

COMPETITION, RISK NEUTRALITY AND LOAN COMMITMENTS

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We rationalize fixed rate loan commitments (forward credit contracting with options) in a competitive credit market with universal risk neutrality. Future interest rates are random, but there are no transactions costs. Borrowers finance projects with bank loans and choose ex post unobservable actions that affect project payoffs. Credit contract design by the bank is the outcome of a (non-cooperative) Nash game between the bank and the borrower. The initial formal analysis is basically in two steps. First, we show that the only spot credit market Nash equilibria that exist are inefficient in the sense that they result in welfare losses for borrowers due to the bank's informational handicap. Second, we show that loan commitments, because of their ability to weaken the link between the offering bank's expected profit and the loan interest rate, enable the complete elimination of informationally induced welfare losses and thus produce an outcome that strictly Pareto dominates any spot market equilibrium. Perhaps our most surprising result is that, if the borrower has some initial liquidity, it is better for the borrower to use it now to pay a commitment fee and buy a loan commitment that entitles it to borrow in the future rather than save it for use as inside equity in conjunction with spot borrowing.

1. Introduction

The purpose of this paper is to provide an economic rationale for bank loan commitments in a competitive credit market – where both spot and forward contracting are possible – characterized by universal risk neutrality. Existing explanations of loan commitments assume either risk aversion or transactions costs.¹ For example, Thakor and Udell (1987) assume that

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¹In an interesting paper that models both sides of the loan commitment market, Campbell (1978) uses a general utility function for the borrower. In his model, though, a demand for loan commitments can only arise if borrowers are risk averse. James (1981) assumes both borrowers and banks are risk neutral, but does not formally justify why commitments exist. Rather, his objective is to explain a borrower's choice between a commitment fee and a compensating balance. For another paper on the subject, see Berkovitch and Greenbaum (1986). In that paper too, loan commitments are rationalized in a risk neutral world with asymmetric information.

borrowers are risk averse,² whereas Melnick and Plaut (1986) assume lenders are risk averse. And the transactions costs argument appears repeatedly in popular justifications of loan commitments [see Mason (1979), for example].

Neither risk aversion nor transactions costs, in our opinion, provide a completely satisfactory answer to the puzzle of why bank loan commitments are so prevalent.³ Assuming risk aversion is limiting for two reasons. First, it seems to lead quite directly to loan commitment demand purely on the well known grounds of risk sharing. Second, it does not correspond well with reality where hedging/diversification opportunities for banks and borrowers could be better risk dissipation mechanisms than loan commitments. Transactions costs, on the other hand, may well be the motivating factor for certain prearranged credit lines. However, they fail to explain the existence of a wide variety of loan commitment contracts. For example, if the principal goal is to minimize the borrower's transactions costs, why should *fixed rate* loan commitment contracts be observed? A floating rate commitment that provides the borrower a guaranteed source of funds would do just as well.⁴

We provide an information-based, *equilibrium* rationale for loan commitment demand in a *universally risk neutral, competitive* credit market devoid of frictions such as transactions costs.⁵ The model is as follows. At an initial

The model has borrowers taking first period loans to finance projects that require incremental second period financing. The amount of second period financing required is unknown at the outset but is revealed (only) to the borrower at the start of the second period. Now, the borrower has no incentive to invest in the project in the second period when its total (first and second period) repayment obligation exceeds its *maximum possible* terminal payoff. But the bank does want investment to be continued in these states. Thus, there is an ex post inefficiency. It is shown that a loan commitment can restore incentive compatibility through a 'split' pricing structure that accommodates a lower second period repayment obligation for the borrower.

²Although Thakor and Udell (1987) rationalize the existence of loan commitments in their framework, their main objective is not to explain why loan commitments exist, but to explain the informational role of specific characteristics of loan commitment contracts.

³Currently, outstanding loan commitments at U.S. commercial banks amount to billions of dollars, and bank participation in this activity is rapidly growing [see Greenbaum, Soss and Thakor (1985)].

⁴A more serious problem with assuming transactions costs in a model of a competitive equilibrium under asymmetric information is that they introduce 'fixed cost' elements and hence increasing returns to scale in the supply functions of banks. This interferes with establishing the existence of a competitive (non-cooperative) equilibrium [see, for example, Wilson (1977)].

⁵Greenbaum, Kanatas and Vennezia (1986), in research done independently of ours, provide the insight that asymmetric information is central in rationalizing loan commitments in a risk neutral milieu. In their model, loan commitments have the added advantage of allowing the bank to plan ahead and thus acquire funds at a lower cost than it could in the (future) spot market. In our model, loan commitments provide no such service. Another important distinction is that a loan commitment in Greenbaum, Kanatas and Vennezia improves the bank's information extraction capability – in a revelation principle context – whereas it reduces distortionary effort supply incentives in our model. Thus, the two papers highlight two distinct functions of loan commitments under imperfect information. Another paper that explains why risk neutral borrowers may purchase loan commitments is Kanatas (1987). However, Kanatas predicts that loan commitments are purchased explicitly to back up commercial paper, whereas our paper predicts a more general use of commitments.

point in time, a risk neutral borrower can approach a risk neutral bank for a fixed rate loan commitment that guarantees funds availability the next period. Alternatively, it can wait until the next period and borrow in the spot market at the prevailing spot rate. Interest rates are random. The borrower knows at the initial point in time that it will need funds next period to invest in a one-period project that will become available then. The project's payoff is random at the time of investment, but the borrower can take some action *prior* to investing in the project that can affect the payoff distribution. We view this as 'developmental activity' that precedes the actual project investment and the subsequent market introduction of the product obtained as an output from the project. Examples are R&D, pre-product introduction advertising, promotional campaigns, test marketing, etcetera. The borrower's action choice is unobservable to the bank. Thus, the bank does not know the borrower's payoff distribution – but the borrower does – when it lends to it. Given competition, the bank's problem is to design credit contracts that maximize the borrower's expected utility subject to the constraint that the bank at least breaks even. We model this problem as a non-cooperative (Nash) game between the competitive bank and the borrower.

