Asset Transfers and Self-Fulfilling Runs

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Abstract

We introduce a new mechanism that eliminates self-fulfilling runs on a Diamond Dybvig intermediary. If a depositor wants to end their relationship with the intermediary early, they can withdraw goods *or* take ownership of unliquidated assets from the intermediary's balance sheet. We interpret this mechanism as a repo contract or a bankruptcy plan. What frictions prevent intermediaries from transferring assets to depositors? High transaction costs and within-intermediary idiosyncratic return risk. Our results are robust to the introduction of an asset market with adverse selection.

1 Introduction

Are solvent financial intermediaries vulnerable to self-fulfilling runs? The canonical environment for discussing this question is provided by Diamond and Dybvig

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(1983) (henceforth DD), who study a financial intermediary characterized by the ability to pool deposits and the requirement to pay withdrawal requests sequentially. They argue that the intermediary may not be able to provide efficient liquidity insurance to depositors without creating the possibility of a run. We show that this result relies on the implicit restriction that the intermediary can transfer goods but not assets to depositors. We formalize an unrestricted version of their environment and show there exists a simple mechanism that, using asset transfers, eliminates runs. This result suggests that the answer to our initial question depends crucially on whether financial intermediaries can transfer ownership of their assets to depositors. To this end, we enrich the DD environment by introducing relevant frictions. We demonstrate that access to an asset market with adverse selection neither replicates nor hinders the effectiveness of asset transfers for eliminating runs. By contrast, we find that the effectiveness of the asset transfer relies on sufficiently low transaction costs and within-intermediary idiosyncratic return risk.

In the DD environment, there are two main periods and an intermediary with holdings of an asset. The asset can be liquidated in the earlier period or held until the later period for a positive return. Depositors privately know their liquidity type: impatient and only able to consume in the earlier period or patient and able to consume in either period. In the DD demand deposit mechanism, depositors arrive sequentially in the earlier period and the intermediary offers two options: withdraw goods for immediate consumption or come back in the later period to receive a pro rata share of the return on the intermediary's asset holdings. The intermediary wants to provide liquidity insurance, which effectively allocates more assets to each impatient depositor than to each patient depositor. This creates the possibility of a self-fulfilling run in which patient depositors withdraw goods early because they are concerned others are doing the same and that the intermediary will therefore become insolvent.

We propose an alternative mechanism, in which the intermediary offers depositors the original two options as well as a third: immediately taking ownership of an asset from the intermediary's balance sheet. We refer to the third option as an "asset transfer". Although to our knowledge, asset transfers have not been discussed in the DD literature, we believe there is nothing in the original environment preventing their use.[1] Our main result is that this mechanism allows the intermediary to provide optimal liquidity insurance without introducing the possibility of a run. Conceptually, our mechanism says to depositors: if you are worried about a run and don't need to consume immediately, then you can swap your claim on the intermediary for a claim directly on the intermediary's assets. An appealing feature is that, in most cases, depositors don't choose asset transfers in equilibrium. Instead, the asset transfer acts as an off-equilibrium option that allays any fear of patient depositors running and withdrawing goods early.

The asset transfer has many real world interpretations. A literal interpretation is a repurchase agreement (repo contract), in which the intermediary (borrower) gives the depositor (lender) an asset (collateral) that can be kept if the depositor is worried about a run. Importantly, like in a repo contract, even if the intermediary goes bankrupt and has outstanding liabilities, the depositor maintains ownership of the asset. Although we do not see these arrangements in the retail banking sector, they are prevalent in the wholesale banking sector, which operates beyond the remit of deposit insurance.[2] Alternatively, the asset transfer can be interpreted as part of a bankruptcy plan that gives depositors the option to progressively disassemble the intermediary if they believe it will become insolvent. This has a flavor of the requirement in the Dodd-Frank Act that intermediaries have a plan for how to dismantle efficiently. This interpretation is appealing because the progressive break up of the intermediary is already inherent to the finite horizon setting of the DD model. We simply bring the dissolution of the intermediary into an earlier period. Finally, we can also interpret asset transfers as giving depositors units of a securitized port-

[1]For a thorough discussion and interpretation of the essential features that characterize the DD environment, see Wallace (1988).

[2]See Pozsar et al. (2010) and Pozsar (2014).

folio or stakes in a mutual fund of the intermediary's assets.

A clear implication of our main result is that the self-fulfilling run literature should focus more on the frictions involved in transferring assets. As such, to understand when an intermediary—particularly one funded through repo—is run prone, we extend the original environment in three ways. First, we introduce an asset transfer cost, which we interpret as a transaction or bankruptcy cost or as capturing that depositors are less efficient holders of the asset[3]. We show that the asset transfer can only eliminate runs if this cost is sufficiently low.

Second, we eliminate the ability to directly liquidate assets and instead introduce an asset market with intermediaries selling assets of unobservable heterogeneous quality. This allows us to address the concern that the DD environment contains implicit asset trading frictions that, if made explicit, would make asset transfers ineffective at eliminating runs. Asset trading frictions may be thought to be implicit for two reasons: as a foundation for the liquidation cost in the original model and to prevent hidden trading from unwinding the insurance provided by the intermediary[4]. We find that asset transfers are still necessary for preventing runs because, unlike relying on trading, they allow the intermediary to provide different depositors with allocations of different market values. Moreover, the asset transfer's effectiveness is not hindered by adverse selection in the asset market because transferring assets allows a healthy intermediary to directly offer its high return to its patient depositors.

Third, we introduce idiosyncratic return risk within an intermediary. The intermediary can create a fully diversified portfolio, but can only transfer units of the asset that still bear risk. We show that if idiosyncratic return risk is sufficiently large—even without any aggregate risk—then an asset transfer that risk-averse patient depositors prefer over taking goods is too expensive and asset transfers cannot

[3] For example, in papers on delegated monitoring, such as Diamond (1984) and Williamson (1986), individual depositors must pay higher monitoring costs than an intermediary that pools resources.

[4] See Jacklin (1987) and Farhi et al. (2009).

prevent runs. This seems particularly relevant in light of the recent work by Ospina and Uhlig (2018), which shows that the increase in the average loss rate on mortgage backed securities during the 2007-2009 financial crisis was relatively low compared to the increase in the dispersion of loss rates.

Our extension with idiosyncratic return risk contributes to a literature showing that small changes in an asset's return distribution can have large effects on its value as collateral. Gorton and Pennacchi (1990), Dang et al. (2012), and Gorton and Ordoñez (2012) argue that during financial crises, uninformed investors are concerned they will end up holding low quality assets. In these models, small changes in an asset's return distribution can make the asset "information sensitive". Goldstein and Pauzner (2005) and Huang (2013) show that shocks to the aggregate return on an intermediary's assets can lead to runs. We provide another explanation for this amplification by showing that an intermediary can become run prone if its assets experience an increase in idiosyncratic return risk, even if the aggregate return is unchanged.

It is illustrative to compare our paper to Jacklin (1987), which introduces an equity contract that, at first glance, may appear similar to our asset transfer. There are two key differences. First, the equity contract in Jacklin (1987) is a claim on the residual holdings of the intermediary, whereas our asset transfer is effective exactly because it delivers a claim on future goods independent of the intermediary and so ends a depositor's relationship with a failing intermediary. Second, unlike our asset transfer, the equity contract relies on ex-post depositor trade to deliver different allocations to impatient and patient depositors, which constrains those allocations to deliver the same market value (preventing any provision of insurance under the generalized preferences in Jacklin (1987)).

