On the Efficiency of Cash Settlement

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Abstract: This paper investigates the question of why banks almost always settle payments in cash as opposed to debt. Our model suggests that adverse selection with respect to the quality of bank assets may be the primary motivation underlying this practice. Banks with higher-quality assets prefer not to exchange debt with other banks if their debt is indistinguishable from that of banks with lower-quality assets. Banks with higher-quality assets prefer to sell off assets to informed outside agents in return for cash, which can then be used in settlement. Willingness to settle in cash serves as a signal of the quality of a bank's assets; hence, in equilibrium all banks settle in cash. If information flows are disrupted so that no outsiders are informed, then the signaling value of cash settlement is lost. The last result is consistent with the use of debt-based settlement schemes during the National Banking Era (1864-1914).

JEL classification: G21, N20, N21

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The existence of banks poses the following paradox. Among financial intermediaries, banks typically hold the greatest proportion of extremely illiquid assets, e.g., loans, while also holding the greatest proportion of highly liquid liabilities, e.g., demand deposits.

Numerous theories have been proposed to explain the apparent liquidity mismatch between the two sides of banks' balance sheets.[1] The most widely cited explanation of this phenomenon is that proposed by Diamond and Dybvig (1983) and related papers.[2] The idea of these papers is that par-valued deposit contracts may offer ex ante identical depositors the optimal degree of insurance against the risk of having to consume earlier rather than later, while providing depositors some portion of the returns from long-term, illiquid investments.

One difficulty in applying the Diamond-Dybvig model to real-world banking is that the Diamond-Dybvig model is a model of a single, benevolent, mutually owned bank, whereas the banking industry in almost all developed economies consists of multiple, proprietary, and presumably profit-maximizing banks. A reasonable question to ask is whether the optimal insurance nature of Diamond-Dybvig deposit contracts would be retained in a more realistic, disaggregated model of commercial banking. Papers such as Bhattacharya and Gale (1987) and Chari (1989) suggest that the answer may be a qualified "yes." That is, by setting up a mutual insurance arrangement that pools the risks that banks face from random demands for their liquid assets, either a first-best (Chari) or second-best (Bhattacharya & Gale) allocation can be attained.

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[1] See Bhattacharya and Thakor (1993) for a survey of recent work in this area.
[2] See especially Bryant (1980) and Jacklin (1987).

A *prima facie* argument against the applicability of the Chari/ Bhattacharya-Gale results, however, is the apparent rarity of such arrangements in the real world. In the everyday course of business, banks accumulate claims against each other's assets ("checks") which have to be tallied and presented to the appropriate bank ("cleared"). Before these checks can be considered final payments, an offsetting exchange of assets ("settlement") must occur. In many instances the only asset accepted in interbank settlement is a reserve asset, which today means outside fiat money and earlier times meant specie or the equivalent. This commonplace practice of settling interbank claims by exchange of reserve assets ("cash settlement") stands in contrast to theoretical results which suggest that the efficient arrangement would be settlement by exchange of interbank debt.

The idea of debt settlement is not without historical precedent, however. Throughout banking history there have been episodes where settlement has been effected via interbank debt, particularly during times of financial crisis. Among the best-studied of such episodes are the banking crises of the U.S. National Banking Era (1864-1914). During financial panics, associations of banks in the larger cities would suspend requirements for cash settlement and offer their members the option of settling in "clearinghouse loan certificates," i.e., senior debt issued against bank assets which was discounted a uniform, preset rate.[3] The practice of settling in clearinghouse certificates during these periods suggests that there may exist conditions under which settlement of interbank claims in debt dominates cash settlement.

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[3] See e.g., Cannon (1910, pp. 77-78), Timberlake(1984, 1993), or Gorton (1985). A noteworthy feature of the loan certificate system was that loan certificates could only be issued by mutual assent of the clearinghouse members, or in the case of the larger clearinghouses, after a vote by a governing committee.