With this setup we establish, under plausible conditions, that if the borrower is restricted to spot borrowing, there are two possibilities. Either a (Nash) equilibrium does not exist or if it exists, it is inefficient. The inefficiency manifests itself in the borrower choosing an action lesser than the first best. The reason for this inefficiency is that interest rates have a distortionary effect on the supply of productive inputs,⁶ and the higher the interest rate the greater is the distortion in the borrower's action away from the first best. Because there are states of nature in which the borrower's spot interest rate is relatively high, the borrower chooses a lower-than-first-best action in anticipation of these adverse states. This creates a natural economic incentive for a (fixed rate) loan commitment. With such a contract the bank can set the borrowing rate low enough to ensure that the borrower chooses a first best action, thereby eliminating any welfare distortions linked to interest rates. Of course, this rate will usually be so low that the bank will suffer a loss on the loan itself. To recoup this loss, the bank can charge a commitment fee upfront. The key is that this commitment fee is paid initially and thus becomes a 'sunk cost' for the borrower, with no impact on the action choice. We show that such an arrangement strictly Pareto dominates spot contracts.

In this analysis we assume that the borrower borrows the *same* amount in the spot market as it does under the loan commitment. However, the assumption that the borrower has sufficient initial liquidity to pay the commitment fee implies that this liquidity could be carried over for a period.

⁶See also Stiglitz and Weiss (1983).

It could then be used as an equity input by the borrower to reduce its spot borrowing relative to its borrowing under the commitment. It is well recognized that the moral hazard-related distortions caused by debt can be reduced by increasing the borrower's equity input. Surprisingly, *we find that it is better for the borrower to use its initial liquidity to pay the commitment fee and purchase a loan commitment rather than save it for use as equity in conjunction with spot borrowing.*

The rest of this paper is arranged as follows. Section 2 contains a formal description of the basic model and the (spot market) competitive equilibrium which is obtained in the first best (full information) case. Section 3 has the spot market competitive equilibrium when the bank is unable to observe the borrower's action choice. Section 4 presents the analysis that establishes the optimality of a fixed rate loan commitment in this setting. The implications of borrower equity are examined in this section. Section 5 concludes.

2. The basic model and the full information solution

We consider a perfectly competitive credit market in which banks compete for both deposits and loans. In addition, universal risk neutrality is assumed. This implies that (i) the bank depositors receive an expected return equal to the risk free rate, and (ii) the bank earns zero expected profit. For simplicity, and because it sacrifices no generality here, we assume complete deposit insurance, so that the riskless rate is the bank's deposit funding cost. Throughout the paper, the supply of deposits is taken to be perfectly elastic at the spot riskless rate.

At an initial point in time ($t=0$), the borrower knows that it needs funds next period (at $t=1$) to invest in a one-period project that will become available then. The project requires a one dollar investment which is assumed to be financed by a bank loan. At the time of investment ($t=1$), the project's payoff is random but the payoff distribution is known to the borrower. In particular, we assume that the project's payoff, realized at $t=2$, has a 'two spike distribution'. That is, the return on the project in the 'good' state is some positive number and in the 'bad' state it is zero. At $t=0$, that is prior to investing in the project, the borrower can undertake one of two actions, a_1 or a_2 , with $a_1 > a_2 > 0$. The action choice affects the payoff distribution in two ways. First, a higher action increases the success probability, $p(a_i) \in (0, 1)$, of the project. Second, the payoff of the project in the good state, $X(a_i)$, is positively affected by a higher action. These effects imply $p(a_1) > p(a_2)$ and $X(a_1) > X(a_2) > 0$. Furthermore, the action a_1 is 'better' than the action a_2 in the sense that the expected utility of the borrower, if it self-finances, is greater than a_1 than with a_2 . The action a_i should be viewed as a developmental activity that precedes the actual project investment, as discussed in the Introduction. Undertaking the action is costly

to the borrower. The costs are $V(a_i)$, with $V(a_1) > V(a_2) > 0$. We assume that doing nothing is always feasible for the borrower. That is, even though we have defined the feasible action space for the borrower as $\{a_1, a_2\}$ – and will continue to use this feasible set in our formal analysis – we allow the borrower an action choice from $\{a_1, a_2, 0\}$. If $a=0$ is chosen, then $p(a)=0$, $X(a)=0$ and $V(a)=0$. The reason for working with the action space $\{a_1, a_2\}$ is that we will consistently assume that, if an equilibrium exists, then the borrower's reservation utility of zero (which results from choosing $a=0$) is always exceeded by the equilibrium utility. Thus, $a=0$ will never be an optimal action and little is lost by notationally dropping its availability.

We assume that at $t=1$, the riskless spot interest rate can take a value R_l with probability θ , and R_h with probability $1-\theta$, with $R_h > R_l > 1$. (Interest rates in this paper are really *interest factors*, i.e., one plus the interest rate.) The realization of the riskless spot interest rate has a direct impact on the borrower's net payoff in that it affects the loan interest rate, $r(a_i | R_j)$, charged by the bank. The loan interest rate is written as $r(a_i | R_j)$ to indicate that it depends on the realization of the riskless spot interest rate, $R_j \in \{R_l, R_h\}$, and also on the bank's beliefs about the borrower's action choice, $a_i \in \{a_1, a_2\}$. (These beliefs trivially coincide with the true action choice when a_i is ex post observable to the bank.) It is assumed that the loan interest rate is the only credit instrument available to the bank.⁷ Also, we assume taxes are zero. We discuss taxes in section 4.

Moral hazard potentially exists since the action a_i of the borrower is unobservable to the bank, although in this section we shall assume that the bank can freely observe borrower action choices. Thus, the bank generally does not know the borrower's payoff distribution when it lends to it. Note that this moral hazard is different from the moral hazard in the standard principal-agent model in the sense that the action choice of the borrower in our model *precedes* the contract choice of the bank. In game-theoretic terminology,⁸ the informed agent (borrower) moves first. Moreover, in the case of asymmetric information, we also assume that, although the bank can observe whether or not a borrower's project was successful, it cannot observe the actual project payoff. If the bank extends a loan at a given interest rate, then all that it knows (or can agree with the borrower upon) is that, given the borrower's optimal (unobservable) action choice in response to the offered loan contract, the return in the successful state exceeds the promised repayment. That is, the ex post information set of the borrower is partitioned finer than that of the bank. Taken in conjunction with the assumptions that the loan interest rate is the only spot contracting instrument available and that the borrower has limited liability protection, this assumption implies

⁷Thus, we ignore other – potentially important – credit instruments like collateral [see Besanko and Thakor (1987b) for an analysis of the incentive effects of collateral].