Formally, our approach follows a literature, pioneered by Green and Lin (2000, 2003) and Peck and Shell (2003), which focuses on whether a mechanism designer—interpreted as a competitive financial sector—facing the essential features of the DD "banking" environment can strongly implement the first-best allocation. We are most related to the papers in this literature that propose indirect mechanisms to solve the run problem, such as Andolfatto et al. (2014) and Cavalcanti and Monteiro (2016). We make two contributions. First, our mechanism does not require the same level of commitment as do other indirect mechanisms. In Andolfatto et al. (2014), the intermediary must commit to punishing some depositors who choose the third option even though doing so will not be ex-post optimal. In Cavalcanti and Monteiro (2016), the intermediary uses the third option in their indirect mechanism to extract information, from an arbitrarily small collection of depositors, to work out whether to freeze deposits. Hence, their mechanism as well as other mechanisms that essentially use withdrawal freezes, such as in De Nicolo (1996), are subject to the commitment problems described in Ennis and Keister (2009, 2010). Second, our mechanism has a simple real world interpretation that allows us to develop new criteria for whether intermediaries are subject to self-fulfilling runs. Moreover, it suggests a new direction for future research: investigating the difficulties involved in creating and transferring assets.

Our paper is structured as follows. In section 2, we set up the DD environment, define our mechanism, and prove our main result. In section 3, we introduce an asset market with adverse selection. In section 4, we introduce idiosyncratic return risk. In section 5, we conclude.

2 The Classic Model

2.1 The Environment

We consider the classic DD environment with a sequential service constraint formalized in the manner of Wallace (1988). There are three time periods, $t = 0, 1, 2$, and a continuum of depositors indexed by $i \in [0, 1]$. Each depositor i has preferences given by

$$U(c_{i,1}, c_{i,2}; \theta_i) = \begin{cases} u(c_{i,1}), & \text{if } \theta_i = I \\ u(c_{i,1} + c_{i,2}), & \text{if } \theta_i = P \end{cases}$$

where $c_{i,t}$ represents depositor i's consumption in period t of the good and $\theta_i \in \{I, P\}$ is the depositor's type. If $\theta_i = I$, then depositor i is impatient and only cares about consumption in period 1. If $\theta_i = P$, then depositor i is patient and cares about total consumption across periods 1 and 2. A depositor's type is revealed to them at $t = 1$ and is private information. Denote by λ the probability that a depositor is impatient. By the law of large numbers, λ is also the fraction of depositors who are impatient, so there is no uncertainty about the aggregate type distribution. The function u is twice differentiable, strictly increasing, strictly concave, and has the property that, for all $c \geq 0$, $-cu''(c)/u'(c) > 1$.

Each depositor is endowed with one unit of the consumption good in period 0. Depositors have access to a constant returns to scale investment technology for transforming the endowment into the consumption good in later periods. An investment in period zero yields a return of $R > 1$ units of the good in period 2 per unit of the good invested. If the project is interrupted in period 1, before completion, it yields 1 unit of the good per unit invested. It is useful to think of this investment as generating a perfectly divisible asset that allows the holder, in period 1, to make an irreversible choice between 1 unit of the good per unit of the asset in period 1 and R units of the good per unit of the asset in period 2. If the holder chooses to receive goods in period 1, then we say the asset has been liquidated.

There is also an intermediary in which depositors can pool resources to manage liquidity risk. In period 0, endowments are deposited and invested, which generates an intermediary balance sheet in period 1 consisting of a unit measure of the asset described above. In period 1, depositors cannot interact with each other and each depositor contacts the intermediary once. Upon contact, the intermediary offers a menu of options. In period 2, depositors can interact with each other and the intermediary freely. At the beginning of period 1, each depositor is allocated a place in line $s \sim U[0,1]$ independent of their type, where s represents the proportion of depositors ahead of them. When a depositor interacts with the intermediary, all they observe are the options offered. In particular, they neither observe their own place in line nor the actions of previous depositors. The depositor selects one of the options and the intermediary can make an immediate transfer. The depositor and intermediary do not interact again until the following period. These restrictions placed on the intermediary are called the "sequential service constraint".

The environment described thus far captures all the features from the original DD model, as conceptualized by Wallace (1988): (i) depositors are either *impatient* and only value consumption in the earlier period or *patient* and value consumption in each of the two periods, (ii) each depositor's realized patience type is private information, (iii) investments cannot be restarted after being converted into goods, and (iv) in the earlier period, depositors are isolated and successively visit the intermediary once. We believe the literature has interpreted the third feature as implying that the intermediary cannot transfer ownership of the asset to a depositor without liquidating. We disagree and instead make this implicit restriction explicit with a per unit asset transfer cost of ε units of the consumption good. If the intermediary transfers 1 unit of the asset, then it must liquidate another ε units of its asset holdings to cover the cost. We view previous papers in the literature as implicitly setting $\varepsilon = \infty$.

2.2 Unconstrained Social Planner

Suppose there is a benevolent social planner who can observe depositor types and directly control allocations. The social planner maximizes depositors' period 0 expected utility subject to the aggregate resource constraint. DD show that the first-best (FB) allocation satisfies:

$$(c_{i,1}, c_{i,2}) = \begin{cases} (c_1^*, 0), & \text{if } \theta_i = I \\ (0, c_2^*), & \text{if } \theta_i = P \end{cases}$$

where c_1^* and c_2^* satisfy the Euler equation $u'(c_1^*) = Ru'(c_2^*)$ and the aggregate resource constraint $(1-\lambda)c_2^* = R(1-\lambda c_1^*)$. Since $R > 1$ and the coefficient of relative risk aversion is always strictly greater than 1, it follows that $1 < c_1^* < c_2^* < R$. These inequalities demonstrate that the planner provides insurance for agents' type risk, which can be interpreted as liquidity insurance.

2.3 Constrained Social Planner

Following Green and Lin (2000, 2003), we use a mechanism design approach to investigate which outcomes can be achieved by a constrained planner in the environment described in section 2.1. The constrained planner faces the sequential service constraint and an information asymmetry about each depositor's type.

The state space is $\Omega^{[0,1]}$, where $\Omega = \{I, P\} \times [0,1]$ has typical element $\omega = (\theta, s)$, which consists of a depositor's private type $\theta \in \{I, P\}$ and their place in line s.[5] Let $\mathscr{A}$ denote the action space for each depositor. The action profile of all depositors is denoted $\mathbf{a} \in \mathscr{A}^{[0,1]}$ and a_s is the action of the depositor at place s in line. An outcome function is a mapping $g : \mathscr{A}^{[0,1]} \times [0,1] \to \mathbb{R}_+^3$. It specifies that if depositors play $\mathbf{a}$, then the depositor at position s gets allocation

$$g(\mathbf{a}, s) = (c_1(a_s, s; \mathbf{a}), c_2(a_s, s; \mathbf{a}), \kappa(a_s, s; \mathbf{a})),$$

where $c_t(a_s, s; \mathbf{a})$ is the units of the consumption good given to the depositor in period t and $\kappa(a_s, s; \mathbf{a})$ is the units of the asset transferred to the depositor in period

[5] For a space M, the notation $M^{[0,1]}$ denotes the space of mappings $f : [0,1] \to M$.

1.[6] A mechanism is a pair $\Gamma = (\mathscr{A}, g)$. The constrained social planner is restricted to choose a sequential service feasible mechanism:

Definition 1 (**Sequential Service Feasible Mechanism**). Let $B(s;\mathbf{a})$ denote the measure of the intermediary's holdings of the asset at place s if depositors play $\mathbf{a}$. A mechanism $\Gamma = (\mathscr{A}, g)$ is sequential service feasible if for all action profiles $\mathbf{a} \in \mathscr{A}^{[0,1]}$, the outcome function satisfies:

1. Budget feasibility: $\int_0^1 c_2(a_s, s; \mathbf{a}) ds \leq RB(1; \mathbf{a})$

2. Sequential service constraint: The period 1 payouts to the depositor at place s in line, $c_1(a_s, s; \mathbf{a})$ and $\kappa(a_s, s; \mathbf{a})$, can only depend on s itself and $\{a_l : l \leq s\}$, the actions of depositors at place up to and including s.

