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Economic Theory

Why banks should keep secrets★

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Summary. We show that it is sometimes efficient for a bank to commit to a policy that keeps information about its risky assets private. Our model, based upon Diamond-Dybvig (1983), has the feature that banks acquire information about their risky assets before depositors acquire it. A bank has the option of using contracts where the middle-period return on deposits is contingent on this information, but by doing so it must also reveal the information. We derive the conditions on depositors' preferences and banking technology for which a bank would prefer to keep information secret even though it must then use a non-contingent deposit contract.

Keywords and Phrases: Deposit contracts, Interim information.

JEL Classification Numbers: D8, G21, G28.

1 Introduction

In the 1980's, poor credit risks caused the failure of many Savings & Loans. In response to these failures, the U.S. government enacted legislation devised to prevent such crises. The Financial Institutions Reform, Recovery, and Enforcement Act of 1989 and the Federal Deposit Insurance Corporation Improvement Act of 1991 made changes to banking laws designed to reduce moral-hazard problems and prevent losses from federal insurance.[1]

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[1] FIRREA; P.L. 101-73, 103 STAT. 183. FDICIA; P.L. 102-242, 105 STAT. 2236. There was also the Crime Control Act of 1990 (P.L. 100-86, 101 STAT. 552) and the Competitive Equality Banking Act of 1987 (P.L. 101-647, 104 STAT. 4789)

Part of these laws limit the ability of a bank to keep information private by creating a minimum capital requirement, imposing a new examination standard for bank assets, and implementing a risk-based insurance scheme. A minimum capital requirement entails accurate measurements of a bank's capital. Likewise, a risk-based insurance scheme is based on both a bank's capital and the riskiness of a bank's investments. These changes require altering both the examination standard and accounting methods of bank assets. Furthermore, they increase revelation about a bank's assets as do other moves to have banks mark loans at market value rather than book value.[2] Thus, these laws could theoretically reveal more information. Moreover, Morgan (2002) finds empirical evidence that banks indeed have information to reveal.[3] This leads us to the main question of the paper: Could this increase of information about a bank's assets have unintended adverse effects?

This question of whether an increase in information can lead to a decrease in welfare appears in other contexts. Hirshleifer (1971) shows that an increase of information may hurt efficiency in an exchange economy (the breadth of examples was recently expanded by Schlee, 2001). Verrecchia (1982) then shows such may be the case in insurance markets.[4] Eckwert and Zilcha (2003) study when additional information may hurt in a production economy. In a different setting, Maskin and Tirole (1990, 1992) analyze a principal-agent model where an informed principal does strictly better by not revealing his information. In another context, Kaplan and Zamir (2000) show that in an auction a seller can exploit this "information property" by giving buyers additional information making the outcome of the auction worse for the buyers and better for the seller with an overall welfare loss.

To ask this question in a banking context, we use a version of the Diamond-Dybvig model (1983) with a risky investment where the bank and depositors are asymmetrically informed about the return on investment in the middle period. While similar environments have been analyzed in the literature (see Gorton, 1985; Jacklin and Bhattacharya, 1988; Alonso, 1996; Hazlett, 1997), our model is tailored toward the question we wish to answer.

As in Diamond-Dybvig, we have three periods in which initially depositors don't know whether they will enjoy only the middle period good or enjoy both the middle and last period goods. The former are the impatient depositors, while the latter are the patient depositors. Each depositor's type is private information and discovered only in the middle period. A bank has access to an illiquid constant-returns-to-scale investment technology. This technology offers a safe middle-period return and an uncertain last-period return. A key assumption is that in the middle period, only the bank learns the risky last-period return. In the initial period, a

[2] Book values hide the real value of fixed-rate loans by ignoring changes to market interest rates.

[3] Morgan (2002) compares the Moody's and S&P's ratings of firms and finds that they differ the most in bank and insurance companies. This shows that banks are inherently more opaque than other firms.

[4] We can understand this result by looking at recent developments of genetic tests that determine a woman's predisposition to breast cancer. These tests provide benefits such as more frequent screenings for susceptible women and preemptive surgery; however, if insurance companies could screen applicants with such tests, genetically predisposed women would not be able to obtain insurance. Overall, society may be worse off.

bank offers a deposit contract that specify payments to depositors. A bank also has the ability to make the middle-period payments (not just the last-period payments) contingent upon the bank's information. However, a bank writing such contingent contracts implicitly reveals its information – depositors cannot be ignorant of the same information on which their received payments are based. The only way for a bank to keep its information private is to write contracts with a non-contingent middle-period payment. Thus, we permit a bank to choose whether to reveal its information and offer contingent contracts or not to reveal its information and offer non-contingent contracts (a third option of revealing its information and offering a non-contingent contract is weakly dominated by the second).

This dilemma of the bank allows us to answer our question in the following line of reasoning. If a bank always chooses to reveal its information with a contingent contract, then forcing a bank to reveal its information will have no effect. However, if there is a case when a bank chooses to offer a non-contingent contract and doing so leads to a strictly better outcome, then the same contract with information revealed will result that when the return is low, the patient depositors would claim to be impatient depositors. Thereby, the bank would be forced to offer the inferior, contingent contract. Thus, forcing a bank to disclose information will have an adverse effect.