⁸See, for example, Stiglitz and Weiss (1984).

that ex post payoff-contingent contracts of the Bhattacharya (1980) type are precluded. Moreover, given the ex post payoff unobservability assumption, the analyses of Diamond (1984), Gale and Hellwig (1985), and Townsend (1979) can be used to show that the optimal contract between the bank and the borrower is a pure debt contract.⁹

We will now establish that when the bank observes the action of the borrower (symmetric information), the first best allocation is attainable. A *first best allocation* is defined as a credit contract that gives the borrower exactly the same expected utility it would enjoy if it *self-financed* the project and optimally selected its action. Given any action $a_i \in \{a_1, a_2\}$, the borrower's expected utility from self-financing is

$$p(a_i)X(a_i) - V(a_i) - R_f,$$

where R_f is (one plus) the current riskfree interest rate. Since we assume an initial \$1 investment, R_f is the (compounded) future value of the initial investment. Because the credit market is competitive, banks will compete with each other to offer borrowers the most attractive contracts. Thus, in a competitive equilibrium, borrower utilities will be maximized, subject to the constraint that banks at least break even. This is in the spirit of Jaffee and Russell (1976) and Besanko and Thakor (1987a,b). In Assumption (A.1) below we formalize the earlier statement that the action a_1 is 'better' than the action a_2 in the sense that the expected utility of the borrower, if it self-finances, is greater with a_1 than with a_2 .

$$p(a_1)X(a_1) - V(a_1) > p(a_2)X(a_2) - V(a_2). \quad (\text{A.1})$$

Given symmetric information, the bank can unambiguously determine the loan interest rate $r(a_i | R_j)$, $i \in \{1, 2\}$, $j \in \{l, h\}$, that guarantees zero expected profit. The loan interest rate is such that the expected interest receipts equal the cost of deposits which, in turn, is equal to the realized riskless rate. This gives

$$p(a_i)r(a_i | R_j) = R_j \Rightarrow r(a_i | R_j) = \frac{R_j}{p(a_i)}, \quad i \in \{1, 2\}, j \in \{l, h\}. \quad (1)$$

⁹Basically, one would require that none of the ex post return is observable to the bank – the borrower can expropriate it for its own consumption without effective bank verification – so that an equity contract is infeasible. But since the bank can observe whether the project succeeded or not, it can impose a sufficiently large penalty on the borrower in case there is default following project success. If this penalty is large enough, the borrower will indeed repay the loan, conditional on project success. Such a penalty will be infeasible when the project is unsuccessful because the borrower has no funds with which to pay the penalty.

The borrower chooses its optimal action at $t=0$ knowing that the bank can observe its action choice, and offer a credit contract predicated upon that action choice. Thus, the borrower determines its action as follows:

$$a \in \operatorname{argmax}_{a \in \{a_1, a_2\}} \{ \theta p(a)[X(a) - r(a | R_l)] + [1 - \theta]p(a)[X(a) - r(a | R_h)] - V(a) \}. \quad (2)$$

Substituting (1) and (2) indicates that a_1 will be optimally chosen if

$$\begin{aligned} p(a_1)X(a_1) - \theta R_l - [1 - \theta]R_h - V(a_1) \\ > p(a_2)X(a_2) - \theta R_l - [1 - \theta]R_h - V(a_2). \end{aligned}$$

Given Assumption (A.1), the above inequality always holds. This shows that symmetric information permits attainment of the first best allocation.

Before proceeding with the asymmetric information case, we will state some general assumptions which will ease our computational burden in the asymmetric information case by facilitating focus on a limited set of reasonable spot market equilibria. These assumptions are

- (i) $X(a_2) - r(a_i | R_h) \leq 0, a_i \in \{a_1, a_2\}$,
- (ii) $X(a_2) - r(a_i | R_l) \geq 0, a_i \in \{a_1, a_2\}$,
- (iii) $X(a_1) - r(a_i | R_j) \geq 0, a_i \in \{a_1, a_2\}$ and $R_j \in \{R_l, R_h\}$.

(A.2.i) implies that borrowers will never invest at $t=1$ if they choose action a_2 at $t=0$ and the high interest R_h is realized. This is assumed to hold even if they get a contract based on the first best action a_1 . (A.2.ii-iii) imply that in all other cases, given an action choice at $t=0$, the borrowers will invest at $t=1$. We also make the following additional assumption:

$$[1 - \theta]p(a_i)[X(a_i) - r(a_i | R_h)] - V(a_i) < 0, a_i \in \{a_1, a_2\}. \quad (A.3)$$

(A.3) implies that it is never optimal for the borrower to undertake any positive action at $t=0$ if he knows that it is only possible for him to get the project financed in the bad ($R=R_h$) state. We now turn to an examination of the asymmetric information case.

3. The spot market competitive equilibrium under asymmetric information

In section 2 we presented the full information equilibrium. We now return to the general model formulation in which the bank cannot observe the borrower's action and is not able to write ex post payoff-contingent contracts. In this case, the bank's informational handicap may be welfare-

distorting. More specifically, a borrower, noting the unobservability of its action choice, might optimally decide to choose the low action a_2 . In anticipation of this, the bank will adapt its credit contract. Consequently, in the resulting (Nash) equilibrium, any welfare loss will be fully borne by the borrower. It is easy to see that lack of observability of borrower action by the bank will be welfare-distorting if

$$\begin{aligned}
 & \max \{0, \theta \max \{0, p(a_2)[X(a_2) - r(a_1 | R_1)]\} \\
 & \quad + [1 - \theta] \max \{0, p(a_2)[X(a_2) - r(a_1 | R_h)]\} - V(a_2)\} \\
 & > \max \{0, \theta \max \{0, p(a_1)[X(a_1) - r(a_1 | R_1)]\} \\
 & \quad + [1 - \theta] \max \{0, p(a_1)[X(a_1) - r(a_1 | R_h)]\} - V(a_1)\}. \quad (3)
 \end{aligned}$$

We assume (3) holds. Basically, (3) says that the full information credit contract is not incentive compatible when the bank cannot observe borrower actions *ex post*. Anticipation of a first best contract always induces the borrower to choose a_2 , a lower-than-first-best action. Note that this moral hazard problem exists despite borrower (agent) risk neutrality. The standard result of principal-agent models that a first best can be obtained with agent risk neutrality [see, for example, Harris and Raviv (1979)] implicitly assumes that *limited liability* is not a concern (either because the agent has no limited liability protection or because debt is riskless). *We have both limited liability and risky debt*. Combining (3) with (A.2) yields the following assumption about parameter values which guarantees that (3) will hold, given our earlier parametric assumptions.

$$\begin{aligned}
 & \theta p(a_2)[X(a_2) - r(a_1 | R_1)] - V(a_2) \\
 & > \theta p(a_1)[X(a_1) - r(a_1 | R_1)] + [1 - \theta]p(a_1)[X(a_1) - r(a_1 | R_h)] - V(a_1). \quad (A.4)
 \end{aligned}$$

(A.4) implies that the bank cannot profitably offer the first best loan contracts $r(a_1 | R_j)$, $R_j \in \{R_1, R_h\}$. Therefore, we have to look for second best equilibria. Our first proposition is based on an examination of the entire range of possibilities in order to find the set of feasible Nash equilibria in the spot credit market.