We use the Bayes Nash Equilibrium (BNE) concept to discuss implementation. The definition of implementation is standard.[7] The mechanism induces the following game. Each depositor chooses a mixed strategy that can depend on whether they are patient, $\theta \in \{I, P\}$, and the options they are offered, but not explicitly on the actions of previous depositors or on their place in line, s. In a BNE, depositors play an action $a \in \mathscr{A}$ to maximize their expected utility, taking $\mathbf{a} \in \mathscr{A}^{[0,1]}$ as given since they have measure zero.

We focus on the implementation of social choice functions in which each depositor's allocation depends only on whether they are impatient or patient, i.e. their allocation is given by $h : \{I, P\} \to \mathbb{R}^3_+$.[8] The mechanism Γ **weakly implements** the social choice function characterized by h if there exists a BNE of the game induced by Γ in which impatient depositors receive $h(I)$ and patient depositors receive $h(P)$.

[6]These are the only three objects in the economy, so this is as general an outcome space for g as possible.

[7]For example, see Palfrey (1993).

[8]Indeed, we only consider the implementation of the unconstrained first-best allocation, which is of this form.

The mechanism Γ **strongly implements** the social choice function if, in every BNE of the game induced by Γ, depositor allocations are given by h.

The canonical question in the DD literature can be phrased as: does there exist a sequential service feasible mechanism that strongly implements the first-best allocation? If this is not the case, then we say the environment is "fundamentally unstable" since we cannot achieve the first-best without introducing the possibility of suboptimal equilibria.

2.4 Demand Deposit Mechanism

DD and most of the subsequent literature study mechanisms with the direct action space $\{W_G, W_0\}$[9], where W_G represents withdrawing goods in period 1 and W_0 represents waiting to withdraw goods in period 2.[10] Their original (demand deposit) mechanism Γ_D has outcome function

$$\left(c_1^D(a_s,s;\mathbf{a}), c_2^D(a_s,s;\mathbf{a}), \kappa^D(a_s,s;\mathbf{a})\right) = \begin{cases} \begin{bmatrix} (c_1^*,\, 0,\, 0), & \text{if } B(s;\mathbf{a}) > 0 \\ (0,\, 0,\, 0), & \text{if } B(s;\mathbf{a}) = 0 \end{bmatrix}, & \text{if } a_s = W_G \\ (0,\, RB(1;\mathbf{a})/m_0,\, 0), & \text{if } a_s = W_0 \end{cases}$$

where m_0 is the fraction of depositors who choose W_0 and

$$B(s;\mathbf{a}) = 1 - \int_0^s c_1^D(a_s,s;\mathbf{a})ds$$

[9]Technically, DD allow depositors to withdraw a fraction in period 1. However, this is equivalent to the setup here because we have a continuum of depositors and allow for mixed strategies. $\{W_G, W_0\}$ can be thought of as a direct action space because it has the same dimension as the type space.

[10]Notable exceptions are Andolfatto et al. (2014) and Cavalcanti and Monteiro (2016), who also propose indirect mechanisms.

is the measure of the intermediary's holdings of the asset remaining at place s. DD prove that the mechanism Γ_D is sequential service feasible and weakly implements the first-best allocation. More specifically, they show that the game induced by Γ_D has a "truth telling" BNE as well as a "run" BNE. In the truth telling BNE, impatient depositors choose W_G, patient depositors choose W_0, and the allocation is the first-best. In the run BNE, all depositors choose W_G in period 1 and the intermediary runs out of resources before the end of the line (i.e., there exists an $\bar{s} < 1$ such that $B(\bar{s};\mathbf{a}) = 0$ and so all depositors in places $s \geq \bar{s}$ receive no goods in either period).

2.5 Asset Transfer Mechanism

We define an asset transfer mechanism Γ_K that makes use of the intermediary's ability to transfer ownership of units of the asset. Let the action space be $\{W_G, W_0, W_K\}$, where the actions W_G and W_0 have the same interpretations as before and the new action W_K transfers ownership of κ units of the intermediary's holdings of the asset to the depositor (without liquidating those units of the asset). The outcome function is defined by

$$\left(c_1^K(a_s,s;\mathbf{a}), c_2^K(a_s,s;\mathbf{a}), \kappa^K(a_s,s;\mathbf{a})\right)$$
$$= \begin{cases} \begin{bmatrix} (c_1^*,\, 0,\, 0), & \text{if } B(s;\mathbf{a}) > 0 \\ (0,\, 0,\, 0), & \text{if } B(s;\mathbf{a}) = 0 \end{bmatrix}, & \text{if } a_s = W_G \\ \begin{bmatrix} (0,\, 0,\, \kappa), & \text{if } B(s;\mathbf{a}) > 0 \\ (0,\, 0,\, 0), & \text{if } B(s;\mathbf{a}) = 0 \end{bmatrix}, & \text{if } a_s = W_K \\ (0,\, RB(1;\mathbf{a})/m_0,\, 0), & \text{if } a_s = W_0 \end{cases}$$

where κ is a single number[11] and, if we let $\varepsilon \geq 0$ be the per unit cost of transferring the asset, then

$$B(s;\mathbf{a}) = 1 - \int_0^s c_1^K(a_s, s; \mathbf{a})ds - (1+\varepsilon)\int_0^s \kappa^K(a_s, s; \mathbf{a})ds$$

is the measure of the intermediary's holdings of the asset left at place s. By construction, Γ_K is sequential service feasible.

It follows immediately from depositor preferences that impatient depositors liquidate any asset holdings in period 1 and patient depositors do not. We take this optimal decision as given for the remainder of the paper.

Theorem 1. *Γ_K can strongly implement the first-best allocation if and only if $\varepsilon < c_2^*/c_1^* - 1$.*

Proof. Necessity: We show the contrapositive that if $\varepsilon \geq c_2^*/c_1^* - 1$, then Γ_K cannot strongly implement the first-best (FB). If $\varepsilon \geq c_2^*/c_1^* - 1$, then $(c_1^*/R, c_2^*/(R(1+\varepsilon))]$ is empty, so it must be that either $\kappa \leq c_1^*/R$ or $\kappa > c_2^*/(R(1+\varepsilon))$. If $\kappa \leq c_1^*/R$, then Γ_K does not strongly implement the FB. In this case, both impatient and patient depositors weakly prefer to choose W_G over W_K. Hence, as in the game induced by Γ_D, there exists a BNE in which all depositors choose W_G and the FB is not achieved.

