Bank Runs: a short literature review

Deborah Olukan

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1 Introduction

2 Game Theory

Game theory is the predicting of the outcome of games of strategy in which the competing participants have incomplete information about the others intentions. A classic example of game theory is the prisoners dilemma, in this situation there are two prisoners that are being interrogated to reveal their involvement in a crime; they can either be innocent or guilty. Prisoners are then faced with a choice, either confess or not confess to their participation in the crime, they also have no means of communication. Table 1 is illustrates all possible outcomes in a payoff matrix.

		Prisoner B	
		Confess	Not Confess
Prisoner A	Confess	-2,-2	0, -3
	Not Confess	-3, 0	-1,-1

Table 1: Prisoner's payoff matrix

The **payoff** is the length of prison sentence which is denoted by the negative sign, the higher the number the better.

The 4 possible outcomes of the dilemma are:

- If both **Prisoner A** and **B** *confess*, they go to prison for 2 years.
- If both **Prisoner A** and **B** do *not confess*, they go to prison for 1 year.
- If **Prisoner A** *confesses* and **Prisoner B** chooses to *not confess*: Prisoner A goes free, Prisoner B is sentenced to 3 years
- If **Prisoner B** *confesses* and **Prisoner A** chooses to *not confess*, Prisoner B goes free, Prisoner A is sentenced to 3 years.

The **Dominant Strategy** would be the outcome that has the best payoff, regardless of the other players' strategy. The dominant strategy for both Players would be to *Confess*, regardless of the other players actions.

The **Nash Equilibrium** is a point where players gain no additional benefit from deviating. Based on that definition, in this game we see that the Nash equilibrium is to always *Confess*.

Nonetheless, there are scenarios were two Nash equilibria exist in one setting; this concept of multiple equilibria, is the basis of the Diamond-Dybvig model that we briefly outline in the following section.

3 The Diamond-Dybvig Model

The theoretical literature on bank runs is largely built on the seminal paper by Diamond and Dybvig (1983). The bank is modelled as a liquidity insurance provider that pools depositors' resources to invest in profitable illiquid long-term assets, and at the same time, issues short-term demand deposits to meet the liquidity need of depositors. The mismatch between the bank's assets and liabilities opens the gate to bank runs.

And so, this section will provide a simplistic overview of the Diamond-Dybvig (1983) model of instability; at which their key finding was that bank fragility occurred through an imbalance in assets and liabilities.

As we understand it, we know that Investment requires initial expenditure in order to gain returns in the future. Long term investments, which are usually entities with long maturity and low liquidity, are the most beneficial. Diamond and Dybvig pointed out that, there would be agents that could experience changes in circumstances and they would require cash immediately. These type of agents would demand more liquid accounts, allowing them access to their deposits whenever. Diamond and Dybvig outlined the bank's role as an textitintermediary between **saver** (depositors) agents and **borrower** agents, as bank's provide both long-term viable loans and liquid accounts. Based on this *service* banks gain profits by charging a fee, this fee would be an interest rate.

Diamond and Dybvig 1983 outlined two possible outcomes based on the above sentiment . The first is the based on the assumption that all savers would never demand cash simultaneously, therefore banks would only expect small withdrawals sporadically. This would allow for banks to provides long-term loans, only keeping a small amount as cash reserves. The second outcome is that all savers *do* make a demand for cash simultaneously; in this case savers could only withdraw cash on a *first come, first serve* basis as banks would run out of cash, leaving last saver agents with nothing. As a result In second outcome, if agents expect their counterparts to withdraw their cash, the rational response for agents would be to rush to do same thing but before the others. Diamond-Dybvig coined this ”run on the bank” a self-fulfilling prophecy, were an agent's decision to withdraw was dependent on the expectation of other agents decision. Thus, the Diamond-Dybvig model demonstrated the possibility of multiple Nash equilibriums.

In the first section we explored a simple Prisoners' dilemma game, we will adapt the game to illustrate the popular Diamond-Dybvig multiple equilibria outcome *(See Table 2)*.