Proposition 1. The only two possible Nash equilibria in the spot credit market are

- (i) *the bank lends at $r(a_2 | R_1)$ if $R = R_1$ and rations credit if $R = R_h$,*
- (ii) *the bank lends at $r(a_2 | R_1)$ if $R = R_1$ and at $r(a_2 | R_h)$ if $R = R_h$.*

There are welfare losses (relative to first best) in both equilibria.

Proof. We will first prove that the allocations described above are indeed Nash equilibria.

(i) Suppose the bank lends at $r(a_2 | R_1)$ if $R = R_1$, and rations completely if $R = R_h$. This is a Nash equilibrium if the borrowers (who correctly anticipate the bank's policy in equilibrium) indeed choose action a_2 . This is the case if the following condition holds:

$$\theta p(a_2)[X(a_2) - r(a_2 | R_1)] - V(a_2) > \theta p(a_1)[X(a_1) - r(a_2 | R_1)] - V(a_1). \quad (4)$$

A comparison of (4) with (A.4) shows that (4) is a weaker condition than (A.4).¹⁰ Hence, we have proved the existence of this Nash equilibrium.

(ii) Alternatively, the bank might offer $r(a_2 | R_1)$ and $r(a_2 | R_h)$ if R is R_1 and R_h , respectively. This is a Nash equilibrium [use (A.2)] if

$$\begin{aligned} & \theta p(a_2)[X(a_2) - r(a_2 | R_1)] - V(a_2) \\ & > \theta p(a_1)[X(a_1) - r(a_2 | R_1)] + [1 - \theta]p(a_1)[X(a_1) - r(a_2 | R_h)] - V(a_1). \end{aligned} \quad (5)$$

Again, comparing (5) with (A.4) shows that (5) is a weaker condition than (A.4).¹¹ So we have also proved the existence of this Nash equilibrium.

These two Nash equilibria are inefficient (second best). Both involve the distortionary action choice a_2 . Moreover, in the first equilibrium, rationing also occurs. This is an even more serious welfare distortion. We now show that no other Nash equilibrium exists. This part of the proof involves an exhaustive examination of all possible candidates for Nash equilibrium.

- (a) The bank offers $r(a_1 | R_1)$ if $R = R_1$ and $r(a_1 | R_h)$ if $R = R_h$. This candidate equilibrium is directly ruled out by Assumption (A.4).
- (b) The bank offers $r(a_2 | R_h)$ if $R = R_h$ and rations if $R = R_1$. This will never be a Nash equilibrium. To see this, look at Assumption (A.2). One can see there that the action a_2 together with the occurrence of the $R = R_h$ state implies that investing at $t = 1$ provides the borrower with negative utility. Thus, the proposed contract violates the individual rationality constraint.
- (c) The bank offers $r(a_1 | R_1)$ if $R = R_1$, and rations if $R = R_h$. Using (A.2), we see that this is not a Nash equilibrium if $\theta p(a_2)[X(a_2) - r(a_1 | R_1)] - V(a_2) >$

¹⁰In the appendix, it is shown that (4) is weaker than (A.4).

¹¹See the appendix.

$\theta p(a_1)[X(a_1) - r(a_1 | R_1)] - V(a_1)$. We can compare the above inequality with (A.4) to see that it always holds. Hence, this is not a Nash equilibrium.

- (d) The bank offers $r(a_1 | R_h)$ if $R = R_h$, and rations if $R = R_l$. This is not a Nash equilibrium if $[1 - \theta]p(a_1)[X(a_1) - r(a_1 | R_h)] - V(a_1) < [1 - \theta]p(a_2)[X(a_2) - r(a_1 | R_h)] - V(a_2)$. In addition, the left-hand side of this inequality should be positive for a Nash equilibrium; otherwise, the borrower would be better off under autarky. By (A.3), however, the left-hand side is negative. Hence, the contract offered by the bank cannot be a Nash equilibrium.
- (e) *Mixed action contracts.* Any credit contract that involves $r(a_i | R_l)$ if $R = R_l$ and $r(a_j | R_h)$ if $R = R_h$, with $i \in \{1, 2\}$, $j \in \{1, 2\}$ and $i \neq j$, can clearly never be a Nash equilibrium.

This exhausts the list of possible candidates for Nash equilibria and completes the proof. Q.E.D.

The reason why the efficient action ($a = a_1$) is unattainable is that the competitive spot borrowing rate for the borrower in the high interest rate state (and possibly also the low interest rate state) is so high that the borrower's *net* payoff (the project return less the repayment obligation) is too low to induce a choice of $a = a_1$. The borrower thus chooses $a = a_2$. The key observation here is that an increase in the loan interest rate reduces the marginal return to effort for the borrower, an incentive effect that manifests itself in the borrower lowering effort supply.¹² This distortionary incentive effect of the spot interest rate creates a natural economic incentive for a (fixed rate) loan commitment. This is analyzed next.

4. Loan commitments and Pareto efficiency

In this section we wish to establish that a loan commitment¹³ can eliminate the second best distortions inherent in spot lending. The idea is that loan commitments can reduce the dampening effect that interest rates have on the supply of productive inputs such as effort. Our intuition is as follows. With a (fixed rate) loan commitment, the bank can set the loan interest rate so low that the borrower's action choice problem mirrors its

¹²For a similar observation, see Chan and Thakor (1987). An increase in the loan interest rate has other distortionary effects as well, particularly those related to investment choice. See, for instance, Stiglitz and Weiss (1981, 1983).

¹³A fixed rate loan commitment contract is defined as a promise by the bank to lend up to a certain amount at or during a prespecified time at a fixed rate of interest. Essentially, the bank sells the customer a put option that contractually ties the bank to make a future loan but gives the customer the option of taking or not taking it [see Thakor (1982) and Thakor, Hong and Greenbaum (1981)].

choice problem with self-financing. This will result in the borrower choosing a first best action even in a Nash equilibrium with ex post informational deficiencies. The borrowing rate under the loan commitment in this case will generally be so low that the bank will suffer a loss on the loan itself. To recover this loss, the banks can charge a commitment fee upfront.¹⁴ The key is that the commitment fee is paid initially and thus becomes a state-independent 'sunk cost' for the borrowers with no impact on the action choice. The analysis below will show that this arrangement not only Pareto dominates spot contracts, but even provides a first best resolution of moral hazard. Throughout this analysis we assume that the loan commitment contract must be honored by the bank and continue to assume that there are no taxes. We argue later on that introducing taxes will only increase the attractiveness of a loan commitment.