Next, we show that if $\kappa > c_2^*/(R(1+\varepsilon))$, then Γ_K does not strongly implement the FB. In this case, there exists a non-FB BNE in which impatient and patient depositors choose whichever of W_K and W_G gives them higher utility (and mix in any proportion if they are indifferent) and the intermediary runs out of resources strictly before the end of period 1. To see this, suppose depositors mix only between W_K and W_G and let α and β be the probabilities with which impatient and patient

[11] In Appendix A, we prove Lemma 1, which shows that this restriction does not affect whether the first-best is strongly implementable.

depositors choose W_G, respectively. For convenience, define

$$\tilde{B}(s;\mathbf{a}) = 1 - \int_0^s c_1^* \mathbb{1}_{\{a_s = W_G\}} ds - (1+\varepsilon) \int_0^s \kappa \mathbb{1}_{\{a_s = W_K\}} ds,$$

which is the measure of the intermediary's holdings of the asset that theoretically would be left at place s (possibly negative) if the intermediary were to pay out c_1^* units of the consumption good to each depositor who chooses W_G and κ units of the asset to each depositor who chooses W_K, regardless of the value of $B(s;\mathbf{a})$. If $\tilde{B}(s;\mathbf{a}) \geq 0$, then $B(s;\mathbf{a}) = \tilde{B}(s;\mathbf{a})$. If $\tilde{B}(s;\mathbf{a}) < 0$, then $B(s;\mathbf{a}) = 0$. Now, we will show that, given α and β, there exists an $s_0 \in (0,1)$ such that $\tilde{B}(s_0;\mathbf{a}) = 0$. First, $\tilde{B}(0;\mathbf{a}) = 1$. Moreover,

$$\tilde{B}(1;\mathbf{a}) = 1 - \lambda(\alpha c_1^* + (1-\alpha)(1+\varepsilon)\kappa) - (1-\lambda)(\beta c_1^* + (1-\beta)(1+\varepsilon)\kappa).$$

We can only have $\alpha < 1$ if impatient depositors weakly prefer to choose W_K over W_G, which requires that $\kappa \geq c_1^*$, which implies that $(1+\varepsilon)\kappa \geq c_1^*$. It follows that either $\alpha = 1$ or $\alpha < 1$ and $(1+\varepsilon)\kappa \geq c_1^*$. Hence,

$$\alpha c_1^* + (1-\alpha)(1+\varepsilon)\kappa \geq c_1^*.$$

Furthermore, both c_1^* and $(1+\varepsilon)\kappa$ are strictly greater than c_2^*/R. As such,

$$\beta c_1^* + (1-\beta)(1+\varepsilon)\kappa > c_2^*/R.$$

Bringing the two inequalities together yields

$$\begin{aligned}
\tilde{B}(1;\mathbf{a}) &< 1 - \lambda c_1^* - (1-\lambda)c_2^*/R \\
&= 1 - \lambda c_1^* - (1 - \lambda c_1^*) \\
&= 0,
\end{aligned}$$

where the second line follows from the fact that optimality of the FB implies that the resource constraint, $(1-\lambda)c_2^* \leq R(1-\lambda c_1^*)$, binds. It then follows from the continuity of $\tilde{B}(s;\mathbf{a})$ in s that there exists an $s_0 \in (0,1)$ such that $\tilde{B}(s_0;\mathbf{a}) = 0$ and so $B(s_0;\mathbf{a}) = 0$. As such, the intermediary has a measure 0 of the asset remaining at the end of period 1, i.e. $B(1;\mathbf{a}) = 0$, and any depositor choosing W_0 gets 0 units of the consumption good in period 2. Therefore, all depositors weakly prefer to choose one of W_G and W_K, which implies that impatient and patient depositors choosing whichever of W_G and W_K gives them higher utility forms a BNE. This BNE does not achieve the FB because a positive measure of depositors with sufficiently large s ($s > s_0$) receive 0 units of the consumption good in both periods 1 and 2.

This argument also shows that $(1+\varepsilon)\kappa < 1$ is not sufficient for Γ_K to strongly implement the FB. If $(1+\varepsilon)\kappa \in (c_2^*/R, 1)$ and all depositors choose W_K, then the intermediary will not run out of resources before the end of period 1. However, in this case, since $c_1^* > 1$, all impatient depositors will choose W_G. Then, the intermediary will not have sufficient resources to provide κ (and certainly not c_1^*) to each patient depositor because

$$(1-\lambda)(1+\varepsilon)\kappa + \lambda c_1^* > (1-\lambda)c_2^*/R + \lambda c_1^* = 1.$$

<u>Sufficiency:</u> We now show that if $\varepsilon < c_2^*/c_1^* - 1$, then there exists a choice of κ such that Γ_K strongly implements the FB. If $\varepsilon < c_2^*/c_1^* - 1$, then $(c_1^*/R, c_2^*/(R(1+\varepsilon))]$ is non-empty. Let $\kappa = c_2^*/(R(1+\varepsilon))$. Since $\kappa \leq c_2^*/R < c_1^*$, impatient depositors have a strictly dominant strategy: W_G. Moreover, since $c_2^*/(R(1+\varepsilon)) > c_1^*/R$, we have that $R\kappa > c_1^*$ and patient depositors strictly prefer to choose W_K over W_G. It follows that impatient depositors choose W_G and patient depositors mix between W_K and W_0. Suppose patient depositors choose W_K with probability β. Then, the measure

of the intermediary's holdings of the asset at the end of period 1 is

$$\begin{aligned} B(1;\mathbf{a}) &= 1-\lambda c_1^* - (1-\lambda)\beta(1+\varepsilon)\kappa \\ &= 1-\lambda c_1^* - (1-\lambda)\beta\frac{c_2^*}{R} \\ &= (1-\lambda)(1-\beta)\frac{c_2^*}{R}, \end{aligned}$$

where the last equality follows from the fact that the resource constraint binds in the FB. As such, depositors who choose W_0 receive

$$\frac{B(1;\mathbf{a})}{(1-\lambda)(1-\beta)} = c_2^*$$

units of the consumption good in period 2. If $\varepsilon > 0$, then $\kappa = c_2^*/(R(1+\varepsilon)) < c_2^*/R$ and, for any $\beta \in [0,1]$, W_0 is a strictly dominant strategy for patient depositors. In this case, the unique BNE of the game induced by Γ_K consists of impatient depositors choosing W_G and patient depositors choosing W_0 and yields the FB allocation. Alternatively, if $\varepsilon = 0$, then $\kappa = c_2^*/R$ and, for all $\beta \in [0,1]$, patient depositors are indifferent between choosing W_K and W_0. As such, for all $\beta \in [0,1]$, there exists a BNE in which impatient depositors choose W_G and patient depositors mix over W_K and W_0, choosing W_K with probability β. These are all the BNE and each yields the FB allocation.

As an aside, the above arguments show that if Γ_K strongly implements the FB, then the FB is also the unique outcome that survives the iterated deletion of strictly dominated strategies. $\square$

To understand this proof, it is helpful to recall why a run can occur in the demand deposit mechanism. The first-best allocation is exactly budget feasible if the impatient depositors choose W_G and the patient depositors choose W_0. In this case, which we call "truth telling", the intermediary provides insurance by liquidating $c_1^* > 1$ units of the asset for each impatient depositor and keeping the remaining assets, $1 - \lambda c_1^*$, to provide $c_2^* < R$ units of the good to each patient depositor in period 2. Since $c_1^* > 1$, if a sufficiently large fraction of patient depositors choose W_G, then the intermediary's holdings of the asset are depleted before all depositors have been served and any depositors who choose W_0 receive nothing. Thus, it is not incentive compatible for a patient depositor to choose W_0 if sufficiently many other patient depositors choose W_G.