We find such a case by first finding the technological conditions under which the patient depositors' incentive constraints will bind. Then, by showing that if these constraints are indeed binding and the depositors are moderately risk averse (the degree of relative risk aversion is between 1 and 2), then the bank will conceal its information by offering non-contingent contracts.

The format of this paper is as follows. Section 2 describes the model. The solution concept is defined and the reduced social planner's problem is derived in Section 3. Results are analyzed in Section 4 and the conclusions are discussed in Section 5. The proofs of all the lemmas and properties are listed in the Appendix.

2 Model

The environment, similar to Diamond-Dybvig (1983) (henceforth DD), is described in this section.

Time periods, goods, depositors and preferences

There are three time periods, 0, 1, and 2 (referred to as initial, middle, and last), and one good for each period. Let c_t denote an allocation of time t good and $c = (c_0, c_1, c_2)$ denote an allocation bundle. There is a continuum with measure one of ex-ante identical depositors. Each depositor is endowed with one unit of time 0 good. At time 1, depositors privately discover their type, either impatient (i) or patient (p). Impatient depositors enjoy only the time 1 good ($u_i(c) = u(c_1)$), while the patient depositors enjoy both the time 1 good and the time 2 good ($u_p(c) = u(c_1 + c_2)$). The utility function, u, is twice differentiable, increasing and strictly concave. Each depositor has an equal chance of being either type and there is no aggregate uncertainty in depositor types.

The bank and savings technologies

We start by looking at a single bank with the depositors' best interests in mind and later discuss in Section 5 how this benevolence may be a result of a competitive banking sector. This bank has no endowment, but has access to two constant-returns-to-scale investment technologies: one liquid and the other illiquid.[5] The illiquid technology is risky and converts one unit of time 0 good into either $(1-\tau)$ units of time 1 goods or an uncertain amount, R_s, of time 2 good that depends upon the state of world, s. There are two states of the world: high $(s = h)$ and low $(s = l)$. The probability of a high state is μ, while the probability of a low state is $1 - \mu$. The bank *privately* learns the state at time 1. This illiquid technology is described by

$$\left\{(z_0, z_1, z_2) \in \mathbb{R}_- \times \mathbb{R}_+ \times \mathbb{R}_+ | \ \frac{z_1}{(1-\tau)} + \frac{z_2}{R_s} \leq -z_0\right\}.$$

A bank can invest z_0 units of time 0 good, to obtain z_1 time 1 goods and z_2 time 2 goods, where the choice of z_1 and z_2 is made at time 1 and where z_0, z_1, z_2 are subject to the above budget constraint, $z_0 \leq 0$ and $z_1, z_2 \geq 0$.

The liquid technology is not risky and can both convert one unit of time 0 good into one unit of time 1 good and convert one unit of time 1 good into ρ units of time. The liquid technology is also accessible by the depositors.[6] It is described by

$$\left\{(z_0, z_1, z_2) \in \mathbb{R}_- \times \mathbb{R} \times \mathbb{R}_+ | \ z_1 + \frac{z_2}{\rho} \leq -z_0\right\}.$$

Again where the choice of z_0 is at time 0 and where the choice of z_1 and z_2 is made at time 1. Note that z_1 can be negative which means that one can convert time 1 goods into time 2 goods without having invested at time 0.

The technologies are such that $R_h > R_l > \rho > 0$ and $0 < \tau \leq 1$. These imply that early liquidation of the illiquid asset is costly in two respects. First, time 1 liquidation yields less than invested while the liquid technology would return just that. Second, independent of the state s, the future return of any good invested in the liquid technology, ρ, is lower than the worst case return of the illiquid technology, R_l.[7]

Timing

Decisions are made during the initial and middle periods. During the initial period, the bank offers a contract, that is, an agreement with a depositor where the depositor gives up one unit of time 0 good in exchange for a certain amount of either time 1

[5] This two technology environment closely resembles the technology in Cooper and Ross (1998).

[6] This alternative investment is reminiscent of Gorton (1985) where depositors may have an outside investment that is preferred to the bank's technology; however, here an outside investment is always inferior.

[7] Also, switching technologies in the middle period produces a two-period reward of only $\rho \cdot (1-\tau)$ instead of at least R_l.

goods or time 2 goods. A contract is described more explicitly below in the contract section. A depositor sees the bank's offer and decides whether or not to accept it.

During the middle period, nature determines the state of the investment, the depositors' types and the order the depositors play in the middle period. There is an equal chance of any queuing order for the depositors. Each depositor learns his type and each bank learns the state of the world. All depositors queue in the order that was determined by nature and are sequentially served by the bank (as described below in the sequential service section). When served, a depositor must decide whether or not to withdraw. In the last period, the depositors who decided to wait make withdrawals. In summary, depositors make two decisions (whether to agree to the contract and timing of withdrawals) while the bank makes one (choice of contract).

Contract

The contract offered in the initial period in exchange for one unit of time 0 good is of the form $\{x_l, y_l(f), x_h, y_h(f), F\}$. In each contract, x_s corresponds to the amount of time 1 good that will be given to someone withdrawing in the middle period when less than F (the suspension point) depositors have already withdrawn and the state is $s = l, h$, while the function $y_s(f)$ corresponds to the amount of time 2 good that will be given to someone withdrawing in the last period if the state is s and f depositors withdrew in the middle period (where f is between 0 and F).

