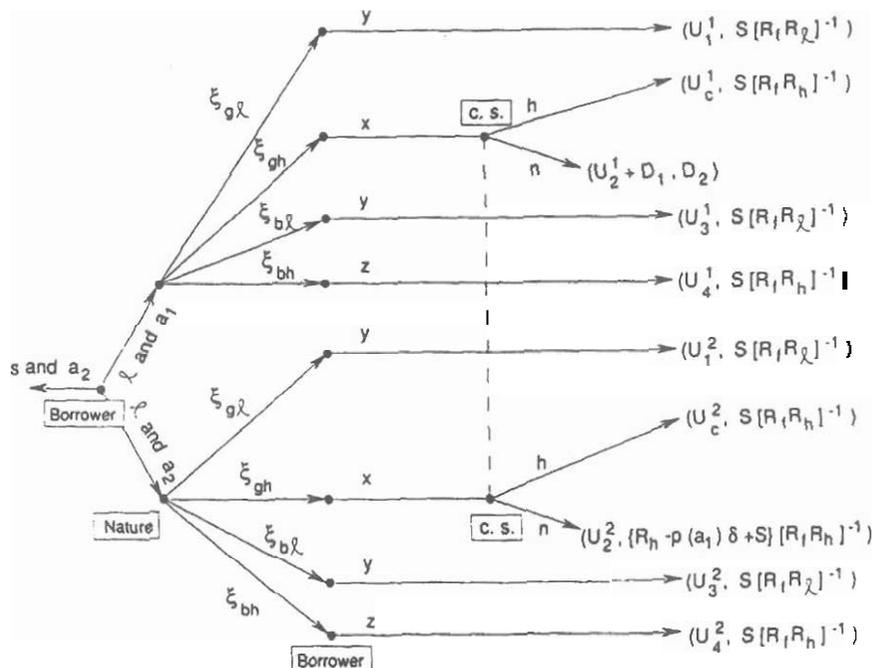


Fig B.1. Extensive form for commitment game.

Notes for fig. B.1

- Nature is a **passive** player.
- The borrower's **decision** at $t=0$: 'l' (purchase loan **commitment**) and 's' (plan to **borrow** in spot market at $t=1$).
- The borrower's **decisions** at $t=1$: 'x' (take down loan **commitment**), 'y' (**don't take** down loan commitment but borrow in **spot** market), and 'z' (**avoid** both commitment **takedown** and **spot** borrowing **i.e.**, don't invest).
- Terminal **nodes** have **payoffs** (discounted to $t=0$ values): first term in **payoff** pair is **borrower's expected** utility over terminal ($t=2$) **wealth** and the **second** term is the **c.s. expected (terminal) wealth**. Both **expectations** are assessed at $t=1$, after ξ has been **realised** but prior to the **realization** of the **borrower's project cash flow**. $U_i^j =$ **borrower's expected** utility with anion a_i and state realization ξ_j , **assuming** commitment is not taken down: $U_i^c =$ **borrower's expected** utility if commitment is taken down.
- Pnny whose turn it is to move is indicated in each rectangular **box**
- **Definition of terms:**

$$D_1 \equiv \{p(a_1)R_h + p(a_1)S' - p(a_1)^2\delta\}(R_f R_h)^{-1}$$

$$D_2 \equiv \{(1 - p(a_1))(R_h - p(a_1)\delta + S)\}(R_f R_h)^{-1}$$

For $t \in \{1, 2\}$:

$$U_1^j = \{p(a_1)X(a_i, G) - R_l p(a_1)(p(a_1))^{-1}\}(R_f R_l)^{-1} - V(a_i) - g,$$

$$U_0^c = \{p(a_1)X(a_i, G) - p(a_1)\delta\}(R_f R_h)^{-1} - V(a_i) - g,$$

$$U_3^j = \{p(a_1)X(a_i, B) - p(a_1)R_l(p(a_1))^{-1}\}(R_f R_l)^{-1} - V(a_i) - g,$$

$$U_4^j = -V(a_i) - g,$$

$$U_2^j = \{p(a_1)X(a_1, G) - R_h\}(R_f R_h)^{-1} - V(a_1) - g,$$

$$U_2^z = -V(a_2) - g.$$

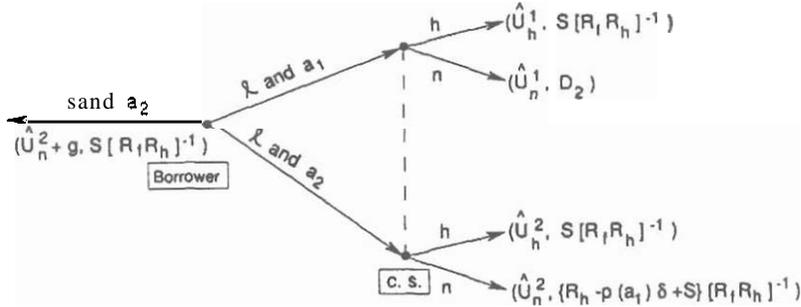


Fig. B.2. 'Condensed' extensive form for commitment game.