Now consider the asset transfer mechanism when ε is sufficiently small so that the intermediary can choose a κ that satisfies $c_1^*/R < \kappa = c_2^*/(R(1+\varepsilon))$. For any depositor strategy profile, all impatient depositors strictly prefer to choose W_G over W_K or W_0 and all patient depositors strictly prefer to choose W_K over W_G. Hence, the only possible incentive compatible deviation from truth telling is for patient depositors to choose W_K. Since $(1+\varepsilon)\kappa < c_2^*/R$, if a positive measure of patient depositors choose W_K, then unlike if they were to choose W_G, the intermediary is left at the end of period 1 with *more* units of the asset per patient depositor who chose W_0. In this sense, W_K is an off-equilibrium path option that, by strictly dominating W_G for patient depositors, ensures that it is always incentive compatible for patient depositors to choose W_0. As such, the indirect mechanism Γ_K is able to strongly implement the first-best while the direct mechanism Γ_D cannot.[12] Finally, when $\varepsilon = 0$ and $\kappa = c_2^*/R$, then W_K can be played in equilibrium and a direct mechanism is able to strongly implement the first-best. If the asset transfer is costless, then in period 1, the intermediary can conclude its relationships with *all* depositors by giving units of the good to impatient depositors and units of the asset to patient

[12]Note that, in this context, the revelation principle does not imply that the restriction to direct mechanisms is without loss of generality. As discussed in Palfrey (1993), it is possible that an indirect mechanism strongly implements the first-best whereas the direct mechanism only weakly implements the first-best.

depositors.[13]

Theorem 1 shows that if the asset transfer cost is sufficiently large, then the asset transfer mechanism cannot strongly implement the first-best. The following corollary shows that if $\varepsilon < R-1$, then asset transfers still allow the intermediary to provide some insurance without creating the possibility of a run. Consider allocations in which an impatient depositor consumes $\bar{c}_1$ goods in period 1 and a patient depositor consumes $\bar{c}_2$ goods in period 2. Consider the case in which the allocation is incentive compatible, budget feasible, and provides insurance, i.e. $1 < \bar{c}_1 \leq \bar{c}_2 < R$.

Corollary 1. *The demand deposit mechanism weakly implements $(\bar{c}_1, \bar{c}_2)$ and there is an equilibrium in which all depositors run. The asset transfer mechanism can strongly implement $(\bar{c}_1, \bar{c}_2)$ as long as $\bar{c}_1/\bar{c}_2 < 1/(1+\varepsilon)$.*

Proof. The first statement follows from the same argument that shows there is a run in the original demand deposit mechanism. The second statement follows from the proof of Theorem 1. □

Figure 1 shows the maximum degree of insurance that an intermediary using the asset transfer mechanism can provide without fear of a run, as a function of the asset transfer cost. If $\varepsilon < c_2^*/c_1^* - 1$, then the asset transfer mechanism can strongly implement first-best insurance, $\bar{c}_1/\bar{c}_2 = c_1^*/c_2^*$. If $\varepsilon \geq R-1$, then asset transfers are not useful because the return they offer patient depositors is outweighed by the transfer cost. In that case, the asset transfer mechanism, like the demand deposit mechanism, can only strongly implement autarky, $\bar{c}_1/\bar{c}_2 = 1/R$.

Remark on Possible Interpretations: A literal interpretation of the asset transfer mechanism is a repurchase agreement (repo contract). To see this more clearly, sup-

[13] The intermediary has two options, transferring the asset immediately and transferring the good immediately, one of which is relatively more valuable to patient depositors, the other of which is relatively more valuable to impatient depositors, and neither of which has a value dependent on the actions of other depositors. With these two options, the intermediary can separate impatient and patient depositors into their FB allocations without creating the possibility of a run.

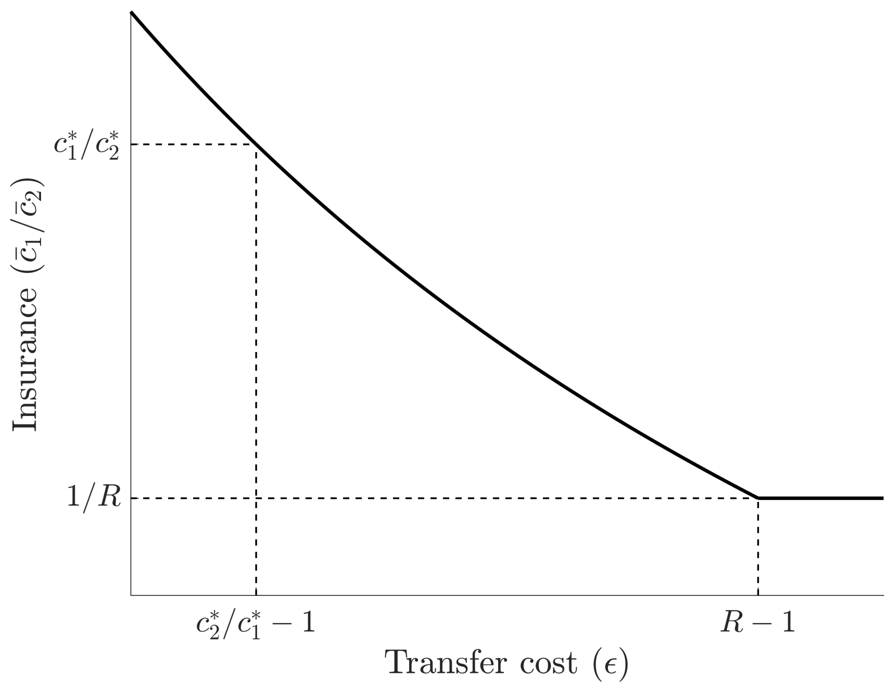

Figure 1: The line depicts the maximum degree of insurance the asset transfer mechanism can provide (measured by $\bar{c}_1/\bar{c}_2$) as a function of the asset transfer cost. Autarky is $\bar{c}_1/\bar{c}_2 = 1/R$. First-best insurance is $\bar{c}_1/\bar{c}_2 = c_1^*/c_2^*$. When the transfer cost is less than $c_2^*/c_1^* - 1$, the intermediary can but does not want to provide more than first-best insurance.

pose the intermediary executes the mechanism by doing the following. In period 0, each depositor keeps κ units of the asset and gives $1-\kappa$ units to the intermediary. In period 1, if a depositor chooses W_G or W_0, then the intermediary repurchases the depositor's holdings of the asset using period 1 goods or the promise of period 2 goods, respectively. If a depositor chooses W_K, then they end the repurchase agreement and walk away with their κ units of the asset. Alternatively, the asset transfer can be interpreted as part of a bankruptcy plan that gives depositors the option to progressively disassemble the intermediary if they believe it will become insolvent. Finally, we can interpret asset transfers as giving depositors units of a securitized portfolio or stakes in a mutual fund of the intermediary's assets. Depending on the interpretation, it may make sense to think of the asset transfer cost as a transaction cost, a bankruptcy cost, a penalty cost for defaulting on a repo contract, or as capturing that depositors are less efficient holders of the asset.

Remark on Commitment: One advantage of the asset transfer mechanism is that it does not require the same level of commitment as does the withdrawal freeze mechanism introduced by DD. Under the withdrawal freeze mechanism, the intermediary only pays out goods in period 1 if it has sufficient holdings of the asset to pay out c_2^* units of the good in period 2 to each of a measure $(1-\lambda)$ of depositors. This ensures that a patient depositor strictly prefers W_0 regardless of the actions of other depositors and so there is no run equilibrium. If a benevolent planner has full commitment, then the withdrawal freeze strongly implements the first-best. However, Ennis and Keister (2009, 2010) provide an example in which if a sufficiently large fraction of patient depositors choose W_G, then a benevolent planner will want to abandon the withdrawal freeze and make such large payments to unserved impatient depositors in period 1 that the period 2 payments to patient depositors who chose W_0 fall below c_1^*. Hence, if the benevolent planner cannot commit to freezing withdrawals, then whether a patient depositor strictly prefers W_0 over W_G again depends on the actions of other depositors and the run equilibrium reemerges. By contrast, under the asset transfer mechanism with $\kappa > c_1^*/R$, a patient depositor always strictly prefers W_K over W_G regardless of the actions of other depositors *and* regardless of whether the intermediary later abandons the mechanism. Taking the asset transfer, like withdrawing goods immediately, ends a depositor's relationship with the intermediary and gives the depositor something whose value does not depend on the actions of others. In this sense, our mechanism works without the form of commitment required by the withdrawal freeze.