A contract is feasible if it is technologically possible for both states. If at $f = F$ all time 1 payments come from the liquid technology and all time 2 payments from the illiquid technology, then this requires $y_s(f)(1 - f) \leq R_s(1 - F \cdot x_s) + (F - f)\rho x_s$ for all $f \leq F$ and $s = l, h$.

This contract is enforceable. A bank must pay the amounts specified in its contract. If a payment is state dependent, the bank offering that payment is obligated to pay the amount corresponding to the actual state. Thus, after the realization of the state at time 1, a bank must liquidate a sufficient portion of its investment in order to meet potential time 1 demands $F \cdot x_s$.

Sequential service

During the middle period, depositors are sequentially served in the following manner. At the front of the queue, there is a teller window. There is a sign with the amount that the bank is paying depositors, x_s, posted above the window. Once at the front of the queue a depositor has to decide either to withdraw or to leave and come back in the last period. If depositors of measure F have chosen to withdraw, the bank must immediately change the sign to read zero.

Depositors are myopic; their poor vision prevents them from seeing how many depositors stand before them or after them in queue. However, if the posted amount is nonzero, a depositor can deduce that the number of depositors who already withdrew is less than the cutoff, F. If the payoff is zero and the contract offered a nonzero initial payoff ($x_s > 0$), a depositor can deduce that the number of depositors who already withdrew is greater than the cutoff. If a depositor chooses to be served at the window, he can not return in the last period. In the last period, all depositors who have not already withdrawn are served simultaneously.[8,9]

Information transmission

It is costless for the bank to transmit the state of its investments. However, a feature of our model is that a bank prefers depositors not to learn this information.[10] There is still a dilemma since if a bank wishes to pay impatient depositors a contingent middle-period payment, by our sequential-service constraint it *must* also transmit the state of its investment with this payment. The only way to hide information is for the bank to make a non-contingent middle-period contract. Hence, we coin the term "revealing contract" for a contingent contract and "non-revealing contract" for a non-contingent contract.

Differences from Diamond-Dybvig

There are three key differences between our model and DD. First, in our model the illiquid investment technology has risk. Second, there is a liquid investment technology that if $\rho > 1$, will be used by any patient depositor that chooses to withdraw early. Finally, a bank has the ability to suspend payments. This allows a bank to costlessly prevent bank runs which allows us to focus the paper on the risk-sharing contracts derived from the model.[11]

[8] The results of this paper would not change if depositors sequentially queued in the last period or if the depositors who decide to withdraw in the middle period could receive both time 1 and time 2 goods.

[9] The sequential-service constraint presented here is different from the constraint in DD in that all depositors queue at the bank (as opposed to only early withdrawers). It resembles the sequential-service constraint in Wallace (1988, 1990), but differs in that only the early withdrawers go to the window. That way, the depositors are able to gain information about the state of the bank, while the bank learns nothing about the non-withdrawing depositors.

[10] Generally in mechanism design, the designer would not like to release information before eliciting information from the agents. The withholding of information leads to extra slack in the incentive constraints [which then need only be satisfied by expectation over states rather than each state individually (see Tirole, 1990)]. Our structure is more rigid due to the sequential-service constraint. This prevents a bank (the designer) from collecting information (whether a depositor is impatient) from all the depositors (agents) before making allocation decisions. It also forces a bank to reveal these allocation decisions before finishing the collection of information. If, for instance, the sequential service constraint had forced depositors to decide whether or not to withdraw without seeing how much they will receive, then the bank would offer contingent contracts and reveal as little as possible. An exception is (contrary to our assumptions) if $\rho(1-\tau) > R_l$, then the bank (designer) would want the patient depositor to take the middle-period payment in the case of a low return (similar to Gorton, 1985) and hence communicate this.

[11] Costless prevention of bank runs is due to the lack of aggregate uncertainty in the number of impatient depositors.

3 Solution concept

While so far there is only one bank, we will solve this model as a social planner (as does DD) and discuss how this may arise competitive banking environment.

Social planner's problem

The bank's contract, the depositors' choice of agreement, and depositors' withdrawal dates form a *solution* to the social planner's problem if they maximizes the ex-ante welfare of depositors subject to the following constraints:

- All contracts, $\{x_s, y_s(f), F\}$, are feasible.
- Each depositor's decision to agree to the contract is individually rational given the other depositors' decisions and expected withdrawal dates.
- For any preference type (patient or impatient) and any possible time 1 withdrawal offer generated by the contract, a depositor's withdrawal date maximizes his expected utility given this solution. (This later forms the incentive-compatibility constraints.)

Equivalent social planner's problem

We use the following lemma to reduce the planner's problem to the more manageable formulation listed after the lemma.