Notes for fig. B.2

- Extensive form drawn for state ξ_{ph} (only state in which **c.s. metastrategy** relevant).
- Payoff pair in terminal nodes have borrower's **expected utility first** and **c.s. expected payoff second**. Expectations of borrower's utility are assessed at $t=0$ and are across ξ realizations, i.e., prior to borrower's action choice. Expectations of the c.s. payoff are assessed at $t=1$, conditional on ξ_{ph} , since c.s. knows ξ when deciding whether to honor commitment.

■ *Definitions of terms:*

$$\begin{aligned}
 \hat{U}_h^1 &= \theta \Psi U_1^1 + \Psi(1-\theta)U_2^1 + (1-\Psi)\theta U_3^1 + (1-\Psi)(1-\theta)U_4^1 \\
 &= \theta(\Psi p(a_1)X(a_1, G) + (1-\Psi)p(a_1)X(a_1, B) - R_1)(R_f R_h)^{-1}, \\
 &\quad + (1-\theta)\{\Psi p(a_1)X(a_1, G) - \Psi p(a_1)\delta\}(R_f R_h)^{-1} - V(a_1) - g, \\
 \hat{U}_n^1 &= \hat{U}_h^1 - \{\Psi(1-\theta)p(a_1)(\{1-p(a_1)\}(r(a_1|R_h) - \delta) - S)\}(R_f R_h)^{-1}, \\
 \hat{U}_h^2 &= \theta \Psi U_1^2 + \Psi(1-\theta)U_2^2 + (1-\Psi)\theta U_3^2 + (1-\Psi)(1-\theta)U_4^2 \\
 &= \theta\{\Psi p(a_2)X(a_2, G) + (1-\Psi)p(a_2)X(a_2, B) - R_2 p(a_2)(p(a_1))^{-1}\}(R_f R_h)^{-1} \\
 &\quad + (1-\theta)\{\Psi p(a_2)X(a_2, G) - \Psi p(a_2)\delta\}(R_f R_h)^{-1} - V(a_2) - g, \\
 \hat{U}_n^2 &= \hat{U}_h^2 - \Psi(1-\theta)p(a_2)(r(a_1|R_h) - \delta).
 \end{aligned}$$

$$D_3 \equiv (R_h - p(a_1)\delta)(p(a_1)\{R_h - p(a_1)\delta + S\})^{-1}.$$

Now, because $S \in (S', \bar{S})$, it is easy to verify that $D_3 > 1$. Thus, $m=n$ is the optimal strategy of the **c.s.**

Borrower's metastrategy

We consider the metastrategy of the borrower when it has the choice of accepting or rejecting the loan commitment contract. Since n is a dominant strategy for the **c.s.**, the borrower's only consistent belief is $\mu_b \equiv \Pr(m=n) = 1$ and $1 - \mu_b = 0$. Now, $\hat{U}_n^2 + g > \hat{U}_n^1$ and $\hat{U}_n^2 > \hat{U}_n^1$ [follows from (PR-2)]. Thus, the borrower's metastrategy is to choose s given p . Finally, since the **c.s.** does not borrow at $t=0$, depositors' metastrategy is irrelevant \square

Proof of Theorem 3. We will consider a bank with $N = \infty$. Because the CD contract makes the depositors' payoff independent of the bank's strategy,

their beliefs about the strategy are irrelevant. Only their beliefs about each borrower's action choice matter. As in the previous proof, we designate their beliefs about that action choice by the probability μ_d . We will argue later on that the only consistent belief for depositors is to assign $\mu_d = 1$.