3 Asset Market

So far, we have interpreted the asset's liquidation value as technological. However, we can also interpret the DD environment as implicitly capturing an asset market with trading frictions. Trading frictions play two roles. First, they generate a liquidation value below the asset's maturity payoff, which creates a role for the intermediary to provide insurance. Second, they dissuade patient depositors from taking goods in period 1 to use in the asset market rather than waiting to take goods in period 2.[14] A natural question emerges: is the asset transfer mechanism still necessary and effective in the presence of an asset market with trading frictions?

In this section, we make these frictions explicit by eliminating the liquidation value in the investment technology and allowing "good" intermediaries with high quality assets to sell their assets into a market with adverse selection problems. In this environment, the asset transfer is different from asset trading in two ways. First, the value of the asset transfer depends only on the quality of the particular intermediary's assets rather than on the average quality of assets in the market. Second, the asset transfer gives the intermediary more freedom to offer different allocations to impatient and patient depositors, whereas the asset market forces the intermediary to provide all depositors allocations with the same market value. Returning to our question, we show that the answer is yes; the asset transfer mechanism is as necessary and effective as before.

3.1 Environment Changes

Formally, we make the following adjustments to the environment from section 2.1. For simplicity, we set the asset transfer cost, ε, to zero. We impose that intermediaries are no longer able to liquidate assets in period 1. Instead, at each place in line, s, an anonymous Walrasian market opens for trading goods and assets. In

[14] See Jacklin (1987) and Farhi et al. (2009) for discussions of why hidden trading can unwind insurance provision.

period 1, at each place in line, a measure of patient agents arrive with ω units of the good. Also, the financial system now has two sectors: a "healthy" sector and a "distressed" sector. The healthy sector consists of a unit measure of intermediaries and their depositors modeled as in section 2.1. The distressed sector is modeled in the following way. In period 1, at each place in line, there is a measure of intermediaries with μ_0 units of low quality assets that pay $R_0 < R$ units of the good in period 2. These intermediaries must sell all their assets at any price at each place in line.[15] All agents can participate in all markets. We impose that goods must be consumed immediately at each place in line.[16]

3.2 Asset Market

We focus on the case in which at most a measure zero of healthy intermediaries experience runs, which ensures that patient depositors at healthy intermediaries have at most a measure zero of goods or assets to trade in the market. We discuss the possibility of positive measure runs at the end of this section.

We begin by describing the equilibrium objects in the asset market. Let p denote the price of an asset. The aggregate supply of assets comes from the distressed intermediaries that supply μ_0 and the healthy intermediaries that supply $\mu(p) \in [0,1]$. The aggregate demand for assets comes from the measure of patient agents outside the financial system. Let $\bar{R}$ denote the average return in the asset market, which is given by

$$\bar{R} \equiv \frac{\mu_0 R_0 + \mu(p) R}{\mu_0 + \mu(p)}.$$

[15] This can be interpreted as the forced selling of assets by intermediaries in administration following bankruptcy.

[16] This simplifies the problem by ensuring that the market is the same at each place in line.

The aggregate demand function is then

$$\delta(p,\bar{R}) \equiv \begin{cases} \frac{\omega}{p}, & \text{if } p < \bar{R} \\ \left[0, \frac{\omega}{p}\right] & \text{if } p = \bar{R} \\ 0, & \text{if } p > \bar{R} \end{cases}$$

Market clearing is demand equals supply:

$$\delta(p,\bar{R}) = \mu_0 + \mu(p).$$

It follows that, in equilibrium, $p \leq \bar{R}$. This implies that buyers in the market face an effective rate of substitution of $\bar{R}/p$ period 2 goods per period 1 good and healthy intermediaries in the market face a higher effective rate of substitution of R/p period 2 goods per period 1 good.

3.3 Intermediary Problem

In this subsection, we solve the problem of a price taking healthy intermediary that maximizes the welfare of its depositors. This can be interpreted as the intermediary problem in a competitive market. Formally, the problem is the same as before except that now they must choose how many assets to sell rather than how many assets to liquidate and there is an additional incentive compatibility constraint that patient depositors must not want to accept goods in period 1 to purchase assets.[17]

[17]Technically, there are always incentive compatibility constraints that each depositor type must prefer their allocation. However, these constraints never bind in the original environment.

The intermediary's problem is

$$\max_{c_1,c_2,\mu}\left\{\lambda u(c_1)+(1-\lambda)u(c_2)\right\}$$
$$\begin{aligned} s.t. \qquad \lambda c_1 &= p\mu \\ (1-\lambda)c_2 &= R(1-\mu) \\ \frac{\bar{R}}{p}c_1 &\leq c_2, \end{aligned}$$

where μ is the measure of assets sold at each place in line and the final inequality is the incentive compatibility constraint. The first order condition is given by

$$u'(c_1)\geq \frac{R}{p}u'(c_2),$$

where it holds with equality when the incentive compatibility constraint does not bind. Other than the additional incentive compatibility constraint, this is the same problem as before except that R has been replaced by R/p. We denote the solution to this problem by $c_1^*(p)$, $c_2^*(p)$, and $\mu^*(p)$.

In the following theorem, we show that the asset transfer mechanism can strongly implement $(c_1^*(p),c_2^*(p))$, i.e. there is not a run equilibrium.

Theorem 2. *The demand deposit mechanism weakly implements the allocation $(c_1^*(p^*),c_2^*(p^*))$ and there is an equilibrium in which all depositors at that intermediary run. The asset transfer mechanism strongly implements $(c_1^*(p^*),c_2^*(p^*))$.*

Proof. The first statement follows from the same argument that shows there is a run in the original demand deposit mechanism.

For the second statement, first note that when considering the asset transfer, as in section 2, impatient depositors optimally convert any asset holdings into goods and patient depositors optimally hold any assets until maturity.

Next, we want to show that, as in section 2.2, the intermediary provides insurance: $p < c_1^*(p) < c_2^*(p) < R$. First, since $R > \bar{R} \geq p$ and u' is strictly decreasing, the first order condition implies that $c_1^*(p) < c_2^*(p)$. Now, suppose the incentive compatibility constraint binds. Since $\bar{R} < R$, it follows that $c_2^*(p) < (R/p)c_1^*(p)$. Since $c_1 = p$ and $c_2 = R$ satisfies the budget constraint with equality, it follows that $p < c_1^*(p) < c_2^*(p) < R$. On the other hand, suppose the incentive compatibility constraint does not bind. Then the first order condition must hold with equality and, following the same logic as in section 2.2, it must be that $p < c_1^*(p) < c_2^*(p) < R$.

Finally, the arguments in the proof of Theorem 1 only relied on a binding budget constraint and the fact that the intermediary provided insurance, not on the fact that the first order condition held with equality. Since the intermediary still provides insurance and the value of the asset transfer is unaffected by the asset market, the arguments from the proof of Theorem 1 still hold. The theorem follows. $\square$

Remark on the Environment: The asset market has adverse selection, as characterized by the wedge between R and $\bar{R} < R$. This wedge serves two purposes. First, since $p \leq \bar{R} < R$, it implies a liquidation cost, which creates a role for healthy intermediaries to provide insurance; otherwise, in autarky, all agents could consume R by selling the asset if impatient and holding it to maturity if patient. Second, since $\bar{R} < R$, adverse selection ensures that the intermediary can provide insurance without tempting patient depositors to "run" and take period 1 goods to use in the asset market. This is because it introduces a wedge in the asset market between the effective rate of substitution at which healthy intermediaries can turn period 2 goods into period 1 goods and the effective rate of substitution at which their patient depositors can turn period 1 goods into period 2 goods.