Lemma L1. *The solution to the social planner's problem separates depositors by allocating only time 1 goods to impatient depositors and time 2 goods to patient depositors.*

The proof of L1 is in the Appendix. We should note that L1 allows us to ignore the good of a particular time period being given to more than one type of depositor as in pooling or partial pooling contracts as well as ignore goods from both time periods being given to a depositor. This shows that the planner would set $F = .5$. Since the illiquid technology gives a higher return over two periods than the liquid technology, the planner would also want to invest all the funds used to pay patient depositors in the illiquid technology. Likewise, since the liquid technology yields a higher return from the initial to the middle period, the planner would want to invest all of the funds used to pay the impatient depositors in the liquid technology. We should further note that the planner's problem, presented below, has a unique solution.[12]

Social Planner's Problem (reduced) *is selecting a contract* $\{x_s, y_s(f), F\}$ *such that* $F = .5$, $y_s(f) = (y_s \cdot (1-F) + \rho x_s(F-f))/(1-f)$ *and* $\{x_l, y_l, x_h, y_h\}$ *solve* $\max_{x_l, y_l, x_h, y_h}(1-\mu)[u(x_l) + u(y_l)] + \mu[u(x_h) + u(y_h)]$

[12] The maximand is a linear combination of concave functions and is therefore also concave. The feasibility constraint is linear so the set of points that satisfy it is convex. Therefore, the solution is unique.

subject to the following constraints of feasibility and either revealing incentive-compatibility or *non-revealing incentive-compatibility (of the patient depositors):*

Feasibility	$y_s = R_s(2 - x_s)$ and $x_s, y_s \geq 0$ for $s = l, h$
Revealing incentive constraints	$u(\rho \cdot x_s) \leq u(y_s)$ for $s = l, h$
Non-revealing incentive constraints	$u(\rho \cdot x_l) \leq (1 - \mu) \cdot u(y_l) + \mu \cdot u(y_h)$ and $x_l = x_h$

4 Results

We begin this section by looking at the full-information allocation (the allocation chosen if the planner learns the types of the depositors at time 1) to see if it is a solution to the planner's problem. This allocation is also the first-best allocation. In order to see if it is indeed a solution, we need to see if it satisfies the incentive-compatibility constraints. If so, then the first-best allocation is a solution to the model. If it does not, then the planner has the choice of using either a second-best contingent contract or a non-revealing non-contingent contract. The existence of parameters resulting in the latter would support the bank's prerogative to keep secrets.

Full-information solution

Denote $(x_l^*, y_l^*, x_h^*, y_h^*)$ as the solution to the full-information problem (the planner's problem without incentive-compatibility constraints). This solution has the following properties (all of which are proved in the Appendix).

Property P1. *The solution is independent of the probability of the high state of investment μ.*

This follows from the planner's inability to risk-share between the high and low states due to the budget (feasibility) constraints.

Property P2. *The patient depositor receives more in the high state than the low state, that is, $y_h^* > y_l^*$.*

It is reassuring that the patient depositors receive more in the high state of the world, because only they can reap the rewards of the higher technological output.

Property P3. *In each state, the patient depositor receives more than the impatient depositor, that is, $y_l^* > x_l^*$ and $y_h^* > x_h^*$.*

This result is consistent with DD and logical since it is less costly to provide a good to the patient depositor. We now see that although the bank knows the state in the middle period, the impatient depositors gain from the higher state only if there is sufficient risk aversion.

Assumption A1. *Relative risk aversion is greater than 1 ($-\frac{u''(x)x}{u'(x)} > 1$ for all $x > 0$).*

Assumption A2. *Relative risk aversion is less than 1 (* $-\frac{u''(x)x}{u'(x)} < 1$ *for all* $x > 0$*).*

Property P4. *Under A1, the impatient depositor receives more in the high state than in the low state, that is,* $x_h^* > x_l^* > 1$. *Under A2, the impatient depositor receives less in the high state than in the low state, that is,* $x_h^* < x_l^* < 1$.

We see that only when there is sufficient risk-aversion, as in A1, is a bank a risk-sharing institution. This result agrees with the results of DD and occurs since, unlike the risk-sharing in Rothschild-Stiglitz (1976), transfer between the two types of depositors does not occur at a one-to-one ratio (impatient depositors are at a disadvantage). Therefore, there is a trade off between risk-sharing and the total surplus to be shared. When risk-aversion is high, the risk-sharing aspect dominates. When risk-aversion is low, the total surplus aspect dominates.

Theorem 1. *If either A2 holds or* ρ *is less than or sufficiently close to one, the contract that solves the social planner problem is equivalent to the full-information contract.*

Proof. If A2 holds, then P4 implies that $x_h^* < x_l^* < 1$. This in turn implies that $y_s^* > R_s \cdot x_s^*$. Since $\rho < R_s$, it must also be that $y_s^* > \rho \cdot x_s^*$. We also see that even if A2 does not hold, then P3 states that $y_s^* > x_s^*$. Thus, even when $\rho > 1$ for sufficiently small ρ, we have $y_s^* > \rho \cdot x_s^*$ – also satisfying the incentive-compatibility constraints of the planner's problem. □

We see that for low enough ρ, the incentive compatibility constraints do not bind. Thus, the optimal contract is revealing, that is, the allocation to the impatient depositors is contingent upon the state.[13] This result agrees with the standard DD model in that the first-best solution is obtainable as the *unique* equilibrium when the bank has the option of using either a suspension scheme (as in this paper) or deposit insurance (as in DD).

When incentive constraints bind

Normally, since private information exists for both types of depositors, we must consider incentive constraints for both types. However, the incentives for the impatient depositors are such that they will always want to report truthfully. Lying would only result in them obtaining a good that they did not desire. The same is not true for the patient depositors. If too much is offered to impatient depositors, patient depositors will be inclined to lie and try to withdraw early.

