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Sequential decisions in the Diamond–Dybvig banking model

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ABSTRACT

We study the Diamond–Dybvig model of financial intermediation (Diamond and Dybvig, 1983) under the assumption that depositors have information about previous decisions. Depositors decide sequentially whether to withdraw their funds or continue holding them in the bank. If depositors observe the history of all previous decisions, we show that there are no bank runs in equilibrium independently of whether the realized type vector selected by nature is of perfect or imperfect information. Our result is robust to several extensions.

1. Introduction

It is very inefficient from a social point of view if fundamentally healthy banks are run, so policy should try to prevent its occurrence. Our paper contributes to the literature on bank runs by proposing a theoretical model in which no bank run is the unique equilibrium outcome in a game in which depositors decide sequentially whether to keep the money in the bank or to withdraw it and where it is commonly known that the bank is healthy. Our result requires an extremely high level of available information about previous choices to prevent this kind of bank runs and our theoretical finding is robust to relaxing some of the informational conditions. We convey a clear message to policy makers by highlighting the importance of making depositors' decisions to keep the money in the bank observable to the remaining depositors in the queue which have not yet decided whether to withdraw their money or not. Improving transparency regarding this issue, for example, by publishing the amount of money kept in the bank at increased maturities would potentially decrease the likelihood of bank runs on healthy banks.

While economic conditions and fundamentals are important factors that determine to a large extent if a bank suffers a run (Gorton, 1988; Calomiris and Mason, 2003), several studies point out convincingly that there are banking panics in periods with no economic distress (Ennis, 2003) and that even banks with good fundamentals experience runs (De Graeve and Karas, 2014).

Our model hinges on the assumption that depositors react to other depositors' observed decisions which is supported by empirical studies. Kelly and O'Grada (2000), Starr and Yilmaz (2007), and Iyer and Puri (2012) empirically analyze real-world bank runs and stress that depositors' observed actions affect their peers' decisions. Notably, in all of these cases the banks that suffered the run were fundamentally healthy, bad news about another bank sparked the run. Experimental evidence also suggests that observability plays an important role in the emergence of bank runs (see, for example, Garratt and Keister, 2009; Schotter and Yorulmazer, 2009; Kiss et al., 2012). Moreover, Kiss et al. (2014) study a small-scale environment resembling the Diamond–Dybvig setup in which bank runs are caused by coordination problems. They find that the more depositors can observe previous decisions, the less likely it is that participants withdraw their funds from the bank. More information about previous decisions seems to reduce the likelihood of

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bank runs. In Garratt and Keister (2009) and Kiss et al. (2014) there were no fundamental problems with the bank and it was common knowledge, so there fundamental problems or negative information about the bank extracted from the behavior of other depositors cannot be behind the runs.

Motivated by the relevance of observability of depositors' decisions even in case of fundamentally healthy banks, we modify the canonical Diamond–Dybvig model (1983) assuming that depositors perfectly observe the actions taken by those who precede them. We model a sequential-move game with a finite number of depositors who contact the bank in an exogenously given fixed order to communicate whether to leave the money deposited or to withdraw it. We assume that there is aggregate certainty about liquidity types, an assumption used by Diamond and Dybvig (1983) and in recent models, such as Ennis and Keister (2009a).[2]

Converting the original Diamond–Dybvig setup in which depositors decide simultaneously into a sequential-move game yields interesting results. When liquidity types and actions are perfectly observed, then no bank run occurs and the Pareto efficient allocation is the unique equilibrium outcome. Our main contribution is to extend this result to the case when the sequence of liquidity types is of imperfect information, that is, a depositor's liquidity type is her private information.

Under perfect information, our result is obtained by backward induction. Waiting (that is, keeping the funds deposited in the bank) dominates withdrawal for the last patient depositor if enough depositors waited before her. Anticipating this decision, the next to last patient depositor's decision is of the same nature, and by moving backwards, all patient depositors wait.