Note that the results in this section would be the same if instead of adverse selection, we introduced a short-term asset and a binding liquidity floor as in Farhi et al. (2009). For our purposes, they are equivalent in that each creates the necessary wedge in the asset market.

Remark on Positive Measure Runs: So far, we have focused on economies in which at most a measure zero of intermediaries face runs. If we allowed a positive measure of runs, then the asset market price would depend on how many runs occur. This introduces complications because we would need to model how intermediaries' contracts respond to changes in the asset price caused by runs. Modeling these complications is beyond the scope of this paper and it's not clear they impact the effectiveness of the asset transfer mechanism.

4 Idiosyncratic Return Risk

A clear economic implication of Theorem 1 is that we need to understand the impediments to transferring assets from intermediaries to depositors in order to understand why runs can occur in a DD environment. In section 3, we showed that unobservable return risk across intermediaries does not impact the effectiveness of asset transfers. In this section, we instead introduce unobservable return risk within an intermediary. Compared to the asset transfer cost in section 2, this speaks directly to why depositors might have a disadvantage in holding the asset relative to an intermediary whose only ability is aggregation. This is particularly relevant for the repo contract interpretation, in which the penalty cost may be hard to motivate.

In our extended environment, the intermediary holds a diversified portfolio with a deterministic return, but can only transfer idiosyncratically risky units of the asset during period 1. We show that if idiosyncratic return risk is sufficiently large, then an asset transfer that patient depositors prefer over taking goods is too expensive and the asset transfer mechanism is no longer effective. We can interpret this as explaining when intermediaries funded through repo contracts are run prone.

4.1 Environment Changes

We build on our original environment in section 2.1 without the asset market from section 3. We set $\varepsilon = 0$. We impose the additional restriction on preferences that $\lim_{c \to 0} u(c) = -\infty$. Instead of the investment technology in section 2.1, suppose depositors have access to the following. An agent chooses the number of projects in which to invest and the amount of their endowment to invest in each project. Each investment of x units of the endowment yields a distinct project that generates x units of the consumption good if interrupted in period 1 and Rx units of the consumption good if held until period 2, where R is random and i.i.d. across projects:

$$R = \begin{cases} R_H, & \text{w.p. } q \\ R_L, & \text{w.p. } 1-q \end{cases}$$

and the expected return is $\bar{R} = qR_H + (1-q)R_L$. We impose that each investment must be of size greater than or equal to $\bar{x} > 0$. This stylized restriction captures that agents may face an increasingly large average cost as they invest in increasingly small projects.[18] The important result is that depositors can only invest in finitely many projects, leaving them exposed to not only liquidity preference risk but also idiosyncratic return risk. An intermediary, by contrast, can invest in uncountably many projects and so will create a fully diversified portfolio with non-random period 2 return $\bar{R}$.

We restrict the intermediary by imposing that each project and the ownership of each project are perfectly indivisible; all the intermediary can do with each project is liquidate, transfer, or hold it until period 2 *in its entirety*. In particular, the intermediary can transfer projects to a depositor, but cannot create a new, diversified,

[18]The required minimum size makes our investment technology similar to the one in Diamond (1984) and Williamson (1986), although it plays a different role in their papers in which it justifies costly monitoring.

and transferable asset consisting of fractions of projects. Thus, even though the intermediary fully diversifies its portfolio, it can only transfer assets that bear the same idiosyncratic risks that a depositor would have faced had they invested on their own. We interpret this setup as allowing the intermediary to provide insurance by pooling resources but limiting the intermediary's ability to securitize its portfolio.[19]

4.2 Intermediary Problem

We explore the ability of the asset transfer mechanism to strongly implement the first-best in this setting. First, note that the constrained planner problem and the first-best allocation are the same as in section 2.3 with R replaced by $\bar{R}$. For simplicity, we suppose parameters are such that it is sufficient to consider the case in which the intermediary offers, as its asset transfer, one project of size κ to each depositor and, when choosing κ, the constraint $\kappa \geq \bar{x}$ is not binding.[20] Hence, the intermediary has a measure $1/\kappa$ of distinct investments, each of size κ.

Define $\eta \equiv R_H/R_L$. Observe that the environment in section 2 is the special case with $\eta = 1$. As such, given $\varepsilon = 0$, we know that if $\eta = 1$, then Γ_K can strongly implement the FB. For $\eta > 1$, we prove the following theorem, which says that for fixed preferences and a fixed average return, the first-best can be strongly implemented if and only if the dispersion of idiosyncratic returns is sufficiently low.

Theorem 3. *If $\eta = R_H/R_L$ is varied while R_H and R_L adjust so that $\bar{R}$ and q are held constant, then there exists a $\bar{\eta} \in (1,\infty)$ such that Γ_K can strongly implement the FB if and only if $\eta < \bar{\eta}$.*

[19]We consider the case in which the intermediary effectively cannot perform any securitization, but we believe the results are qualitatively unchanged so long as the intermediary cannot perfectly securitize its portfolio.

[20]More specifically, we suppose parameters are such that the following hold. If the intermediary can strongly implement the first-best by offering, as its asset transfer, a single project of size κ, then $\bar{x} \leq \kappa$. If the intermediary cannot strongly implement the first-best with any such asset transfer, then $\bar{x}$ is sufficiently large so that offering to transfer two or more projects to any depositors wouldn't allow for strong implementation of the first-best.

See Appendix B for the proof. The intuition for the theorem is the following. Patient depositors accepting the asset transfer now face idiosyncratic return risk. As return dispersion increases, the intermediary must offer a higher κ to maintain patient depositors' preference for the risky asset transfer over the risk free withdrawal of goods. Eventually, the required κ is so large that a non-first-best equilibrium emerges in which all patient depositors take the asset transfer. In this equilibrium, the intermediary's holdings of the asset are depleted before all depositors have been served in period 1, leaving nothing for any depositors who choose W_0 and for some of the depositors who choose W_G or W_K.

As with the asset transfer cost in section 2, even if $\eta \geq \bar{\eta}$ and the asset transfer mechanism cannot strongly implement the first-best, the asset transfer mechanism may still be able to strongly implement some degree of insurance, unlike the demand deposit mechanism.

5 Conclusion

We showed in section 2 that a benevolent intermediary facing the "classic" DD environment can choose a simple mechanism that strongly implements the first-best allocation. This mechanism involves offering asset transfers that are sufficiently large to prevent patient depositors from withdrawing goods early but sufficiently small that the intermediary never runs out of resources from transferring assets. We interpret this mechanism as a bankruptcy plan that gives depositors the option to progressively disassemble an insolvent intermediary, as giving depositors stakes in a mutual fund of the intermediary's assets, or as a repo contract in which the intermediary (borrower) gives the depositor (lender) an asset (collateral) that can be kept if the depositor is worried about a run.

An implication of the result in section 2 is that to understand self-fulfilling runs, greater attention needs to be given to the assets on intermediaries' balance sheets, the difficulties involved in transferring them, and the willingness of depositors to hold them. In sections 3 and 4, we studied possible sources of these frictions. We showed that impediments to asset trading based on adverse selection do not infringe on the intermediary's ability to transfer assets. Rather, the effectiveness of the asset transfer mechanism for preventing runs depends on the dispersion of asset quality at the intermediary in question rather than in the market overall. A noteworthy feature of the model in section 4 is that if return dispersion increases, then the possibility of a run may emerge even though the aggregate return on the intermediary's assets is unchanged. These implications could be tested empirically in future work.