Our analysis in this section proceeds in two parts. Initially, we analyze loan commitments with the assumption that the borrower puts up no equity of its own and borrows from the bank the entire amount of financing needed for the project. That is, any liquidity the borrower has available at the outset is invested in the commitment fee. (The borrower's initial liquidity is assumed limited, so that the commitment fee completely exhausts it.) We then allow the borrower the choice of replacing the loan commitment with a spot loan combined with an equity input. That is, instead of investing its initial liquidity in the commitment fee, the borrower can use it as its equity input to the project and hence reduce its bank borrowing by that amount. We provide an explicit comparison of these two alternatives and prove formally that loan commitments always Pareto dominate.

4.1. Loan commitments with no borrower equity

The forward credit market – involving loan commitments – in our model works as follows. At $t=0$ the borrower approaches a bank for a fixed rate loan commitment that guarantees funds availability at $t=1$. The loan commitment contract consists of a commitment fee g that must be paid at $t=0$ and a precommitted loan interest rate δ (one plus the loan interest rate) >0 that applies to the borrower's (risky) loan taken at $t=1$. The loan interest is chosen to be low enough to guarantee that the borrower chooses a first best action. We assume that such a δ is less than R_1 , so that the loan commitment is always exercised.

¹⁴Because it is not that important here, we suppress the question of where the borrower obtains the funds for paying the commitment fee. Little generality is lost by assuming that the borrower's initial ($t=0$) wealth endowment accommodates the commitment fee but is insufficient to permit self-financing. We do, however, analyze in this section the borrower's choice between the loan commitment and *partly* self-financing a spot loan.

Proposition 2. *There exists a loan commitment contract that induces the borrower to choose the first best action. Moreover, the (forward credit market) equilibrium resulting from this contract offer strictly Pareto dominates any spot credit market equilibrium and produces a first best level of expected utility for the borrower.*

Proof. We first establish that the loan commitment contract is incentive compatible. Note that incentive compatibility requires that

$$p(a_1)[X(a_1) - \delta] - V(a_1) > p(a_2)[X(a_2) - \delta] - V(a_2).$$

Rearranging this inequality gives us

$$p(a_1)X(a_1) - p(a_2)X(a_2) - V(a_1) + V(a_2) > \delta[p(a_1) - p(a_2)]. \quad (6)$$

Given (A.1), the incentive compatibility condition (6) clearly holds for all δ sufficiently small.¹⁵ Having determined a loan commitment interest rate $\delta \in (0, r(a_1 | R_1))$ such that (6) holds, the bank will choose a commitment fee g as follows:

$$g = \frac{p(a_1)[\theta r(a_1 | R_1) + [1 - \theta]r(a_1 | R_b) - \delta]}{[R_f]^2}, \quad (7)$$

where R_f (one plus the current riskless rate) represents the bank's discount rate. The commitment fee g is determined such that it exactly compensates the bank for the loss it suffers on the loan taken down under the loan commitment. Note that $p(a_1)[\theta r(a_1 | R_1) + [1 - \theta]r(a_1 | R_b)]$ is the total expected interest receipt based on the spot market interest rate, while $p(a_1)\delta$ is the expected receipt under the loan commitment. The commitment fee compensates the bank for the difference between these two. Discounting is necessary because the commitment fee is paid up front ($t=0$), while the interest payments accrue to the bank at the end of the second period. We now determine the borrower's expected utility under the loan commitment.

¹⁵In principle, there is nothing in our model to disallow negative loan interest rates, i.e., δ can be less than 1. This is because the loan commitment is an *option*, and we have assumed that the bank's precommitment to honor the terms of this option contract is *binding*. That is, the borrower may decide not to exercise the commitment option but the bank *must* lend if the borrower exercises. (In the next section we consider the bank's incentive to not honor the commitment.) In this case, the bank does not care about the loan interest rate as long as the commitment fee is large enough to ensure at least zero expected profit.

If institutional considerations disallow $\delta \leq 1$, then we must assume that, under self-financing, the borrower surplus resulting from a choice of a_1 as opposed to a choice of a_2 is large enough (this is simply a plausible restriction on exogenous parameter values) to ensure that (6) holds even with $\delta > 1$.

This expected utility is

$$p(a_1)[X(a_1) - \delta] - V(a_1) - R_f^2 g. \quad (8)$$

Combining (7) and (8) and then rearranging gives us

$$\theta p(a_1)[X(a_1) - r(a_1 | R_l)] + [1 - \theta]p(a_1)[X(a_1) - r(a_1 | R_h)] - V(a_1). \quad (9)$$

The borrower's expected utility as stated in (9) is exactly equal to the borrower's expected utility in the full information solution in section 2. Hence, we have established that the introduction of a loan commitment leads to the first best equilibrium. Clearly, this equilibrium strictly Pareto dominates *any* spot credit market equilibrium since all spot equilibria that exist involve welfare losses. Q.E.D.

Perhaps the most important insight that emerges from this proposition is that a fixed rate loan commitment can be useful even though its *direct* value to the borrower as an insurance policy against stochastic shifts in future interest rates is zero. In our model, the borrower is risk neutral and hence does not care about being insured against a random borrowing rate. The value of a loan commitment lies in its ability to (at least partially) decouple a bank's expected profit on the loan to the borrower from the loan interest rate, thereby eliminating interest rate-related distortions.

4.2. Loans combined with equity versus loan commitments with no equity

The loan commitment contract we have analyzed involves the payment of an initial commitment fee. Moreover, we have assumed that the bank fully finances the required project investment, which equals \$1. One may argue, however, that allowing the borrower to have sufficient initial liquidity to pay the commitment fee means that the borrower could, as an alternative to the loan commitment, avail of spot borrowing in conjunction with an equity input equal to its initial liquidity. This would reduce the amount it would have to borrow and hence provide an alternative mechanism for coping with moral hazard.¹⁶ In this subsection we compare the loan commitment outcome with the bank loan cum borrower equity outcome.