Below we present a simple model of interbank clearing and settlement. We then use this model to investigate the prevalence of settlement in cash versus interbank debt when banks have private information about the quality of their assets. The resulting adverse selection problem works against debt-based settlement schemes. Specifically, such schemes will always require that banks with higher quality assets subsidize banks with lower quality assets. We find that as long as there are agents outside the banking system with sufficiently good information about the quality of bank assets, then banks with higher quality assets will prefer settlement in cash rather than debt. If the quality of these agents' information is poor then settlement in interbank debt may be preferred by all banks. These results suggest that under most circumstances efficient financial intermediation is likely to characterized by cash settlement of interbank payments.[4]

The paper is organized as follows. Section 1 lays out the economic environment. Section 2 explores the mechanics of interbank clearing and settlement. Results are presented in Section 3. Section 4 concludes and offers directions for future results.

1. The Environment

The following actions take place in our model. Consumers deposit their endowments in one of many Diamond-Dybvig-style banks. Banks use these endowments to fund

[4] The idea of modeling cash payment as a solution to information problems dates at least to Brunner and Meltzer (1971). This notion of money as a solution to adverse selection problems, in particular, has been widely explored in the monetary literature, most recently in papers such as Aiyagari (1989), Williamson (1992), and Williamson and Wright (1994). Our paper differs from those in the monetary literature in that we are specifically concerned with the informational asymmetries associated with the clearing and settlement of interbank claims. Since payment by exchange of claims on bank assets is (by value) the predominant form of payment in developed economies, we believe that our application of this idea will be relevant for policy concerns.

investments whose quality is not publicly observable. Impatient consumers then use their claims on bank assets to purchase consumption goods from another class of agents, i.e., merchants. Payments must be cleared and settled according to a prearranged set of rules agreed upon by all banks. After clearing and settlement occur, returns on investments are realized. Banks are then liquidated, patient depositors are paid off, and any profits accrue to the owners of the banks.

Following Diamond-Dybvig (1983), there will be three time periods in our model, i.e., $t = 0,1,2$. *Depositors*, whose behavior is exogenous to our model, are endowed with one unit of a consumption good in period 0. Depositors deposit this good with *banks,* who promise their depositors one unit of consumption if their claim to bank assets is presented in period 1, and $D>1$ units of consumption if the claim is presented in period 2. All banks offer their depositors this same contract, which offers depositors insurance (in the usual sense of Diamond-Dybvig literature) against the eventuality they will have to consume in period 1.

There are a large number (sufficient to eliminate aggregate uncertainty) of risk-neutral, profit-maximizing banks, each of whom has a large number of depositors. Banks are indexed by their location, where only one bank is at each location. Depositors may only have an account at their local bank. In period 1, a random proportion τ of each bank's depositors becomes impatient for early consumption, and these depositors will use their claims to their bank's assets to purchase their consumption goods. We assume that consumers do not attempt to directly withdraw funds in cash. Instead, impatient consumers are "mobile check-writers" in the sense of McAndrews and Roberds (1995) and they journey to other locations in order to purchase their desired location-specific consumption goods. At each location there is a *corn merchant* who automatically provides a location-specific type of consumption good in return for a valid claim (check) against any bank's deposits.[5]

Checks are cleared in the following fashion. Corn merchants deposit the claims received in payment in their local bank. At the end of period 1, claims are added up and presented to the appropriate banks (i.e., cleared) for settlement by an outside party known as a *clearinghouse*. "Settlement" means that each claim presented must be offset by a transfer of assets from the bank whose check was presented in payment (the "payor" bank) to the bank that presented the check for payment (the "payee" bank). In this paper we consider *gross settlement* which is the simplest settlement scheme.[6] Under gross settlement, checks presented for payment must be offset one-for-one by an opposite transfer of assets, with no netting of claims allowed. Below, we consider what types of assets should be exchanged in settlement.