Table 2 depicts a scenario were Saver agents *A* and *B* have two options: **Withdraw** or **Not to Withdraw**. In order to identify Saver A's dominant strategy, the most self-serving option, we look for the option with the highest payoff.

	Saver A	
		Withdraw	Do not Withdraw
Saver B	Withdraw	0,0	1,2
	Do not Withdraw	2,1	0,0

Table 2: Savers' payoff matrix

Assuming Saver B *Withdraws*, Saver A can either Withdraw or Not with a pay off of (0,2) respectively. If Saver B does *Withdraw*, Saver A can choose Withdraw or Not with (1,0) payoff, respectively. We see that for both Saver's there is no clear dominant strategy.

However, with regards to identifying the Nash Equilibrium, considering both Saver's options, we find that a combination of **(Withdraw, Withdraw)** and **(Do not Withdraw, Do not Withdraw)** are the best options, as neither Saver can increase their payoff by choosing an action different from their current one.

This is a section briefly discusses some key Diamond-Dybvig ideologies that relate the most to our exploration of information-based bank runs. There are other aspects of the model not outlined here that are of equal importance, so if the reader is interested the full paper can be found in the references section.

4 Literature Review

4.1 Co-ordination failure

Based on the Diamond-Dybvig model, we understand that in a co-ordination failure occurs in a system with multiple equilibria; which means agents fail to coordinate their decision-making. This failure occurs in the existence of payoffs and externalities. Researchers have associated coordination failure with the economic phenomena, sunspot equilibria. There is a substantial amount of literature defining Sunspot equilibria, however, a more general explanation is; a economic equilibrium where the market outcome or allocation of resources varies in a way unrelated to economic fundamentals. Hence, the outcome depends on an extrinsic random variable, meaning a random influence that matters only because people think it matters. A vast amount of the literature suggests that bank runs occur due to sunspot equilibrium, which is what this subsection aims to explore.

Boyd, Gomis, Kwak and Smith (2001) aimed to explore the source of banking crisis and found data supporting the existence of ”sunspots”. They suggest that bank failures could occur independently of fundamental shocks. Boyd et al. 2001 argued for the existence of multiple equilibria in bank failure rates, even in the presence of deposit insurance. They found multiple equilibria could exist in the case of simple shifts in agents? beliefs, in the absence of any exogenous shocks. They added that models based on sunspots or based on exogenous shocks are both likely to predict that banking crises will be associated with contemporaneous recessions, and both are consistent with inflation rendering the banking system more vulnerable to problems. And concluded that bank runs may often be the outcome of coordination failures.

Moreover, Duffy and Fischer (2005) provided direct evidence of the existence of sunspot equilibria; they showed that extrinsic or non-fundamental uncertainty influences markets in a controlled environment. These equilibria require a common understanding of the semantics of the sunspot variable, and they appear to be sensitive to the flow of information. Extrinsic uncertainty matters when information flows slowly, as in a call market, but it need not matter when information flows quickly, as in a double auction where infra-marginal bids and offers are observable. Duffy and Fisher 2005 examined behaviour in an environment with a single good and two equilibria. Subjects are either buyers or sellers, and prices are determined either in a call market or in a double-auction market. The sunspot variable consisted of random announcements about the likely market conditions. The realisations of this random variable bearing on the actual market price, but buyers and sellers can use them to coordinate on one of the two certainty equilibria. They found that a common understanding of how sunspot realisations map into actions would be necessary to observe sunspot equilibria in the laboratory; and were the first to provide direct evidence that extrinsic uncertainty can be an important source of volatility in real markets.

Similarly, Garratt and Keister (2009) explored the factors that make coordination failure more or less likely to occur, in the context of bank runs. They found that agents coordinate on the payoff-dominant equilibrium less frequently in the presence of aggregate uncertainty, even when this uncertainty alone poses little or no threat to the solvency of the bank. Aggregate uncertainty relates to the population's general perception of fundamental withdrawal demand. Also, they added that it mattered whether subjects were given multiple opportunities to withdraw (with feedback) or a single opportunity.

Initially, subjects were equally likely to withdraw at the first opportunity in both treatments, but exposure to bank runs had a greater (positive) effect on future withdrawals in the treatment with multiple withdrawal opportunities.