Bank's metastrategy

This is relevant only when the borrower comes for a loan commitment. The probability that the borrower will accept the loan commitment is irrelevant for the bank. Since the bank is the last to move, its perfect metastrategy is given by

$$m = \begin{cases} h & \text{if } \mu_b > D_4 \{D_4 + S\}^{-1}, \\ n \text{ or } h & \text{if } \mu_b = D_4 \{D_4 + S\}^{-1}, \\ n & \text{if } \mu_b < D_4 \{D_4 + S\}^{-1}, \end{cases} \quad (\text{B.7})$$

where μ_b is the probability the bank assigns to the borrower having chosen a_1 , and $D_4 \equiv \Psi \{R_h - p(a_1)\delta\}$. We now discuss the bank's consistent belief at its information set. It is useful to begin by noting that $a = a_1$ is a *dominant* strategy for the borrower which accepts a loan commitment, since $U_h^1 > U_h^2$. Thus, there is no consistent belief of the bank (or the depositors) that puts positive weight on $a = a_2$. On the other hand, if the bank believes that the borrower chose $a = a_1$, then according to its metastrategy it must decide to honor the commitment, and this decision indeed makes it optimal for the borrower to have chosen $a = a_1$. This implies that the only consistent belief at the bank's information set is $\mu_b = 1$. Thus, the bank's optimal choice is h . The borrower – who is the informed player in this game – has a metastrategy which is reduced to a usual strategy, given the fact that the borrower has already **accepted** the loan commitment. This is because if the borrower does not accept the loan commitment, the bank has no metastrategy. Now, **since** $D_4 \{D_4 + S\}^{-1} < 1$, we **need** μ_b to **exceed** a number less than 1 in order for $m = h$. This is certainly true since the only consistent belief of the bank is $\mu_b = 1$.

Note that the depositors' only consistent belief is $\mu_d = 1$, using arguments similar to **those** for the bank. Thus, they will supply deposits.

Generalized borrower metastrategy

This is the borrower's metastrategy **when** it can accept or **reject** the loan commitment contract. Let the probability η be the borrower's belief that the bank will honor the loan commitment. A **necessary** condition for the borrower to purchase the loan commitment is

$$\eta \geq (\hat{O}_n^2 + g - \hat{O}_n^1)(\hat{O}_h^1 - \hat{O}_n^1)^{-1}. \quad (\text{B.8})$$

We also need to preclude the possibility that the borrower will accept the loan commitment at $t=0$ and then choose $\mathbf{a}_.$ (Our earlier incentive compatibility conditions do not help here since they assume $\eta = 1$.) Thus, we need

$$\eta \geq (\hat{O}_n^2 - \hat{O}_n^1)(\hat{O}_h^1 - \hat{O}_h^2 - \hat{O}_n^1 + \hat{O}_n^2)^{-1}. \quad (\text{B.9})$$

Now, if (B.8) holds and (B.9) does not, then the borrower will **accept** the loan commitment and choose $\mathbf{a}_.$ So, we want (B.9) to hold automatically when (B.8) holds. In that **case**, a borrower that chooses a loan commitment will always choose $\mathbf{a}_.$ That is, we need

$$(\hat{O}_n^2 - \hat{O}_n^1)(\hat{O}_h^1 - \hat{O}_h^2 - \hat{O}_n^1 + \hat{O}_n^2)^{-1} < (\hat{O}_n^2 + g - \hat{O}_n^1)(\hat{O}_h^1 - \hat{O}_n^1)^{-1}. \quad (\text{B.10})$$

It is easy to **see** that, if (B.10) holds, then η can be a probability. This is because $\hat{O}_h^1 > \hat{O}_n^2 + g$, implying that

$$(\hat{O}_n^2 + g - \hat{O}_n^1)(\hat{O}_h^1 - \hat{O}_n^1)^{-1} < 1.$$

As long as (B.10) holds, it is possible to have $\eta \in (0, 1]$ such that the borrower buys a loan commitment at $t=0$ and chooses $\mathbf{a}_.$ However, we have **argued** that once the bank issues a commitment, its dominant strategy, in conjunction with its own **consistent** belief about \mathbf{a}_i , is to honor the commitment. Thus, the only consistent belief is for the borrower to set $\eta = 1$. Rearrange (B.10) as

$$\{\hat{O}_h^1 - \hat{O}_h^2 + [\hat{O}_n^2 - \hat{O}_n^1]\}\{\hat{O}_h^2 - \hat{O}_n^2\}^{-1} > \{\hat{O}_n^2 - \hat{O}_n^1\}\{g\}^{-1}. \quad (\text{B.10}')$$

Now, **since** $\hat{O}_h^1 > \hat{O}_h^2$ and $\hat{O}_n^2 > \hat{O}_n^1$ (**see** the proof of Theorem 2), (B.10) holds if $\hat{O}_h^2 - \hat{O}_n^2 < g$. But this is certainly true since

$$g = \{\Psi(1-\theta)p(a_1)(r(a_1|R_h) - \delta)(R_f R_h)\}^{-1}$$

[see (6)] and

$$\hat{O}_h^2 - \hat{O}_n^2 = \{\Psi(1-\theta)p(a_2)(r(a_1|R_h) - \delta)(R_f R_h)\}^{-1}.$$