Under imperfect information, the liquidity type vector is randomly selected by nature and is unobserved by the depositors and the bank. Every depositor, as it is her turn to decide, observes previous decisions and forms beliefs about which type vector was selected, or in other words, whether before her withdrawals were due to impatient depositors only or patient ones as well. Based on her observation, on her belief and on the strategy profile, a depositor determines whether it is optimal for her to withdraw or not. Perfect Bayesian equilibrium, as defined by Fudenberg and Tirole (1991), imposes a strong rationality criterion on the strategy profile and belief system. This enables us to obtain a unique prediction on depositors' behavior which coincides with the solution under perfect information. On the equilibrium path, patient depositors wait and impatient ones withdraw. We show also that this result is robust to moderate alterations in the model, the only exception being that information about previous decisions should be highly detailed.

Although we cast our model in a banking environment, run-like phenomena occur in other institutions and markets as well in which investors can easily withdraw their funds or cease to roll over their investment. In such settings our analysis applies analogously. For instance, Northern Rock, the English bank was not first run by depositors, but by large creditors who provided short-term funding to the bank and did not renew it. Run-like episodes also occurred in money-market, hedge and pension funds (Baba et al., 2009), the repo market (Gorton and Metrick, 2012) and even in bank lending (Ivashina and Scharfstein, 2010).

1.1. *Related literature*

In the classic Diamond–Dybvig framework multiple equilibria exist, and the Pareto efficient outcome of no bank run is no unique equilibrium. This suggests that banks are intrinsically fragile and susceptible to self-fulfilling runs. The subsequent literature attempts to identify elements that lead to this kind of fragility. As Ennis and Keister (2010a) point out, it is important to find the ingredients that help understand fragility in models that follow the Diamond–Dybvig tradition as it has relevant consequences for public policy regarding how desirable government-provided safety net elements, like deposit insurance, and other interventions are. Our paper contributes to this understanding by studying the effect of observability that has been mostly disregarded in theoretical papers although the empirical and experimental evidence mentioned above indicates that it matters. The need to introduce observability in models has been suggested by several researchers. For example, Brunnermeier (2001, p. 214) claims that "... withdrawals by deposit holders occur sequentially in reality, [whereas] the literature typically models bank runs as a simultaneous move game."

There are two approaches in the literature to study bank runs: one is game theoretic and the other based on mechanism design. Given certain constraints, the mechanism design strand of the literature studies how to optimally assign consumption to depositors depending on their announcements.[3] For example, Green and Lin (2003) add aggregate uncertainty about liquidity needs to the Diamond–Dybvig framework and assume that depositors know the order in which they have an opportunity to withdraw. The bank updates its belief about the type distribution after each decision and optimizes the contract accordingly. As a result, complex contracts arise that are contingent on the exact sequence of announcements and payments to depositors may be fairly variable. Nevertheless, the Pareto efficient allocation is shown to be the unique equilibrium outcome.[4]

In the game theoretic approach, first the Pareto efficient allocation is found which a social planner would choose if she knew the type vector. Then, the outcome of a game is studied assuming that types are imperfect information. In the Diamond–Dybvig setup with aggregate certainty about liquidity types the first best yields an optimal simple demand deposit contract that determines how much the bank should pay to those who withdraw early and together with the number of early withdrawals consumption in the second period is determined. If the game is specified as a simultaneous-move game, then a bank run and a no bank run equilibrium arise.

Diamond and Dybvig (1983) show that even if the optimal simple demand deposit contract is maintained, the Pareto efficient allocation becomes the unique equilibrium outcome if the simultaneous-move game is complemented by a suspension of convertibility clause. It stipulates that, after a certain number of withdrawals, payment to subsequent depositors is suspended, guaranteeing the bank enough money to pay later. As a consequence, the mere expectation of suspension is enough to rule out bank runs. Ennis and Keister (2009a, 2010b) show that suspension of convertibility is successful only if the bank can commit to use it as announced. The bank may fail to do so, since once a bank run is underway, suspension may not be *ex post* optimal: many depositors receive no money though they need liquidity. The bank may then attend needy depositors which are exempted from suspension as it happened during the deposit freezes in Argentina in 2001 or in the US in March 1933 (see Ennis and Keister, 2009a). During these episodes, payments were rescheduled but made to those who

[2] Diamond and Dybvig (1983) show for the case of stochastic withdrawals that the results found without aggregate uncertainty about liquidity types need not hold.

[3] Usually a direct revelation mechanism is studied: when contacting the bank, depositors tell the bank their type. When a depositor announces to be impatient, the bank assigns her an optimal consumption based on the available information.

[4] Ennis and Keister (2009b) show that this result fails to hold for correlated types.