This result indicates that the standard approach of modelling bank runs using a one-shot, simultaneous-move game may not be the most appropriate one. Finally, exploring the multiple-withdrawal scenario, Garratt and Keister 2009 found that there was a cut-off rule associated to the updating function, which was that increased withdrawals eventually made the panic rule (withdraw immediately) a superior predictor. This suggests that agents did not stop updating but that they stopped believing that others would play their part of the payoff-dominant equilibrium as coordination broke down and bank runs became more prevalent.

Furthermore, Arifovica, Jiang and Xu (2013) proved experimental evidence of bank runs as pure coordination failures. They investigated how the level of coordination requirement affected the occurrence of bank runs ,as a result of coordination failures in controlled laboratory environments. Using human subjects to play bank-run games and ruling out the deterioration of the bank's assets as the source of bank runs; they focused solely on the variation of coordination. Coordination was measured as the amount of coordination that is required for subjects choosing to wait to receive a higher payoff than those who withdraw. Arifovic, Jiang, and Xu 2013 found that the higher the required amount of coordination, the more likely miscoordination-based bank runs occur. The experimental results in the paper suggested that the level of coordination requirement may also be an important factor that affects the occurrence of sunspot behaviour.

Fehr, Heinemann and Llorente-Saguer (2017) experimented on a coordination game with extrinsic random signals that they systematically varied the stochastic process generating these signals, and measured its behavioural effect. Fehr, Heinemann, and Llorente-Saguer 2017 found find that sunspot equilibria emerged naturally if there are salient public signals. However, highly correlated private signals can also lead to sunspot-driven behaviour, even when this is not an equilibrium. Private signals reduce the power of public signals as sunspot variables. The higher the correlation of extrinsic signals and the more easily they can be aggregated, the more powerful these signals are in distracting actions from the action that minimises strategic uncertainty. The evidence suggested that the impact of salient extrinsic signals depended on the informational environment. As long as private signals with low correlation were the only information, subjects quickly learned to ignore them and focus on the action that minimised strategic uncertainty. It needed at least highly correlated private signals to pull actions away from the secure action and generate sunspot-driven behaviour. Such behaviour results in lower rates of coordination and lower payoffs compared to situations without signals. Salient public signals, however, proved to have a substantial impact on collective perceptions and sunspot equilibria reliably show up in an environment where subjects are neither trained nor recommended to follow these signals.

ibid. found that public signals dId not significantly reduce coordination rates or payoffs. In contrast, if public signals were combined with private signals, the power of public signals reduced. Coordination rates and payoffs were lower than in environments with pure private or public signals. Thus, the co-existence of equally salient public and private signals is harmful to coordination and induces payoff losses.

In summary, researchers found the evidence of the existence of sunspot equilibria and coordination failures as a possible source of bank runs. They found it was important to create a more specific definition of sunspot equilibria to understand how it impacts behaviour. There were also papers that found the aggregate uncertainty played a role in bank runs, the higher the exposure the more likely bank runs were to transpire. Researchers also investigated public and private signals as sunspot equilibria, they found highly correlated signals increased the likelihood of bank runs. Finally, researchers found the higher the need for coordination the more likely bank runs were likely to occur.

4.2 Fundamentals failure

The other popular source of a bank run is fundamental failures. Fundamental failure are described as regional, sectoral, or national macroeconomic shocks to bank borrowers, monetary-policy-induced declines in the prices of the bonds held by banks Ennis 2003 Bank runs are exclusively driven by changes in economic fundamentals, such as a deterioration in the return on investment. Also, Gorton 1988 Bank runs associated with recession hypothesis, when there is a downturn in business cycle. ibid. looked at data from national banks and found that panic events are the consequences of extreme realisations of circumstances that explain behaviour during normal times. Moreover, Miron 1986 Bank runs linked to seasonal fluctuations in liquidity needs of depositors, this was defined as the season hypothesis. Saunders and Wilson 1996 and Schumacher 2000 found not all banks will experience panic, solvency issues tends to increase probabilities of depositors running on particular banks. For example, Gorton 1988, Allen and Gale 1998 and Schumacher 2000 show that bank runs have historically been strongly correlated with deteriorating economic fundamentals, which erode away the value of the bank's assets.