Define $\Omega \in (0, 1)$ as the proportion of the investment that the borrower self-finances. Given the \$1 required investment, Ω can also be defined as the dollar-amount of equity invested in the project by the borrower. The remaining investment, $\$(1 - \Omega)$, is financed by a spot bank loan. To resolve the moral hazard problem in this case, one should choose Ω such that the

¹⁶We thank Michael Brennan for suggesting to us that this possibility should be examined.

following condition is met (note that we take $R_f = \theta R_1 + [1 - \theta]R_h$):

$$\begin{aligned} & \Omega\{p(a_1)X(a_1) - \theta R_1 - [1 - \theta]R_h - V(a_1)\} \\ & + [1 - \Omega]\{\theta p(a_1)[X(a_1) - r(a_1 | R_1)] \\ & + [1 - \theta]p(a_1)[X(a_1) - r(a_1 | R_h)] - V(a_1)\} \\ & \geq \max \left\{ \begin{aligned} & \left[\begin{aligned} & \Omega\{p(a_2)X(a_2) - \theta R_1 - [1 - \theta]R_h - V(a_2)\} \\ & + [1 - \Omega]\{\theta p(a_2)[X(a_2) - r(a_1 | R_1)] \\ & + [1 - \theta]p(a_2)[X(a_2) - r(a_1 | R_h)] - V(a_2)\} \end{aligned} \right], \\ & \left[\begin{aligned} & \Omega\{\theta p(a_2)X(a_2) - \theta R_1 - V(a_2)\} \\ & + [1 - \Omega]\{\theta p(a_2)[X(a_2) - r(a_1 | R_1)] - V(a_2)\} \end{aligned} \right] \end{aligned} \right\} \quad (10) \end{aligned}$$

The right-hand side of the inequality (10) allows for the possibility that, with the lower action choice a_2 , it might be optimal for the borrower *not* to undertake the investment if the spot riskless rate turns out to be R_h . As a matter of fact, the assumptions in section 2 imply that, given action a_2 , the investment will *not* be undertaken in the R_h state. To see this, note that [use (1) and (A.2.i)], $p(a_2)X(a_2) - \theta R_1 - [1 - \theta]R_h - V(a_2) < \theta p(a_2)X(a_2) - \theta R_1 - V(a_2)$ and $X(a_2) - r(a_1 | R_h) < 0$ [use (A.2.i)]. Use these results to rewrite (10) as

$$\begin{aligned} & \Omega\{p(a_1)X(a_1) - \theta R_1 - [1 - \theta]R_h - V(a_1)\} \\ & + [1 - \Omega]\{\theta p(a_1)[X(a_1) - r(a_1 | R_1)] \\ & + [1 - \theta]p(a_1)[X(a_1) - r(a_1 | R_h)] - V(a_1)\} \\ & \geq \Omega\{\theta p(a_2)X(a_2) - \theta R_1 - V(a_2)\} + [1 - \Omega]\{\theta p(a_2)[X(a_2) - r(a_1 | R_1)] - V(a_2)\}. \end{aligned} \quad (11)$$

Now rewrite (11) to get the following explicit restriction on Ω ,

$$\begin{aligned} & -V(a_1) + V(a_2) + p(a_1)X(a_1) - \theta p(a_2)X(a_2) \\ & - \{\theta p(a_1)r(a_1 | R_1) + [1 - \theta]p(a_1)r(a_1 | R_h)\} \\ & + \theta p(a_2)r(a_1 | R_1) \\ & \geq \Omega\{[1 - \theta]R_h - \theta p(a_1)r(a_1 | R_1) - (1 - \theta)p(a_1)r(a_1 | R_h) + \theta p(a_2)r(a_1 | R_1)\}. \end{aligned} \quad (12)$$

Next, using the fact that $R_h \equiv p(a_1)r(a_1 | R_h)$, we can express (12) as

$$\begin{aligned} & V(a_1) - V(a_2) - p(a_1)X(a_1) + \theta p(a_2)X(a_2) - \theta p(a_2)r(a_1 | R_1) \\ & \quad + \theta p(a_1)r(a_1 | R_1) + [1 - \theta]p(a_1)r(a_1 | R_h) \\ & \leq \Omega \{ \theta r(a_1 | R_1) [p(a_1) - p(a_2)] \}, \end{aligned}$$

which implies

$$\Omega \geq \frac{V(a_1) - V(a_2) - p(a_1) \{ X(a_1) - \theta r(a_1 | R_1) - [1 - \theta]r(a_1 | R_h) \} + p(a_2)\theta [X(a_2) - r(a_1 | R_1)]}{\theta r(a_1 | R_1) [p(a_1) - p(a_2)]}. \quad (13)$$

Define the right-hand side of (13) as M . Note that the feasibility restriction on Ω requires that it should be positive. Combining this restriction with (13) yields

$$\Omega \geq \max \{0, M\}. \quad (14)$$

The right-hand side of (13) specifies the *minimum* level of self-financing (or the minimum proportion of the equity input) necessary and sufficient to overcome the moral hazard problem. Note that the denominator of the right-hand side of (13) is obviously positive. Moreover, the numerator is also strictly positive. This latter observation follows from (A.4). To see this, rewrite (A.4) as

$$\begin{aligned} & V(a_1) - V(a_2) - p(a_1) \{ X(a_1) - \theta r(a_1 | R_1) - [1 - \theta]r(a_1 | R_h) \} \\ & \quad + p(a_2)\theta [X(a_2) - r(a_1 | R_1)] > 0. \end{aligned} \quad (A.4')$$

The left-hand side of (A.4') is identical to the numerator of the right-hand side of (13). Hence, we have shown that Ω is strictly positive. This implies that given (13), we can dispense with (14).

The correspondence between (13) and (A.4) should not be surprising. A violation of (A.4) would mean that there is *no* moral hazard even with complete bank financing. Consequently, the minimum level of self-financing required to resolve moral hazard is zero, a condition that also follows directly from (13).

With these preliminaries, we can now establish that a loan commitment is the dominant alternative. The main idea in our analysis is as follows. If the funds necessary for the commitment fee are less than the funds needed for the

equity input for the proportional self-financing of the project – such that in both cases moral hazard is resolved – then the loan commitment contract with full bank-loan financing Pareto dominates the partial self-financing, spot loan option. So, we want to show that

$$\Omega^* > gR_f, \quad (15)$$

where the star denotes an optimal value. Note that we multiply the commitment fee by an interest factor because the commitment fee is paid at $t=0$, while the self-financing Ω^* takes place at $t=1$. Recall from (7) that g is defined as a function of δ . The optimal value for δ is the one that satisfies (6). That is,

$$g = p(a_1)[\theta r(a_1 | R_1) + [1 - \theta]r(a_1 | R_h) - \delta][R_f]^{-2} \quad (16)$$

and

$$\delta = [p(a_1)X(a_1) - p(a_2)X(a_2) - V(a_1) + V(a_2)][p(a_1) - p(a_2)]^{-1}, \quad (17)$$

assuming $\delta \in (0, r(a_1 | R_1))$.