If the optimal full-information contract does not violate the patient depositors' incentive constraints, then the bank need not consider a non-revealing contract in

[13] This contingent contract can be thought of as a partial suspension of payments. This would then agree with Wallace (1988) who said that the partial suspension scheme works best. In the Wallace model, the aggregate uncertainty is in the number of impatient depositors as opposed to the return of the investment. The bad state of the world in the Wallace model occurs when there were more impatient depositors. Thus, a partial suspension occurred when the expected number of impatient depositors increased.

order to hide information; whether the depositors know the state of the bank's investment would be irrelevant. It is only when the incentive-compatibility constraints are binding (or equivalently, the full-information contract violates the incentive constraints) that a bank's decision to offer contingent contracts becomes important. (We now see that such a situation is possible for any utility function that satisfies our standard assumptions: twice differentiable, increasing and strictly concave.)

Lemma L2. *Under A1, there exist parameters ρ, R_l, and R_h such that $R_h > R_l > \rho > y_h^*$ and under such conditions, the full-information allocation violates the incentive constraints.*

L2 is proved in the Appendix. When the full-information contract violates incentive constraints, the social planner must choose between offering the optimal revealing contract or the optimal non-revealing contract. Given that the full-information contract violates the incentive constraints, it must be that the optimal revealing contract has binding incentive constraints. It is not necessarily the case that the optimal non-revealing contract has binding incentive constraints. We now show that under certain assumptions incentive constraints do indeed bind.

Lemma L3. *If utility is CRRA, $u(c) = \frac{c^{1-\alpha}}{1-\alpha}$, with $\alpha > 1$ (A1) and $\rho > R_h^{1/\alpha}$, then both the optimal non-revealing and optimal revealing contracts have binding incentive constraints.*

L3 is proved in the Appendix. We now obtain two lemmas (also proved in the Appendix), which describe properties of the optimal contract, necessary for the main theorem of the paper which follows them.

Lemma L4. *When constraints bind, the expected utility of the optimal revealing contract is linear in μ.*

Lemma L5. *When utility is CRRA and incentive constraints are binding, the expected utility of the optimal non-revealing contract is*
(i) increasing and concave in μ when the relative risk aversion is between 1 and 2
(ii) increasing and convex in μ when relative risk aversion is greater than 2.

Theorem 2. *If utility is CRRA and $\rho > R_h^{\frac{1}{\alpha}}$, then a non-revealing contract will be offered when the relative risk aversion is between 1 and 2, and a revealing contract will be offered when the relative risk aversion is greater than 2.*

Proof (see Fig. 1). To show this, first notice that when μ is either 0 or 1 both contracts provide the same expected utility since the state of nature is known with certainty. From L4, the expected utility of the revealing contract is linear in μ. This implies that when the non-revealing contract is concave in μ it is preferred to the revealing contract, and when the non-revealing contract is convex in μ the revealing contract is preferred. L3 and L4 show that the conditions of this theorem cause the respective concavity requirements to be satisfied. □

We see that when relative risk aversion is between 1 and 2, a bank prefers to offer a non-revealing contract.[14] Such a contract would not be feasible if a bank

[14] In a different framework, Eckwert and Zilcha (2003) show that for higher relative risk aversion (greater than 0.5) more information is worse as opposed to the middle range in our model.

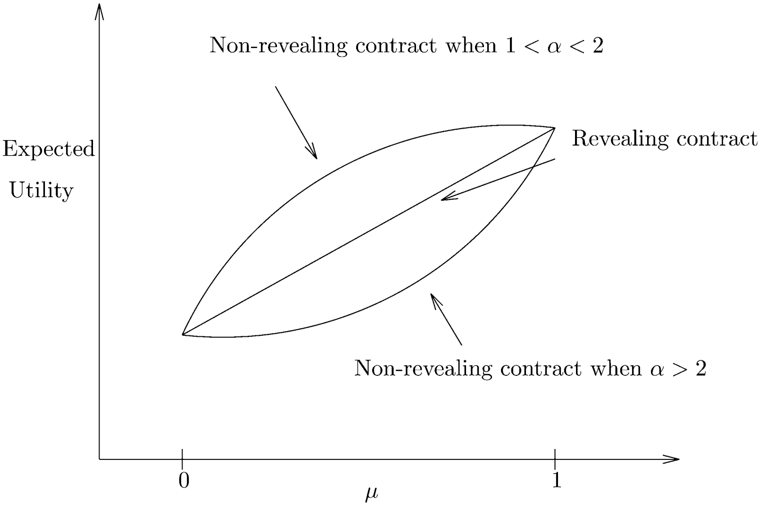

Figure 1. Graph of expected utility vs. μ

were forced to reveal the state of its investments. Thus laws forcing a bank to reveal such information may be detrimental.

Some intuition as to why this is the case can be gained by looking at the costs and benefits of the non-revealing contract versus the revealing contract. The benefits of a non-revealing contract are that there is more risk sharing against the risk of being impatient than in a revealing contract; the patient depositors are more willing to wait when there is a low return since they believe there is a chance of a high return. However, the cost of a non-revealing contract is that the patient depositors bear all the risk of the investment technology, whereas in a revealing contract they share some of that risk.[15] Thus, if depositors are moderately risk-averse this risk is not too costly. On the other hand, if the depositors are very risk-averse, the large difference of the payments in the last period are outweighed by the increased risk sharing against the risk of being impatient.