4.3 Information-based bank runs

Having explored the two most popular sources of bank runs, this subsection aims to investigate the role of information and consider the existence of information-based bank-runs.

To begin, Jacklin and Bhattacharya (1988) introduced the concept of information-based Bank Runs, which contradicted the original proposals suggesting that bank runs occurred from co-ordination or fundamental failures. They suggested that Information-based panic runs arose from two characteristics of asymmetric information: banks not being able to observe true liquidity needs of agents and that agents were misinformed on the quality of bank assets. The Diamond-Dybvig model suggested that a 'run on the bank' was the result of a lack of deposit insurance on even the less riskier bank assets, whereas Jacklin and Bhattacharya (1988) emphasised that heterogeneity in the perception of "world views" resulted in premature disinvestment of long-lived assets.

In comparison to Diamond and Dybvig, whom suggested bank runs arose from "sunspot" phenomena, Jacklin and Bhattacharya investigated the role private information of bank assets payoff on the part of depositors, played in bank runs. They proved that if there was only one risky asset, information-based runs would occur payoff of the risky asset were poor; this would lead banks to liquidate a greater proportion of these assets. However, Jacklin and Bhattacharya (ibid.) suggested that if agents were more risk averse, only then would the Diamond-Dybvig's sunspot equilibria arise, this would be a *pure* panic bank run. This panic would only occur when and if there was circulation of bad information regarding the outlook of the risky asset.

However, contrary to the findings above, Breeden (1984) reported that if agents were risk averse, they were more likely to reverse hedge: to simply consume less at present in order to invest in an uncertain future. In the context of the Jacklin et al (1988) model, if agents have a more risk averse, bad news about the bank's assets would not lead to bank runs. But if we consider multi-bank systems, information-based bank-runs would exist, as agents could move their cash to "safer" bank environments with no bad information.

Moreover, Chari and Jagannathan (1988) provided an information-theoretic rationale for bank runs, they stated that where the general public observe large withdrawals from the banking system, fear of insolvency develop which result in an increase in withdrawals. Chari and Jagannathan (1988) modelled an environment with two sets of agents: an *Informed* and *Uninformed* group. *Informed* agents would withdraw their funds, when they received information indicating low future returns. *Uninformed* individuals would then have incentive to withdraw based on the observation of others. In addition to these types of agents, there was a cluster of agents that made withdraws for reasons unrelated to information. Chari and Jagannathan (ibid.) named the actions of these non-binary agents the "random realisation", and if the cluster got too large, *uninformed* agents would be misled and precipitate a bank run. Chari and Jagannathan (ibid.) concluded that bank runs could even occur if no one had any adverse information about future returns, all that would fuel bank runs is "random realisation".

Additionally, Bikhchandani, Hirshleifer, and Welch (1992) explored bank runs as an information cascade model. They found that agent's generate information externalities that induce other agents to discard their own personal information and follow the actions of other agents. So far, the literature reviewed indicates a bank run occurring due to the information disadvantage that *uninformed* agents experience due to inaccessibility to information; however, there has been no research suggesting the acquisition of information is a possible factor to bank runs. This opens up a discussion on the importance of understanding the different types of agents' psychology, most especially agents that exhibit follower behaviour.

Furthermore, Chen (1999) expanded on the Diamond-Dybvig "first come, first serve" rule applied it to the information externalities concept. The "first come, first serve" rule creates a negative payoff externality between agents, this forces agents to respond to early noisy information regarding failures. In this Chen (ibid.) model, *informed* agents enjoyed the information advantage over the *uninformed* agents by being able to withdraw earlier in bad states with illiquidity[1]. The *uninformed* agents were at an informational disadvantage so they responded to other sources of information before they gained access to any real information. Similar to Chari and Jagannathan (1988), Chen (1999) suggested that bank runs were triggered by variations in information quality and sources, as well as agents accessibility. Furthermore, rather than defining panic as a *post* mistake, ibid. defined panic as the immediate response agents experienced when they had access to early nice information. Considering the multi-bank system, Chen (ibid.) suggested that bank failures[2] would occur when *uninformed* agents made a 'run on the bank' *before* precise information could arrive.