In contrast to impatient consumers, patient consumers find all consumption goods equally desirable. After receiving the contracted amount D of consumption goods from their local bank in period 2, they consume this immediately and there is no need to exchange claims among banks.

Upon receiving deposits at the beginning of period 0, banks invest these deposits in *projects*. Projects pay a positive return $R>D>1$ in period 2 if the project is successful, and (for simplicity) nothing if the project is unsuccessful. The overall proportion of banks with

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[5] The corn merchant device is due to Selgin (1993).

[6] See Cohen and Roberds (1993) for a description of other types of settlement schemes.

successful projects is $\sigma \in (0,1)$. At the beginning of period 0, the population of banks is divided into *good* and *bad* types, with the good types having ex ante probability g of success and the bad types probability b, where $g > \sigma > b$. The overall proportion of good types is γ, which implies $\sigma = g\gamma + b(1-\gamma)$. We also assume that each bank's type is known locally, but is not known by other banks.

At the beginning of period 0, banks purchase projects from other agents at their own location. For simplicity we assume there is no discounting. For a bank of type g, the (locally) actuarially fair price of one unit of an investment project would be gR. We assume, however, that banks have access to projects that other agents do not have, and hence that banks are able to purchase projects at prices that are somewhat better than actuarially fair prices.[7] Hence a bank of type g will be able to purchase one unit of an investment project at a price g_0R, where $g_0 < g$.

Once banks take possession of their investment projects, they are free to resell these projects to risk-neutral parties known as *reserve agents* in exchange for reserves (or cash).[8] Reserves, which are denominated in dollars, may be thought of investments that offer one unit of consumption for sure in period 2. Reserve agents are informed as to each bank's type. However the price received by the banks for their projects may not be actuarially fair due to the following consideration. Upon purchasing their projects, banks

[7] I.e., we are assuming that there are barriers to entry in banking. Without such barriers, it is difficult to rule out "lemons" results, similar to that obtained by Williamson (1992, p.139), where in equilibrium all banks are bad-type banks.

[8] The term "reserve agent" is borrowed from Donaldson (1992). In his model of National Banking Era panics, Donaldson applied this term to participants in the London money markets who were willing to trade specie for bank assets. In a modern context, reserve agents could be thought of as holders of uninsured claims on bank assets, e.g., holders of large CDs, fed funds sellers, etc.

of both types receive additional information about the likely success of their projects. Formally we model this by assuming that banks learn their *subtype*, which is private information. Banks of type g, for example, discover that the true probability of their projects' success is either g^+ or g^-, where

$$g^+ > g > g_0 > g^- > b^+ > b > b_0 > b^-$$

This implies that once banks take possession of their investment projects, these projects become subject to adverse selection. The g^+-subtype banks will not wish to part with their investments at a price less than $\$g^+R$ per unit project, whereas the g^--subtype banks would be happy to part with their investments at any price above $\$g^-R$.

2. Modeling the Settlement Process

In our model, all payments are in the form of checks presented by impatient consumers to the merchant selling their desired consumption good, in return for one unit of this consumption good. Merchants are by assumption unwilling to provide these goods unless checks presented for payment are "validated," i.e., cleared and settled by banks. Banks validate checks against accounts at other banks by presenting these claims to the payor banks, and receiving in return assets worth at least one consumption good in expected value terms. We assume that each banks can be forced by legal constraints to settle according to a prearranged set of rules agreed upon by all banks; failing to settle is not an option.

Each bank is faced with uncertainty concerning the number of checks that will be presented on it during period 1. If we normalize each bank to be of size equal to \$1, then each bank will have to settle $\$\tau$ in claims in period 1, where for computational simplicity $\tau=\bar{\tau}\in(0,1)$ with probability p, and $\tau=0$ with probability $(1-p)$. The amount of this withdrawal demand is unobservable by the reserve agents, though they know the underlying distribution of withdrawal demands.