5 Conclusion

This paper presented a model in which a bank acting as a social planner has private information about the return on its assets. If the bank agrees to a contingent contract, then the depositors learn this information. Once depositors learn this information, it is more difficult to prevent patient depositors from pretending to be impatient. We find that instead a bank may agree to a non-contingent contract in order to keep its information secret. Since the bank sometimes chooses not to reveal its information, we can conclude that there is a potential danger to regulation requiring this information to be made public. In addition, adding a cost to disclosure would

[15] In autarky, the patient depositor bears all the burden of the risk of the technology and the impatient depositor bears all the burden of being impatient.

only further support our primary conclusion. This cost would increase the relative value of the non-contingent contract expanding the region where non-contingent contracts are preferred and increasing the loss from revealing information in such regions.

The planner in our model can be replaced by a decentralized competitive banking sector where banks have zero endowment and access to the banking technologies. If returns are the same for all banks (perfectly correlated) and depositors cannot learn the state of the investments from another bank, due to conditions leading to Bertrand competition,[16] the contract accepted by the depositors in equilibrium is equivalent to the contract that the planner chooses. If depositors were instead able to learn the state from other banks, then this would introduce the possibility of multiple equilibria where banks have trouble coordinating on keeping information secret. If one bank wrote a revealing contract, then it would be best for all others to follow. If all banks wrote a non-revealing contract, then it would be best for each bank to continue to offer a non-revealing contract. Still, since the possibility of a non-revealing equilibrium exists, the primary conclusion would still hold. Finally, if returns for each bank were independent and full diversification were prohibitively costly, then identical results would hold for large costs and similar results would hold for smaller costs.

If a bank is using non-revealing contract, there is a danger of information being revealed. Such revelation can lead to information-based bank runs, since incentive constraints would still be violated. Similar to what happened with Orange County California (see Jorion, 1995), problems are created when there is a low return on investments, but these problems are made worse when they are made public. Impatient depositors such as schools (as opposed to retirement funds) are unable to obtain needed funds. If such information was accidentally released very rarely (say with an exogenous small probability), non-revealing would still be optimal for a bank. This leads to a model with the result that information-based runs can be avoided but the cost of avoiding them is too great (as in Alonso, 1996; Cooper and Ross, 1998).

This paper expands the idea that more information could be worse. It both puts the idea into the framework of banking and introduces a new angle from the better-known insurance example. Rather than discovering who is impatient in the first period (which would break down the insurance market against being impatient), the discovery of a lower than expected returns to investment in the middle period increases the patient depositors' desire to pretend to be impatient.

[16] There may exist additional equilibria where a bank makes positive profits in equilibrium. This was first mentioned by Adao and Temzelides (1998), who eliminate these additional equilibria by restricting the depositors to pure strategies and invoking forward induction arguments. Kaplan (1996) suggests another possibility that assumes each bank has a monopoly over an ϵ number of depositors and taking the limit as $\epsilon \to 0$.

6 Appendix

Proof of Lemma L1

The social planner's problem implies that the optimal contract will separate the impatient from the patient and prevent a bank run. This is shown in several steps.

1. **The contract would result in at least some patient depositors choosing to withdraw at time 2 (as opposed to withdrawing at time 2 due to a suspension of payments).**
   First, suppose that all patient depositors withdraw at time 1 and there is no suspension. The best contract in this case causes all depositors to withdraw at time 1 and receive one unit of time 1 good. A strict improvement is $x_s = 1$, $y_s = R_l$, and $F = .5$. Such a contract separates patient and impatient depositors and is always feasible. Therefore, at least some patient depositors withdraw at time 2.
   Now the only way patient depositors are not choosing to withdraw at time 2 is if they are forced to by a suspension of payments. In this case, there would be an equal number of patient and impatient depositors withdrawing in each period. Here, it would be better to lower the first period payment to $x_s \cdot F$, raise the second period payment by the surplus, and set $F = .5$. The new time 2 payment would be enough to induce the patient depositors to wait and hence leave impatient depositors indifferent between the two schemes.
2. **The contract offered will cause the impatient depositors to withdraw at time 1.**
   The possibilities of the contract are zero payments at both time 1 and time 2, a non-zero payment only at time 1, non-zero payments at both times, and a non-zero payment only at time 2. We can easily eliminate the first two.
   Now, since impatient depositors only value time 1 goods, the only reason for them to withdraw at time 2, would be if the time 1 payment were 0. Since the time 2 payment is greater than 0, it would be an improvement for the planner to offer an amount that slightly larger than 0 for withdrawing at time 1. This would cause the impatient to withdraw at time 1. The savings from not having to pay impatient depositors any time 2 goods could be used to pay for the smaller payment to time 1 withdrawers and the remainder distributed to the patient time 2 withdrawers. Similarly, it would not be desirable to suspend payments by setting $F < .5$ to force impatient depositors to withdraw at time 2.
3. **The contract offered will not pool or partially pool impatient and patient depositors.**
   The possible pooling contracts in which all depositors withdraw at the same time (either 1 or 2) can be ruled out by steps 1 and 2. Partial pooling occurs when either some of the patient depositors withdraw at 1 or some of the impatient depositors withdraw at 2. By the previous step, all impatient depositors withdraw at 1. Therefore the only case left is having some patient depositors withdraw at 1. This can only occur if $E[u(y_s(f))|x_s] \leq u(\rho \cdot x_s)$. If this held with equality, an improvement would be to raise $y_s(f)$ by a small amount causing the patient depositors to wait and pay for it by the returns on the foregone time