In the same way, Yorulmazer (2003) continued investigating information externatilies as the source of bank runs, but explored the herd behaviour of depositors, in a dynamic model. Yorulmazer (2003) suggested that bank runs were triggered by the withdrawal decisions of a few number of depositors revealing they have adverse news about the banks performance. In the dynamic model, at an interim stage, agents received a noisy signals about the quality of the bank's portfolio, namely about the return of the risky asset; it was also noted that these signals would be informative but not perfect. Following this agents would then be able to observe the actions of other depositors who moved before them. Considering that information is noisy, the actions of other agents are valuable. Agents then update their belief based on their own personal signal and the actions of other agents. The herd behaviour arises from an agents actions being influenced by the action of another; a few number of agents could decide to withdraw which would eventually lead to more withdrawals, even if there are good prospects of the bank's assets. Yorulmazer (2003) found that in the presence of noisy private information, information externalities and herd behaviour of depositors would also trigger healthy banks.

To continue with the research in herd behaviour, Drehmann, Oechssler and Roider (2004) explored herding behaviour with and without Payoff Externalities. They aimed to experimentally investigate the effects of several different forms of payoff externalities in a standard information-based herding model. They devised two versions of the model. *Version 1* stated that payoff was dependent exclusively on the agent's own decision. *Version 2* introduced 4 different types of payoff externalities: Network, Follower, Early Bird and Hipster[3]. Agents would have to choose between two investment opportunities, where there was only one successful outcome. Agents were able to see decisions of their predecessors, but not private noisy signals.

The payoff externalities were described as followed: Network payoff were in-

[1]These bad states would be scenarios were banks could not fully repay all agents Chen1999

[2]We are considering Bank Runs a type of Bank Failure.

[3]They also considered treatments in which payoff was directly dependent (positively or negatively) on the decisions of others

stances where agents received a payoff if other agents chose the same action as them. The Follower agents would receive a if other agents decided later as a group to chose the same action. The difference between these positive payoffs are that Network agents made decisions independently, whereas Follower agents made the decision together. The negative payoff agents: Early Bird and Hispter, would have to pay each predecessor who made the same decision as them.

Drehmann, Oechssler, and Roider (2004) found that instances were payoff was based positively on another agent's action, they expected longer but fewer runs; having many predecessors, who made the same choice, runs would be shorter but more frequent. They also found that in scenarios were agents could directly observe each others payoff there was strong evidence supporting that the decision of the agent with the highest reputation significantly influences the choice behaviour of later subjects.

Furthermore, Chen and Hasan (2006) investigated the relationship between the transparency of banks and the fragility of the banking system. They showed that information-based bank runs were inefficient as deposit contracts that were designed to provide liquidity, result in inducing depositors to have excessive incentive to withdraw. In their model, agents would decide whether to withdraw early according to their liquidity needs and the information they have on banks. Chen and Hasan (2006) found that transparency of the banking system could make agents more or less patient when given information about their banks. Chen and Hasan (ibid.) conclude that the scenario where agents become less patient and more likely to withdraw, occurs when there is a high correlation between bank returns and information about banks are relatively precise. Chen and Hasan (ibid.) model brings to light an interesting discussion on how transparent banks should be and if they decide to be transparent, how do they ensure agents use this information to make efficient decisions.

Moving on from transparency, but back to signals, Gu (2010) studied the idea that bank runs occur due to imperfect signal extraction. They stated that bank runs occur as a result of depositors who tried to extract information about bank portfolio quality from the withdrawal histories of others. Gu (2010) reported following the Argentinian banking crisis in 1994, the data reviewed indicated that large depositors were responsible for most of the deposit outflows at the beginning, but smaller depositors began to make substantial withdrawals two months after Schumacher. Starr and Yilmaz (2007) had similar findings, they found that there were increased withdrawals by moderate size account holders tended to boost withdrawals of their smaller counterparts. This suggests that observability of agents actions is a key factor of bank runs, agents make decision based on others decision, not only their personal beliefs.