To model cash settlement, suppose that all banks require transfers of reserves to settle payments. This requirement forces both the plus- and minus-subtype banks to sell assets to reserve agents in order to effect settlement. The requirement that all banks settle, plus the presence of adverse selection (with respect to banks' subtypes) means that in equilibrium projects will sell at a premium, relative to the true worth of the minus-subtype banks' projects. Hence the minus-subtype banks will sell as many as possible of their projects to reserve agents. If the probability of being a plus-subtype is π, then in equilibrium πp plus-subtype and $(1-\pi)$ minus-subtype projects will be sold to reserve agents. Thus, under cash settlement good banks' projects will be fairly priced at $\$\tilde{g}R$, where $\tilde{g}$ is defined as the weighted average of the asset values for the two subtypes, i.e.,

$$\tilde{g}=\frac{\pi p g^{+}+(1-\pi)g^{-}}{\pi p+(1-\pi)}$$

To calculate the ex ante (beginning of period 0) profit Φ_c for good-type banks[9] under cash settlement, we consider the profit of the bank at the end of period 1 for each of the four possible scenarios:

[9] Symmetric calculations would apply to bad-type banks; these are omitted for brevity.

Scenario 1: the bank is the g^+-subtype and has no deposit withdrawals during period 1, i.e., $\tau = 0$. In this case the expected profit of the bank is equal to its capital gain on its projects minus its expected period 2 withdrawals, i.e.,

$$\Phi_c^1 = \frac{g^+}{g_0} - D$$

Scenario 2: the bank is the g^+-subtype and has deposit withdrawals in period 1, i.e., $\tau = \bar{\tau}$. In this case the bank liquidates $\bar{\tau}/(\tilde{g}R)$ of its projects at a capital loss (relative to their value if held to maturity) in order to obtain the reserves necessary for settlement. Its expected profit is equal to its remaining capital gain minus its period 2 deposit withdrawals, i.e.,

$$\Phi_c^2 = g^+R\left(\frac{1}{g_0R} - \frac{\bar{\tau}}{\tilde{g}R}\right) - \left(1 - \bar{\tau}\right)D$$

Scenario 3: the bank is the g^--subtype and has no deposit withdrawals during period 1. Even though the bank has no need for reserves to meet period 1 withdrawal demand, it is still optimal for the bank to sell $\bar{\tau}/(\tilde{g}R)$ of its projects in order to realize a capital gain on the projects (in equilibrium it will not offer to sell more because doing so would reveal the bank's subtype). Sale of these assets will bring in \$τ in reserves. Hence expected profits will be

$$\Phi_c^3 = g^-R\left(\frac{1}{g_0R} - \frac{\bar{\tau}}{\tilde{g}R}\right) + \bar{\tau} - D$$

Scenario 4: the bank is the g^--subtype and has deposit withdrawals in period 1. By analogy with Scenario 2, the expected profit of the bank will be

$$\Phi_c^4 = g^- R\left(\frac{1}{g_0 R} - \frac{\bar{\tau}}{\tilde{g}R}\right) - \left(1 - \bar{\tau}\right)D$$

Weighting the expected profits for each Scenario by its probability, summing, and simplifying, we obtain a particularly simple expression for Φ_c in the limiting case where D=1, i.e.,

$$\Phi_c = \frac{g}{g_0} - 1 \tag{2.1}$$

Equation (2.1) says that under cash settlement, banks will on average neither make nor lose profits by selling their projects to reserve agents. A bank's expected profit will be the expected gain from bank's investment advantage, i.e., g/g_0 in the case of a good bank, minus the (deposit) cost of funding the bank's investments, which goes to unity as $D \downarrow 1$. The same value of expected profits would obtain if the reserve agents had perfect information on banks' subtypes. Under perfect information banks would forgo the capital gains obtained under Scenario 3 above, but they would also cut capital losses experienced under Scenario 2. Due to the simple structure of the model and the risk-neutrality of the banks, these two effects cancel exactly.