Finally, a comment on strategies **off** the equilibrium path. A **borrower** with $\mathbf{a} - \mathbf{a}_.$ will find it ex post **efficient** to sue a bank that reneges. Moreover, the courts will **prematurely** liquidate the **bank's projects** since the **borrower**

collects $\varepsilon > 0$ per project, i.e., it is in the borrower's best interest to force liquidation of the bank's equityholders' projects. \square

References

- Berkovich, E. and S.I. Greenbaum, 1989**, The loan commitment as an optimal financing contract, BRC WP no. 130 (Northwestern University, IL).
- Bhattacharyh S., 1980**, Nondissipative signalling structure and dividend policy. *Quarterly Journal of Economics* 95, 1-24.
- Boot, A., A.V. Thakor and C.F. Udell, 1987**, Competition, risk neutrality and loan commitments, *Journal of Banking and Finance* 11, no. 3, 449-472.
- Boyd, J. and E. Prescott, 1986**, Financial intermediary-coalitions, *Journal of Economic Theory* 38, no. 2, 211-232.
- Campbell, T. 1978**, A model of the market for lines of credit. *Journal of Finance* 33, 231-244.
- Chan, Y. and A.V. Thakor, 1987**, Collateral and competitive equilibria with moral hazard and private information, *Journal of Finance* 42, no. 2, 345-363.
- Diamond, D., 1984**, Financial intermediation and delegated monitoring *Review of Economic Studies* 51, 393-415.
- Gale, D. and M. Hellwig, 1985**, Incentive compatible debt contracts: The one period problem. *Review of Economic Studies* 52, no. 171, 647-663.
- Grossman, S. and M. Perry, 1986**, Perfect sequential equilibrium. *Journal of Economic Theory* 39, 97-119.
- Kanatas, G., 1987**, Commercial paper, bank reserve requirements, and the informational role of loan commitments, *Journal of Banking and Finance* 11, no. 3, 425-448.
- Klein, B. and K.B. Leffler, 1981**, The role of market forces in assuring contractual performance. *Journal of Political Economy* 89, no. 4, 615-641.
- Konakayama, A. T. Mitsui and S. Watanabe, 1986**, Efficient contracting with reliance and a damage measure, *Rand Journal of Economics* 17, no. 3, 450-457.
- Mason, J., 1979**, *Financial management of commercial banks (Warren, Gorham and Lamont, Boston/New York)*.
- Melnick, A. and S. Plaut, 1986**, The economics of loan commitment contracts: Credit pricing and utilization, *Journal of Banking and Finance* 10, no. 2, 267-280.
- Milton, M.H. and A.V. Thakor, 1985**, Moral hazard and information sharing: A model of financial information gathering agencies, *Journal of Finance* 40, no. 5, 1403-1422.
- Mookherjee, D. and I. P'ng, 1989**, Optimal auditing insurance and redistribution. *The Quarterly Journal of Economics* 104, 399-416.
- Ramakrishnan, R.T.S. and A.V. Thakor, 1984**, Information reliability and a theory of financial intermediation, *Review of Economic Studies* 51, 415-432.
- Rockafeller, R., 1972**, *Convex analysis (Princeton University Press, Princeton, NJ)*.
- Rogerson, W.P., 1984**, Efficient reliance and damage measures for breach of contract, *Rand Journal of Economics* 15, no. 1, 39-53.
- Schweizer, U. 1989**, Litigation and settlement under two-sided incomplete information, *Review of Economic Studies* 56, 163-178.
- Shavell, S., 1980**, Damage measures for breach of contract, *Bell Journal of Economics* 11, 466-499.
- Shavell, S., 1984**, The design of contracts and remedies for breach, *Quarterly Journal of Economics* 99, 122-148.
- Thakor, A.V., 1989**, Competitive equilibrium with type convergence in an asymmetrically informed market, *Review of Financial Studies* 2, no. 1, 49-71.
- Thakor, A.V., H. Hong and S.I. Greenbaum, 1981**, Bank loan commitments and interest rate volatility, *Journal of Banking and Finance* 5, 497-510.
- Thakor, A.V. and G.F. Udell, 1987**, An economic rationale for the pricing structure of bank loan commitments, *Journal of Banking and Finance* 11, 271-289.
- Williamson, O.E. 1975**, *Markets and hierarchies: Analysis and anti-trust implications: A study in the economics of internal organization (Free Press, New York)*.