Accordingly, Gu (2010) based his model on the premise that fundamental signals, and signal extraction from the observed withdrawal history, were imperfect. As a result of this, a bank run could even occur when the bank fundamentals are strong. An imperfect signal extraction based bank run could only transpire with non-simultaneous withdrawal decisions.

Gu (2010) proved this by formulating a perfect Bayesian equilibrium in which a depositor withdrew if his expected utility was below his threshold level, otherwise he waited. Expected utility was dependent on the agents beliefs about the quality of the bank's portfolio, and these beliefs are updated recursively by the observed withdrawal history of the other depositors. Gu (2010) found that if the agent's belief were in a intermediate range, the agent followed their private signals: they withdrew if impatient or if the portfolio signal is unfavourable; otherwise, they waited. Consequently, a bank run would occur as a result of the herd of withdrawals when all agents withdrew due to unfavourable signals and/or unfavourable observations on withdrawals. In the case of positive private beliefs, the private signal agents received were not decisive: the agent could have waited to withdraw unless they are impatient. Gu (2010) added that agents' private signals would not have been revealed through his withdrawal behaviour, so withdrawal behaviour could not affect other agents' beliefs or their expected utilities. And so, there would be a 'no bank run' scenario if there was a herd of non-withdrawals.

Gu (2011) investigated the timing of withdraws in relation to bank fragility. Diamond and Dybvig 1983 proposed that withdrawal decisions were made simultaneously. However, in reality we know that at least some withdrawals are made on the information about previous withdrawals of others (Starr and Yilmaz 2007). Ergo, Gu (2011) aimed to create a banking model that allowed agents to choose their withdrawal time. There were three components used in the model: consumption type (patient/impatient), noisy private signals about the quality of the bank's portfolio and withdrawal history of other agents. The signals were received in an exogenously determined sequence, but the timing of withdrawal was determined endogenously. Also, a depositor's simple withdraw-or-not action was not revealed perfectly to others, other depositors could only imperfectly extract the depositor's private signals from their action. Agents, also modelled as depositors, would update their beliefs about the quality of the bank's portfolio accordingly.

Gu (2011) found some of these runs were efficient, in that the bank was liquidated before the portfolio worsened. Others are not efficient; these were cases in which the herd is misled. Agents would make their withdrawal decisions according to their observation of the withdrawal histories of the others as well as their private information about the bank's portfolio. Gu (2011) suggested that the bank would have no information advantage over the depositors, which in reality is not true.

In more sophisticated models, a bank would receive signals about asset returns, there would arise problems such as; how to eliminate the bank's moral hazard problem due to the information asymmetry between the bank and the depositors, and how the bank could reduce the probability of bank runs due to misleading signals. Conversely, Green et al (2003) modelled agents making withdrawal decisions in sequence, without observability of actions; their model did not include aggregate uncertainty, assumed agents report their consumption types truthfully by their actions. Moreover, Gu (2011) assumed there were two dimensions of uncertainty: Consumption uncertainty and asset return uncertainty. Information asymmetry arises between the bank and agents as withdrawal decisions do not fully reveal the private information of an agent.

Equally as important, He and Manela (2014) studied dynamic rumour-based static bank runs with endogenous information acquisition. They looked at the scenario where a liquidity event occurred and a solvent bank became either illiquid with a known probability or remained liquid. This event triggered the spread of a rumour that a liquidity event had occurred exposing the bank to a run. He and Manela (ibid.) suggested that upon hearing the rumour agents waited, fully withdrew and then later redeposited, if the bank survived. He et al (2014) stated that there was a between the marginal benefit of waiting to withdraw and the marginal cost of waiting due to risk of bank failure, when discussing the optimal withdrawal time. He and Manela (ibid.) also added that withdrawal speed was exogenously determined by the rumour spreading speed.