To model settlement via interbank debt, we assume that payments are settled via a literal transfer of projects from the payor bank to the payee bank. Alternatively, this could be thought of as a transfer of collateralized debt, where the bank's projects are the collateral. Since banks have no knowledge of other banks' types, a single price is assigned to all banks' debt. As long as this price is above b^+, then it will pay for bad banks to transfer the maximum amount of funds out during period 1 and to finance these transfers by issue of debt. Good banks, on the other hand, would find their debt underpriced and would issue only the minimum amount of debt necessary to settle payments. Under debt settlement, the fair price of interbank debt would be $\$\tilde{\sigma}R$, where $\tilde{\sigma}$ is defined as the weighted average of the probabilities of success for the good- and bad-type banks, i.e.,

$$\tilde{\sigma} = \frac{\gamma p g + (1-\gamma)b}{\gamma p + (1-\gamma)}$$

To calculate the ex ante (beginning of period 0) profit Φ_d of a good bank, we note that under debt settlement, the equilibrium behavior of the plus- and minus-subtypes is the same. Hence we need only consider two period 1 scenarios.

Scenario 1: A good bank experiences period 1 deposit withdrawals. Its profit can be calculated as the capital loss on its projects, minus its second period withdrawals. Expected profits will be

$$\Phi_d^1 = gR\left(\frac{1}{g_0 R} - \frac{\bar{\tau}}{\tilde{\sigma}R}\right) - (1-\bar{\tau})D$$

Scenario 2: A good bank experiences no period 1 deposit withdrawals. Its profit is just the return on its investments minus its second period withdrawals, i.e.,

$$\Phi_d^2 = \frac{g}{g_0} - D$$

Weighting the two Scenarios by p and $(1-p)$, summing, and setting D=1 yields

$$\Phi_d = \frac{g}{g_0} - 1 - p\bar{\tau}\left(\frac{g}{\tilde{\sigma}} - 1\right) \tag{2.2}$$

Equation (2.2) says that the expected profit of a good bank will be its expected profit under cash settlement [cf. equation (2.1)], minus its expected capital loss on debt issue.

Hence for a good bank, $\Phi_c > \Phi_d$ and cash settlement will be preferred to debt settlement while for a bad bank the reverse will hold by symmetry.

3. Implications

The implications of the model can be summarized in several propositions.

Proposition 1: If given the choice of participating in a pooled (i.e., including good- and bad-type banks) debt-based clearing system, or participating in a cash-based settlement system, good banks would prefer cash settlement, while bad banks would prefer debt. If the choice is cash settlement versus a debt-based system segregated by type, then both types would be indifferent between cash and debt settlement.

Proof: The first part of the proposition follows from immediately from comparison of equations (2.1) and (2.2). To prove the second part of the theorem, note that if banks can be separated by type, then banks have the same amount of information as do the reserve agents. Bank profits will therefore be the same as under cash settlement.□

Corollary to Proposition 1: If banks' types are unobservable, then cash settlement will be preferred by the good banks. Bad banks will be indifferent between participation in a cash or debt-based settlement system.

Proof: Again the first part is immediate from (2.1) and (2.2). To see the second part, suppose that initially all banks were participating in a cash settlement system. Suppose further that a group of banks then broke off to form a separate, debt-based system. From the first part of the corollary, no good banks would want to participate in such as system. Hence only bad banks would participate in the debt-based system. From Proposition 1, the expected profits from participation in such a segregated debt-based system would exactly equal expected profits under cash settlement.□

Proposition 1 and its corollary are characteristic of adverse selection environments.[10] In our model, the problem of adverse selection with respect to asset quality can be perfectly circumvented if bank assets (or debt) can be sold to sufficiently well informed (though not perfectly informed) risk-neutral agents. If outsiders' information on each bank's assets is sufficiently good, then there is no need for banks to accept each other's debt in settlement.