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A Statement and Proof of Lemma 1

Lemma 1. *Define a mechanism Γ that offers depositors three options: W_G, W_0, and W_K. Suppose that if depositors choose W_G or W_0, then they get the same payoff as they would in the demand deposit mechanism (with an appropriate definition of $B(s;\mathbf{a})$). If depositors choose W_K, then they only receive units of the asset. If there does not exist a constant κ such that the asset transfer mechanism (Γ_K) strongly implements the first-best, then Γ does not strongly implement the first-best.*

Proof. Suppose that Γ_K cannot strongly implement the first-best allocation. It follows from Theorem 1 that $1+\varepsilon \geq c_2^*/c_1^*$. Suppose impatient depositors choose W_G and patient depositors choose whichever they prefer of W_G and W_K, breaking ties in favor of W_G. In this equilibrium, suppose a fraction β of depositors are offered a $\kappa > c_1^*/R$. Define $\bar{\kappa}$ to be the average value of κ offered to such depositors (or 0 if $\beta = 0$). It follows that if $\beta > 0$, then $(1+\varepsilon)\bar{\kappa} > c_2^*/R$. Hence,

$$\tilde{B}(1;\mathbf{a}) = 1 - \lambda c_1^* - (1-\lambda)(1-\beta)c_1^* - (1-\lambda)\beta(1+\varepsilon)\bar{\kappa}$$

is strictly less than 0 since $\lambda c_1^* + (1-\lambda)c_2^*/R = 1$ and $c_1^* > c_2^*/R$. As such, the specified strategy profile is indeed optimal. The equilibrium does not achieve the first-best allocation since a positive measure of depositors receive no goods in either period. $\square$

B Proof of Theorem 3

Recall that, throughout this proof, $\bar{R}$ is fixed, which implies that c_1^* and c_2^* are fixed as well. If $\eta = 1$, then we are in the model without idiosyncratic return risk and with $\varepsilon = 0$. As such, Theorem 1 shows that the asset transfer mechanism (Γ_K) can strongly implement the first-best (FB). For the rest of the proof, we suppose that $\eta > 1$.

Proof of Theorem 3. The bulk of the proof follows the same structure as the proof of Theorem 1. We show that κ must fall in an interval for the asset transfer mechanism (Γ_K) to strongly implement the first-best (FB) and so the mechanism cannot strongly implement if the interval is empty. We next show that if the interval is non-empty, then Γ_K can strongly implement the FB. We then have an additional step to show that there exists a threshold $\bar{\eta}$ such that this interval is non-empty if and only if $\eta < \bar{\eta}$.

First, if $\kappa > c_2^*/\bar{R}$, then Γ_K does not strongly implement the FB. Recall that in the proof of Theorem 1, when $\kappa > c_2^*/(R(1+\varepsilon))$, there exists a non-FB BNE in which patient and impatient depositors choose whichever of W_G and W_K gives them higher utility. The same logic applies here when $\kappa > c_2^*/\bar{R}$.

Next, we show there exists a lower bound such that if κ is less than or equal to the lower bound, then Γ_K does not strongly implement the FB. Define $U(\kappa)$ to be the expected utility a patient depositor receives from choosing W_K:

$$U(\kappa) \equiv qu(R_H\kappa) + (1-q)u(R_L\kappa),$$

which is strictly increasing in κ. Observe that, given risk-aversion and $\eta > 1$, $U(\kappa) < u(\bar{R}\kappa)$. If $\kappa \leq U^{-1}(u(c_1^*))$, then patient depositors weakly prefer to play W_G over W_K and, as in the game induced by Γ_D, there exists a BNE in which all depositors play W_G and the FB is not achieved. It follows that $U^{-1}(u(c_1^*))$ is the desired lower bound and that if $\left(U^{-1}(u(c_1^*)), c_2^*/\bar{R}\right]$ is empty, then Γ_K cannot strongly implement the FB.

Now, we show that if $\left(U^{-1}(u(c_1^*)), c_2^*/\bar{R}\right]$ is non-empty, then Γ_K can strongly implement the FB with $\kappa = c_2^*/\bar{R}$. Let $\kappa = c_2^*/\bar{R}$. Then, since $U(\kappa) > u(c_1^*)$, we have that, for patient depositors, W_K strictly dominates W_G. Also, since $c_2^*/\bar{R} < c_1^*$, we have that, for impatient depositors, W_G strictly dominates W_K and W_0. As such, in any BNE, impatient depositors choose W_G and patient depositors mix between W_K and W_0. If patient depositors play W_K with probability β, then the intermediary assets remaining at the end of period 1 are

$$\begin{aligned} B(1;\mathbf{a}) &= 1 - \lambda c_1^* - (1-\lambda)\beta\kappa \\ &= 1 - \lambda c_1^* - (1-\lambda)\beta\frac{c_2^*}{\bar{R}} \\ &= (1-\lambda)(1-\beta)\frac{c_2^*}{\bar{R}} \end{aligned}$$

and depositors who play W_0 receive

$$\bar{R}\frac{B(1;\mathbf{a})}{(1-\lambda)(1-\beta)} = c_2^*$$

units of consumption in period 2 with certainty. Since $U\left(c_2^*/\bar{R}\right) < u(c_2^*)$, it follows that patient depositors strictly prefer to play W_0 over W_K. Hence, the unique BNE consists of impatient depositors choosing W_G and patient depositors choosing W_0, which yields the FB allocation.

We have shown that Γ_K can strongly implement the FB if and only if $U(c_2^*/\bar{R}) > u(c_1^*)$. We now show that there exists an $\bar{\eta} \in (1,\infty)$ such that $U(c_2^*/\bar{R}) > u(c_1^*)$ if and only if $\eta < \bar{\eta}$. First, as η goes to infinity, R_L converges to 0 and $U(c_2^*/\bar{R})$ diverges to negative infinity, which is strictly less than $u(c_1^*)$. Next, at $\eta = 1$, $U(c_2^*/\bar{R}) = u(c_2^*)$, which is strictly greater than $u(c_1^*)$. Finally, we need that $U(c_2^*/\bar{R})$ is strictly decreasing in η. Since $R_L = \bar{R}/(q\eta + 1 - q)$ and $R_H = (\bar{R}\eta)/(q\eta + 1 - q)$, the expected utility a patient depositor receives from an asset transfer of $c_2^*/\bar{R}$ is

$$\begin{aligned} U\left(\frac{c_2^*}{\bar{R}}\right) &= qu\left(R_H \frac{c_2^*}{\bar{R}}\right) + (1-q)u\left(R_L \frac{c_2^*}{\bar{R}}\right) \\ &= qu\left(\frac{\eta c_2^*}{q\eta + 1 - q}\right) + (1-q)u\left(\frac{c_2^*}{q\eta + 1 - q}\right). \end{aligned}$$

The derivative of this expected utility with respect to η is

$$\frac{\partial U\left(\frac{c_2^*}{\bar{R}}\right)}{\partial \eta} = \left[u'\left(\frac{\eta c_2^*}{q\eta + 1 - q}\right) - u'\left(\frac{c_2^*}{q\eta + 1 - q}\right)\right] \frac{q(1-q)c_2^*}{(q\eta + 1 - q)^2},$$

which is strictly negative because $\eta > 1$ and u' is strictly decreasing. Therefore, since $U(c_2^*/\bar{R})$ is continuous in η, the desired $\bar{\eta}$ exists.

$\square$