Contrary to the findings of Jacklin and Bhattacharya (1988), He and Manela (2014) found that information-based bank runs occurred through private information acquisition about liquidity. As a consequence, this exposed otherwise "safe" or "healthy banks" to runs, with endogenous waiting, through a "fear-of-bad-signal-agents" effect: agents that were unsure about bank liquidity, worried that agents who receive worse signals would withdraw before them, this increased their own incentive to run.

Kiss, Rodrigues-Lara and Rosa-Garcia (2014) explored whether social networks would prevent of promote bank runs, they also investigated the effect of observability; agents observability of actions was based on their number of connections. In their model there were two types of agents, *patient* and *impatient*, this information would be considered private. Agents would then decide on whether to withdraw sequentially, according to their position in the line. Their positions were determined randomly and exogenously: this suggests that agents would have had the same probability to be at any position. With position independent of agent type, Kiss et al (2014) suggested that a run on the bank could only occur if one patient depositor withdrew.

Kiss et al (2014) further explored how the type of network structures impacted the subsequent agent's action; for example, if the first two agents were linked then no bank run should arise. This link indicated observability, so when there was no link, this suggested no action could be observed and resulted in a bank run (multiple nash equilibia). Hubert Janos Kiss, Rodriguez-Lara, and Rosa-Garcıa 2014 found that a link between agents *1* and *2* (and a *1* and *3* link) significantly reduced the agent *1*'s withdrawal rate. Moreover, agent *2*'s likelihood of withdrawal was significantly lower when they observed a 'waiting' from agent *1*, but higher when they observed a withdrawal. This observation of previous decisions was also important to agent *3*, who was less likely to withdraw if they observed a waiting.

Overall, the results from the experiment suggested that agent *1*'s behaviour was mainly driven by the fact that their action is observable.

An interesting aspect of information-based bank runs unrelated to banking mechanisms, is agent's psychology during bank run. A recent paper by Dijk 2017 investigated the effect of background emotions on agent's behaviour during a bank run scenario. Dijk (2017) induced emotions by letting subjects recollect and then report on an event in their own lives where the target emotion was strongly felt. In this way the emotions of fear, sadness and happiness were induced prior to participation in a Depositor Game where subjects had to decide whether to keep their deposits in a bank or withdraw their deposits, triggering a bank run.

Dijk(2017) found that subjects induced with background fear were significantly more likely to withdraw their deposits in the subsequent bank run scenario, than subjects that participated in an emotionally neutral baseline treatment. Also, only in the treatment where fear was induced were women significantly more likely to withdraw their deposit than men. There was also some evidence that sadness could actually lower the incidence of withdrawal, whereas happiness did not seem to have a significant effect on likelihood of withdrawal. The results indicated that background emotions played a significant role in determining whether agents ended up in a destructive panic-based bank run equilibrium, or whether they refrained from withdrawing during a panic. Thus, further understanding on managing the emotional underpinnings of depositor behaviour during a banking crisis seems both an important topic for future research and policy development. Understanding how different interventions and styles of communication would affect public mood and emotions could be an essential ingredient in preventing the next financial crisis from spreading.

Finally, when exploring agent characteristics, Kiss, Rodriguez-Lara, Rosa-Garcia (2017) provided evidence of the existence of pure Panic bank runs. They highlight that observing other depositors' decisions affected withdrawal choices. They also added that panic behaviour could be regarded as a new source of bank runs and that observing withdrawals distorts depositors' beliefs. They modelled a depositor game with two types of depositors, *patient* and *impatient* that were ordered by their bids, were patient agents earned the highest payoff. They defined a bank run as the point were a patient agent turns impatient and withdraws. In their model, agents had information on the other agents who withdraw and thus knew the agent's type. Hubert J. Kiss, Rodriguez-Lara, and Rosa-Garcia 2017 argued that the order of decisions were not important as patient depositors stayed at a unique equilibrium where they waited; there is no incentive for them to rush. They found that agents overestimated the likelihood of other patient depositor withdrawals, compared to the theoretical prediction and the experimental data. They also found that the patient agents would withdraw upon the observation of a withdrawal. Additionally, more loss averse/younger subjects were more likely to withdraw when they observed withdrawals.

5 Conclusion

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