We can now derive the central result of our paper.

Proposition 3. The loan commitment contract strictly Pareto dominates a spot loan with borrower equity.

Proof. We need to show that (15) holds, with g and δ given by (16) and (17) respectively. Note first that Ω^* is obtained with an equality in (13). Now combining (16) and (17) gives us

$$gR_f = p(a_1)\{[p(a_1) - p(a_2)]\zeta - \tau\}\{R_f[p(a_1) - p(a_2)]\}^{-1}, \quad \text{where} \quad (18)$$

$$\zeta \equiv \theta r(a_1 | a_1) + [1 - \theta]r(a_1 | R_h),$$

$$\tau \equiv p(a_1)X(a_1) - p(a_2)X(a_2) - V(a_1) + V(a_2).$$

Next, we note that since $r(a_i | R_j) = R_j/p(a_i)$ for $i = \{1, 2\}$, $j \in \{1, h\}$, and $R_f = \theta R_1 + [1 - \theta]R_h$, we have

$$R_f/p(a_1) = \theta r(a_1 | R_1) + [1 - \theta]r(a_1 | R_h). \quad (19)$$

Substituting for $R_f/p(a_1)$ from (19) into (18) yields

$$gR_f = \{[p(a_1) - p(a_2)]\zeta - \tau\}\{[p(a_1) - p(a_2)]\zeta\}^{-1}. \quad (20)$$

Recall now that from (13)

$$\Omega^* = \frac{V(a_1) - V(a_2) - p(a_1)[X(a_1) - \zeta] + p(a_2)\theta[X(a_2) - r(a_1 | R_1)]}{\theta r(a_1 | R_1)[p(a_1) - p(a_2)]}. \quad (13')$$

From (20) and (13') it is clear that (15) holds if

$$\begin{aligned} & \{V(a_1) - V(a_2) - p(a_1)[X(a_1) - \zeta] + p(a_2)\theta[X(a_2) - r(a_1 | R_1)]\} \\ & \quad \times \{\theta r(a_1 | R_1)\}^{-1} \\ & > \{[p(a_1) - p(a_2)]\zeta - \tau\}\zeta^{-1}. \end{aligned} \quad (21)$$

Cross-multiplying in (21) yields the following inequality that must hold:

$$\begin{aligned} & \theta r(a_1 | R_1) \{V(a_1) - V(a_2) - p(a_1)[X(a_1) - \zeta] + p(a_2)\theta[X(a_2) - r(a_1 | R_1)]\} \\ & \quad + [1 - \theta]r(a_1 | R_h) \{V(a_1) - V(a_2) - p(a_1)[X(a_1) - \zeta] \\ & \quad + p(a_2)\theta[X(a_2) - r(a_1 | R_1)]\} \\ & > \theta r(a_1 | R_1)[p(a_1)\zeta - p(a_2)\zeta - \tau]. \end{aligned} \quad (22)$$

Cancelling common terms on both sides of (22) and defining

$$Q \equiv V(a_1) - V(a_2) - p(a_1)[X(a_1) - \zeta] + p(a_2)\theta[X(a_2) - r(a_1 | R_1)],$$

we obtain the following inequality that must hold

$$\theta r(a_1 | R_1)p(a_2)\theta X(a_2) + [1 - \theta]r(a_1 | R_h)Q > -\theta[1 - \theta]\gamma_1 + \theta\gamma_2, \quad (23)$$

where

$$\gamma_1 \equiv r(a_1 | R_1)p(a_2)r(a_1 | R_h),$$

$$\gamma_2 \equiv r(a_1 | R_1)p(a_2)X(a_2).$$

Now note that using either (A.4) or (A.4'), we can assert that $Q > 0$. Hence, a sufficient condition for (23) to hold is

$$\theta r(a_1 | R_1)p(a_2)\theta X(a_2) > -\theta[1 - \theta]\gamma_1 + \theta\gamma_2,$$

which implies that we would like

$$-\theta[1-\theta]r(a_1 | R_l)p(a_2)X(a_2) > -\theta[1-\theta]r(a_1 | R_l)p(a_2)r(a_1 | R_h)$$

to hold. Clearly, this inequality holds if

$$X(a_2) < r(a_1 | R_h). \quad (24)$$

This completes the proof because (A.2) implies that (24) holds. Q.E.D.

This is a striking result. The standard approach to reducing the distortions created by debt-related moral hazard is to require the firm to inject more equity. In the limit, of course, complete self-financing (all inside equity) eliminates moral hazard. However, insufficient initial liquidity/wealth will force the firm to seek some outside financing. As mentioned earlier, in our model this outside financing optimally takes the form of debt. Conventional wisdom says that, in order to minimize distortions, the borrower should fully exhaust its liquidity first as an equity input and then seek outside debt financing only for the remainder. This argument assumes that the borrower operates solely in the spot market. We have shown that, when forward credit markets are accessible, borrowers should purchase loan commitments under which they can assure themselves of future borrowing privileges at predetermined rates. This use of initial liquidity *strictly* dominates the alternative of using it as equity in conjunction with a spot loan.

The intuition behind this finding is as follows. Because a fixed rate loan commitment pegs the loan interest rate at the same level regardless of the spot rate, it reduces the customer's borrowing rate by *different percentages* in the low and high interest rate states. In particular, it provides a greater percentage reduction in the high interest rate state. And this is the state in which interest rate-related distortions are the most severe. On the other hand, partial equity financing reduces distortions evenly across both the low and the high interest rate states. This is clearly less efficient.¹⁷

¹⁷We would like to thank Elazar Berkovitch for suggesting to us that there is another possible factor which reinforces the reason why loan commitments dominate equity. When a customer purchases a loan commitment by paying a commitment fee, it makes an irrevocable investment since the commitment fee is kept by the bank even if the commitment option is not exercised by the customer. With equity, however, the customer has the choice of not investing after it observes the spot borrowing rate. Thus, there is a stronger precommitment by the customer with a loan commitment than with equity. This strengthens its incentives to choose the first best action with a loan commitment.

While this intuition is correct, what is interesting is that it is unnecessary for our result; the dominance of a loan commitment can be sustained *even if* the above effect is absent. In our model, the customer always wants to borrow in the spot market if it does not purchase a loan commitment, and a loan commitment dominates even if one assumes that the spot market equilibrium entails no rationing. That is, in our proof we did not make use of the 'flexibility' of equity relative to loan commitments.