Proposition 2: Suppose that the information flow to reserve agents is disrupted so that they are no longer able to distinguish between good and bad banks. Then all banks will be indifferent between a debt-based and a cash-based settlement system.

Proof: If cash settlement is in effect, and reserve agents cannot distinguish between types, then they would have to price all bank investment projects at $\$\tilde{\sigma}R$ in order to obtain a fair gamble. This is the same valuation of bank projects as in the debt-based settlement system. Hence banks will be indifferent between the two systems.□

Proposition 2 provides some weak support for the existence of debt-based settlement systems during times of panic. Recent theories of financial panics have often described panics as episodes during which normal flows of information about asset quality are disrupted.[11] During such episodes, Proposition 2 suggests that banks would do just as well by holding (claims to) each other's assets as they would by selling these assets to outsiders. Note that by settling in debt during times of crisis, banks in our model would in

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[10] See, e.g., Akerlof (1970).

[11] See Mishkin (1991) and Gorton and Calomiris (1991) for discussions of the role of asymmetric information during National Banking Era panics.

essence be following Bagehot's ([1873] 1991) famous prescription for central bank policy during times of crisis. That is, under a debt settlement system described above, banks "lend freely" to one another in settlement at a rate that would in normal circumstances be considered "high" by banks with good-quality assets, i.e., at a net interest rate $(\tilde{\sigma}R)^{-1} - 1$. Historical evidence suggests that this is precisely what was accomplished by issue of clearinghouse loan certificates during the panics of the National Banking Era.[12]

4. Conclusion

Above we have used a very streamlined model to investigate the question of why banks almost always settle payments in cash as opposed to debt. Our model suggests that adverse selection with respect to the quality of bank assets may be the primary motivation underlying this practice. Specifically banks with higher quality assets would prefer not to issue debt if it is indistinguishable from that of banks with lower quality assets. Banks with higher quality assets would prefer to sell off these assets to more informed agents in return for cash, which can then be used in settlement. Willingness to settle in cash serves as a signal of the high quality of a bank's assets; hence in equilibrium all banks settle in cash. If normal information flows are disrupted so that no outsiders are informed about the quality of banks' assets, then the signaling value of cash settlement is lost.

Though the model presented above is clearly limited in scope, we conjecture that our rationale for cash settlement will be robust to more complex economic environments.

[12] Of course the loan certificates were less than completely effective in stemming the spread of panics. Between the Civil War and the outbreak of World War I, there were five panics of sufficient severity to warrant the issue of loan certificates by the New York Clearing House Association (Timberlake [1993, p.204]); three of these panics were followed by severe recessions. However various accounts of these episodes agree that the loan certificates were effective as a medium for interbank settlement.

However, a critical limitation of the current model is that it provides no strong justification for settlement via debt issue, even under conditions where normal information flows become unreliable. A deeper investigation of clearing and settlement under such conditions will likely require closer modeling of the behavior of agents other than banks, i.e., the depositors and merchants in the context of the model presented above. In the current model, the behavior on the part of both depositors and merchants is rational only if these parties believe that their claims to bank assets will always be honored in full. Though there are clearly some conceivable institutional environments that could be consistent with such beliefs (e.g., when all depositors are fully covered by government-sponsored deposit insurance), it would be hard to argue that real-world banking systems are always characterized by such complete confidence on the part of all participants. If deposit claims cannot be honored in some states of the world, then informed depositors or merchants would have an incentive to "cash out" their claims if they had inside knowledge that such states were likely to occur. Such behavior would create an endogenous, though noisy link between perceptions of banks' asset quality and the distribution of withdrawals. If these perceptions were sufficiently skewed, it could pay for banks to accept each other's debt rather than to attempt to sell their assets at fire-sale prices, suggesting that debt settlement may represent an efficient arrangement in some circumstances. A more precise characterization of these circumstances is a topic for future research.

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