1 goods, which would be strictly greater than ρ. Therefore $E[u(y_s(f))|x_s] < u(\rho \cdot x_s)$. By step 1, there exists at least some patient depositors waiting so $E[u(y_s(f))|x_s] \geq u(\rho \cdot x_s)$. This is a contraction, which implies no partial pooling can occur.

4. **The contract offered will prevent the possibility of a bank run.**
   A speculative bank run occurs if $E[u(y_s(F))|x_s] < u(\rho \cdot x_s)$. It is desirable to prevent since it yields lower expected payoffs. This can be done by setting $F = .5$ since $E[u(y_s(.5))|x_s] \geq u(\rho \cdot x_s)$ (since by step 3 the contract must be separating). □

Proof of Property P1

The solution to the full information problem has only feasibility constraints. The FOCs are

$$R_s u'(y_s^*) = u'(x_s^*). \tag{1}$$

By substituting feasibility into the FOCs, we find

$$R_s u'(y_s^*) = u'(2 - y_s^*/R_s). \tag{2}$$

Notice that equation 2 (there are actually two equations, one for each state s) and the two feasibility conditions are enough to provide a solution. None of the equations contains μ. □

Proof of Property P2

The proof is by contradiction. Assume $y_h^* \leq y_l^*$. Since u is concave, u' is decreasing and thus have $u'(y_h^*) \geq u'(y_l^*)$. This and given our assumption that $R_h > R_l$, yields $R_h \cdot u'(y_h^*) > R_l \cdot u'(y_l^*)$. This shows that given our assumption the LHS of (2) is higher for the high state than the low state. Now let us look at the RHS, $u'(2-y_s^*/R_s)$. Since $y_h^* \leq y_l^*$ and $R_h > R_l$, we have $y_h^*/R_h < y_l^*/R_l$. This implies $u'(2 - y_h^*/R_h) < u'(2 - y_l^*/R_l)$. Thus, given our assumption the RHS is lower for the high state than the low state. This contradicts that the FOC, $R_s u'(y_s^*) = u'(2 - y_s^*/R_s)$, holds for both states. Therefore, $y_h^* > y_l^*$. □

Proof of Property P3

In all states of the world, the return to investment R_s is strictly greater than one. This and (1) imply that $u'(y_s^*) < u'(x_s^*)$. Since u is concave, u' is decreasing. Therefore, $y_s^* > x_s^*$. □

Proof of Property P4

We compute comparative statics on x_s^* and R_s, by substituting feasibility into the FOCs (1) to arrive at $R_s u'(R_s(2-x_s^*)) = u'(x_s^*)$. Taking the total derivative of this yields,

$$u'(R_s(2-x_s^*))dR_s + R_s u''(R_s(2-x_s^*))((2-x_s^*)dR_s - R_s dx_s^*) = u''(x_s^*)dx_s^*.$$

We can now use this equation to solve for dx_s^*/dR_s,

$$\frac{dx_s^*}{dR_s} = \frac{u'(R_s(2-x_s^*)) + R_s(2-x_s^*)u''(R_s(2-x_s^*))}{R_s^2 u''(R_s(2-x_s^*)) + u''(x_s^*)}.$$

Since u is concave, the denominator is negative. Under A1, the numerator is negative, while under A2, the numerator is positive. These results imply that dx_s^*/dR_s is positive under A1 and negative under A2. Since $R_h > R_l$, we have $x_h^* > x_l^*$ under A1 and $x_h^* < x_l^*$ under A2.

We can further show that if $R_s = 1$ then by the FOCs, x_s^* must satisfy $u'(2-x_s^*) = u'(x_s^*)$. This implies $x_s^* = 1$. Making further use of our comparative statics (sign of dx_s^*/dR_s), the inequality of $R_l > 1$ implies that $x_l^* > 1$ under A1 and $x_l^* < 1$ under A2. □

Proof of Lemma L2

The full information contract $\{x_s^*, y_s^*\}$ is such that $y_h^* > y_l^*$ (P2) and $x_h^* > x_l^* > 1$ (by P4 and A1). Since $x_h^* > 1$, feasibility requires that $R_h > y_h^*$. Thus, it is possible to choose an ρ and R_l for each R_h such that $R_h > R_l > \rho > y_h^*$. From this and $y_h^* > y_l^*$, we have $\rho > y_s^*$. While from $x_s^* > 1$, we have $\rho \cdot x_s^* > \rho > y_s^*$. Together we have $u(y_s^*) < u(\rho \cdot x_s^*)$, which violates the ICs. Therefore, the full-information contract violates the ICs and the solution to the social planner's problem will have binding constraints. □