Although we have focused on fixed rate loan commitments, our analysis is applicable also to fixed formula or variable rate loan commitments. Campbell (1978) and Thakor, Hong and Greenbaum (1981) explain that such commitments involve some fixity in the borrowing rate even though this rate is a function of the prime rate. For example, 'prime plus' variable rate commitments fix the add-on over the prime rate that the borrower must pay. In the context of our model, we would end up with different δ 's for the low and the high interest rate states, but these could obviously be designed to provide the greatest percentage reduction in the loan rate in the high interest rate state. We would consequently have the same intuition driving the superiority of loan commitments over spot borrowing with equity.

Finally, a word on taxes. Since the loan commitment fee is tax deductible for the borrower but its equity is not, the introduction of taxes will further enhance the appeal of commitments in our model.

5. Conclusion

We have provided an economic rationale for bank loan commitments in a competitive credit market characterized by universal risk neutrality. Central to our model is an ex post informational asymmetry between the bank and the borrower with respect to the action chosen by the borrower. If the borrower could self-finance, it would choose the first best action. But when the borrower finances the project with a bank loan in the spot credit market, a second best action choice is made. Borrower incentives for reducing effort supply stem from the distortionary effect of loan interest rates that are driven to suboptimally high levels due to random fluctuations in the spot riskless rate.¹⁸ A loan commitment is shown to be capable of eliminating this welfare distortion. With a loan commitment, the bank can set the borrowing rate arbitrarily low such that no distortionary effects are present. This arbitrarily low borrowing rate causes losses to the bank, but the bank is compensated by a commitment fee paid at the initial point in time. Since the commitment fee itself has no incentive effect, the loan commitment contract essentially gives the bank an additional degree of flexibility – relative to a spot credit contract – in contract design and enables it to circumvent the welfare losses related to its inability to observe the borrower's action choice ex post. While it may also sometimes be possible to eliminate these welfare losses with spot credit contracts involving a sufficiently large borrower equity input, we have explicitly shown that the loan commitment contract strictly Pareto

¹⁸The distortionary effect of loan interest rates is not in itself caused by the randomness in the spot rate, but only exaggerated by it. However, randomness in the spot rate is essential to establish the dominance of a loan commitment over equity.

dominates such spot market resolutions.¹⁹ Moreover, the introduction of taxes gives loan commitments an advantage relative to spot borrowing with equity.

A caveat to our analysis deserves note. Our finding that a loan commitment produces the first best outcome is not a general one. Rather, it depends on our assumption that the borrower's action choice is limited to three actions (including the choice of doing nothing). If the borrower's feasible action space was non-denumerable, then we would find that a loan commitment will not generally restore first best. It will, however, still strictly Pareto dominate spot contracts.

The principal contribution of this paper is that it explains the existence of loan commitments under universal risk neutrality, and in the absence of transaction costs. We thus have an explanation for loan commitment demand by corporations owned by diversified shareholders. More fundamentally, our research suggests a new way of looking at the optimality of forward contracts and options in general, namely in terms of their possibly superior incentive effects relative to spot contracts, based purely on the grounds of greater contract design flexibility. From a somewhat narrower perspective, our research points out that discussions of fixed rate loan commitments as simple insurance policies are misguided. The insurance view is not only incapable of explaining why public corporations seek fixed rate loan commitments but it also results in a compelling focus on an aspect of loan commitments that we have formally shown is quite inessential to their (welfare-enhancing) existence.

A secondary contribution of this paper is the implication it has for the credit rationing literature. The papers of Stiglitz and Weiss (1981, 1983) have shown that banks may prefer to ration credit rather than adjust loan interest rates upward because of the adverse sorting cum incentive effects of such a strategy. What our research indicates is that forward contracting, through its ability to lessen interest rate-related distortions, could obviate the need to ration credit.²⁰

Finally, our analysis also sheds new light on the capital structure issue. The agency costs of debt [Jensen and Meckling (1976)] have been identified as a distortion that partly offsets the tax advantage of debt and leads to lower debt usage than predicted by Modigliani and Miller (1963). Our model suggests that a way to reduce debt-related costs without dissipating the associated tax shield is to utilize loan commitments. In fact, a loan

¹⁹Our analysis of the spot market outcome in section 3 does not allow the borrower an equity input, whereas in section 4.1 we let the borrower have sufficient initial liquidity to pay the commitment fee. In light of our analysis in section 4.2, we see that the effect of introducing equity in section 3 would only be to complicate the algebraic comparisons without changing the results or the intuition.

²⁰For research that takes up this issue rigorously, see Boot (1987).

commitment is a more powerful way of reducing moral hazard than even partial self-financing with inside equity.

A fruitful future extension of our analysis would be to endogenize the existence of the bank – perhaps along the lines of Ramakrishnan and Thakor (1984) or Millon and Thakor (1985) – and also explicitly permit the bank the option to dishonor the commitment. Reputation and related effects may then be useful in explaining why commitments are usually honored. Work along these lines is currently underway.

Appendix

To see that (4) is a weaker condition than (A.4), rewrite (4) as

$$\begin{aligned} & \theta p(a_2)[X(a_2) - r(a_1 | R_1)] - V(a_2) \\ & > \theta p(a_1)[X(a_1) - r(a_1 | R_1)] - V(a_1) \\ & \quad - [\theta p(a_1) - \theta p(a_2)][r(a_2 | R_1) - r(a_1 | R_1)]. \end{aligned} \quad (4')$$

It is easy to see that this is less restrictive than (A.4). Next, to see that (5) is a weaker condition than (A.4), rewrite (5) as

$$\begin{aligned} & \theta p(a_2)[X(a_2) - r(a_1 | R_1)] - V(a_2) \\ & > \theta p(a_1)[X(a_1) - r(a_1 | R_1)] - V(a_1) \\ & \quad - [\theta p(a_1) - \theta p(a_2)][r(a_2 | R_1) - r(a_1 | R_1)] \\ & \quad + [1 - \theta]p(a_1)[X(a_1) - r(a_2 | R_h)]. \end{aligned} \quad (5')$$

To show that (5) is less restrictive than (A.4) it is sufficient to show that the right-hand side of (5') is smaller than the right-hand side of (A.4). To see this, note that

$$\begin{aligned} & \text{right-hand side (A.4)} - \text{right-hand side (5')} \\ & = [\theta p(a_1) - \theta p(a_2)][r(a_2 | R_1) - r(a_1 | R_1)] \\ & \quad + (1 - \theta)p(a_1)[r(a_2 | R_h) - r(a_1 | R_h)] \\ & > 0. \end{aligned}$$

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