Proof of Lemma L3

When a contract is revealing and return is high, if the ICs were not binding, the amount paid to the impatient depositors x_h^r should maximize $(1/2)[u(x_h) + u(R_h(2-x_h))]$ over x_h. The FOC is given by $u'(x_h^r) = R_h u'(R_h(2-x_h^r))$. Using the specific form of the utility function $(u(c) = \frac{c^{1-\alpha}}{1-\alpha})$ and raising each side to the $(\alpha-1)/\alpha$ power, we can rewrite this as $u(x_h^r) = R_h^{1-(1/\alpha)} u(R_h(2-x_h^r))$. The IC is violated if $u(R_h(2-x_h^r)) < u(\rho \cdot x_h^r) = \rho^{1-\alpha} \cdot u(x_h^r)$. This indeed occurs if $\rho > R_h^{1/\alpha}$ since u and $1-\alpha$ are negative. Likewise, the IC for the low return is violated whenever $\rho > R_l^{1/\alpha}$. Since $R_h > R_l$, both are violated when $\rho > R_h^{1/\alpha}$.

Likewise, when a contract is non-revealing, if the ICs were not binding, the amount paid to the impatient depositors x^{nr} should maximize $(1/2)[u(x) + \mu \cdot u(R_h(2-x)) + (1-\mu) \cdot u(R_l(2-x))]$ over x. This can be written as $(1/2)[u(x) +$

$u(K(2-x))]$ where K is $(\mu R_h^{1-\alpha}+(1-\mu)R_l^{1-\alpha})^{\frac{1}{1-\alpha}}$. Thus, the ICs will be violated whenever $\rho > K^{1/\alpha}$. Since K is less than R_h, this is violated when $\rho > R_h^{1/\alpha}$. Thus, for both cases the unconstrained optimum will violate the constraints. Since the maximand is concave, the constrained optimal will have binding constraints. □

Proof of Lemma L4

Since the revealing ICs are binding, from the reduced social planner's problem, the optimal revealing contract, (x_s^r, y_s^r), satisfies $y_s^r = \rho \cdot x_s^r$. By substituting into the feasibility constraint $y_s^r = R_s(2 - x_s^r)$, we get $\rho \cdot x_s^r = R_s(2 - x_s^r)$. This yields, $x_s^r = 2R_s/(\rho + R_s)$ and $y_s^r = 2\rho R_s/(\rho + R_s)$.

By using these results, the ex-ante expected utility of the revealing contract equals $\frac{1}{2}[\mu(u(2R_l/(\rho + R_l))+u(2\rho R_l/(\rho + R_l)))+(1-\mu)(u(2R_h/(\rho + R_h))+u(2\rho R_h/(\rho + R_h)))]$. This is of the form $\mu \cdot const_1 + (1 - \mu) \cdot const_2$, which is linear in μ. □

Proof of Lemma L5

Remember that the non-revealing contract, $\{x_s^{nr}, y_s^{nr}\}$, has the property that $x_l^{nr} = x_h^{nr} := x^{nr}$. Now notice that there are two feasibility constraints and one IC with three unknowns: x^{nr}, y_l^{nr}, and y_h^{nr}. Thus, we can use these constraints to solve for the contract:

$$u(\rho x^{nr}) = (1 - \mu) \cdot u(R_l(2 - x^{nr}) + \mu \cdot u(R_h(2 - x^{nr})).$$

By using the specific form of the utility function ($u(c) = \frac{c^{1-\alpha}}{1-\alpha}$), we find that x^{nr} equals $2K(\mu)/(\rho + K(\mu))$ where $K(\mu)$ is $((1 - \mu)R_l^{1-\alpha} + \mu R_h^{1-\alpha})^{1/(1-\alpha)}$. Therefore, the expected utility of the non-revealing contract equals

$$\begin{aligned} EU^{nr} &= \frac{1}{2}[(1-\mu)(u(y_l^{nr}) + u(x^{nr})) + \mu(u(y_h^{nr}) + u(x^{nr}))] = \\ &= \frac{1}{2(1-\alpha)}[\rho^{1-\alpha} + 1](\frac{2K(\mu)}{\rho + K(\mu)})^{1-\alpha} \end{aligned}$$

Denote K_2 as $\frac{1}{2}[(2R)^{1-\alpha} + 2^{1-\alpha}]$. We find that $dEU^{nr}/d\mu$ equals $\rho K_2 K^{-\alpha} K' \cdot (K + \rho)^{\alpha-2}$. The value of K' is $K^{\alpha}(R_h^{1-\alpha} - R_l^{1-\alpha})/(1 - \alpha)$. Since $(1 - \alpha)$ and $(R_h^{1-\alpha} - R_l^{1-\alpha})$ are of the same sign, K' is positive. Since ρ, K_2, and K are also positive, EU^{nr} is increasing in μ.

Denote K_3 as $(R_h^{1-\alpha} - R_l^{1-\alpha})/(1 - \alpha)$. We find that the second derivative, $d^2EU^{nr}/d\mu^2$, is equal to $\rho K_2 K_3(\alpha - 2)(K + \rho)^{\alpha-3}K' = \rho K^a K_2 K_3^2(\alpha - 2)$. The values ρ, K, K_2, and K_3 are all positive. Therefore, the sign of the second derivative is the same sign as $(\alpha - 2)$. This means it is concave when $\alpha < 2$ and convex when $\alpha > 2$. □

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