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 without requiring deposit insurance. During a run, a depositor can take unliquidated intermediary assets in exchange for closing their account. We show our mechanism would have been useful in the most recent banking crisis. We also show our mechanism improves upon suspension if policy makers have limited commitment, depositors repeatedly interact with the intermediary, and/or there is aggregate return risk.

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1 Introduction

The 2007-09 financial crisis and 2023 Silicon Valley Bank collapse showed that bank runs are still a problem. The policy response has been to expand deposit insurance to additional financial institutions and large depositors. However, historical limits on deposit insurance reflect concerns that it encourages inefficient behavior by financial institutions and discourages scrutiny by depositors. We provide an alternative solution to the run problem: a financial intermediary allows depositors to take assets from its balance sheet in exchange for closing their account. In a run, patient depositors take assets, saving the intermediary from costly liquidation. Self-fulfilling runs can no longer be sustained, and if a shock makes a run inevitable, depositors are better off. This mechanism is particularly relevant for the most recent crisis in which a significant portion of deposits were held by large, sophisticated investors with knowledge about the sectors into which their banks were lending.

We return to the canonical environment for discussing bank runs provided by Diamond and Dybvig (1983). There are two main periods and an intermediary with holdings of an asset that can be liquidated in the earlier period or held until the later period for a positive return. Depositors privately know whether they are impatient and can only consume in the earlier period, or whether they are patient and can consume in either period. Depositors arrive sequentially in the earlier period to interact with the intermediary. In the original demand deposit mechanism, the intermediary offers two options: withdraw goods now or come back in the later period to receive a higher quantity of goods. 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 that allows the intermediary to provide liquidity insurance without introducing the possibility of a run. The intermediary offers depositors the original two options as well as a third, which we call the "asset transfer": immediately taking ownership of an asset from the intermediary's balance sheet.[1] 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. Patient depositors will hold the assets until the later period and receive the positive return, so this is the efficient way to provide them value while allowing them to end their relationship with the intermediary. Self-fulfilling runs no longer occur because each patient depositor who takes the asset transfer improves the intermediary's balance sheet, which discourages other patient depositors from withdrawing early. Moreover, if a fall in the asset liquidation value makes a run inevitable—which may have been the case in the recent Silicon Valley Bank run—then asset transfers are still useful because they allow the intermediary to fulfill its obligations to more depositors.

The spirit of introducing asset transfers is that financial intermediaries are not the only potential holders of intermediary assets, especially during a run. Our model offers two key takeaways for when asset transfers are likely to be effective in the real world. First, if depositors are sophisticated and have particular knowledge about, preference for, or ability in holding their intermediary's assets. Second, if the intermediary has a few large depositors because asset transfers may entail fixed costs, such as the time spent negotiating an acceptable package, or idiosyncratic risks that are costly for small depositors to bear.

We apply our analysis to the Silicon Valley Bank collapse and argue that both conditions were satisfied because it had many large, institutional depositors with deep knowledge about the technology sector to which it was lending. Our results suggest that the Silicon Valley Bank run is not a compelling argument for extending deposit insurance to more institutions or to large depositors. Indeed, it is particu-

[1] Although to our knowledge, asset transfers have not been discussed in the Diamond and Dybvig (1983) literature, we believe there is nothing in the original environment preventing their use. For a thorough discussion and interpretation of the essential features that characterize the Diamond and Dybvig (1983) environment, see Wallace (1988).

larly unnecessary and unwise to extend deposit insurance to large sophisticated depositors because they are most able to impose scrutiny on intermediaries and to accept asset transfers during a run. Instead, policy makers should ensure there are contract frameworks in place that enable direct negotiation between financial intermediaries and their depositors over what happens to the intermediary's assets during a run.

It is important to acknowledge that in the real world, we expect that running depositors can use their withdrawals to purchase assets. Thus in Section 4.1, we consider a version of the model with an asset market that the intermediary sells assets to when it wants to liquidate them, and that depositors can access as well. We find that asset transfers remain effective as long as it is more efficient for the intermediary to transfer assets to its depositors directly rather than indirectly through the market by selling and giving the proceeds to depositors, who then purchase assets. This may be the case if there are many types of assets that are hard to distinguish in the market, or if there is limited asset market participation so that a buyer cannot always find the asset they want.

In Section 4.2, we demonstrate that the asset transfer mechanism is more effective than a suspension mechanism. Suspensions are a much discussed solution to the run problem: if too many depositors withdraw goods in the early period, the intermediary temporarily closes, insuring there will be goods available for depositors who show up in the later period. We develop three extensions to the baseline environment that highlight potential problems with suspension that do not apply to asset transfers: limited commitment, repeat visits to the intermediary during the early period, and aggregate return risk. Intuitively, suspension can be an effective off-equilibrium-path threat, but is costly to depositors if actually implemented. Moreover, it can prevent the efficient liquidation of bad assets. On the other hand, asset transfers work because they are optional for each depositor, encourage the efficient use of assets, and improve the intermediary's balance sheet in a run.

Finally, in Section 4.3, we introduce idiosyncratic return risk within an intermediary as one particular reason why an intermediary may be better equipped than depositors to hold assets, even if its only ability is aggregation. 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, so asset transfers cannot prevent runs. This is particularly relevant in light of the work by Ospina and Uhlig (2018), which shows that the increase in the average loss rate on mortgage backed securities during the 2007-09 financial crisis was relatively low compared to the increase in the dispersion of loss rates.

Literature Review: 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)).

Our paper complements the literature arguing that redesigning financial contracts is a better way to reduce financial instability than expanding deposit insurance and bailouts (for example, Cochrane (2014), Philippon (2016)). Previous work mostly focuses on narrow banking and net asset value shares in mutual funds, whereas we eliminate runs by setting up contracts that facilitate direct negotiation between depositors and financial intermediaries. One distinction is that our mechanism preserves the role of an intermediary as a provider of liquidity insurance.

Formally, our approach follows a literature, pioneered by Green and Lin (2000,

2003) and Peck and Shell (2003), which studies whether a mechanism designer—interpreted as a competitive financial sector—facing the essential features of the Diamond and Dybvig (1983) "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. (2017) 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. (2017), 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 suspend withdrawals. Hence, their mechanism as well as other mechanisms that essentially use suspension, such as in De Nicolo (1996), are subject to the commitment problems described in Ennis and Keister (2009, 2010), which we discuss in Section 4.2 along with other reasons why suspension may not work. 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: studying how depositors and intermediaries can set up contracting arrangements to facilitate asset transfers.

2 Asset Transfers in Theory

2.1 The Environment

We consider the classic Diamond and Dybvig (1983) 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 $c_{i,t}$ is 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 the beginning of $t = 1$ 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 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.

Interaction in period 1 is as follows. At the beginning of period 1, each depositor is allocated a place in line s drawn from the uniform distribution on $[0,1]$ 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 intermediary can transfer goods and/or assets to depositors in period 1, and goods in period 2.[2] Asset transfers are subject to a per unit cost: if the intermediary transfers 1 unit of the asset, then the depositor receives $1-\varepsilon$ units. An alternative interpretation is that if the intermediary holds units of the asset from period 1 to 2, then it receives return R units of the good, and if a depositor holds units of the asset, then it receives return $R^a \leq R$, where $R^a := (1-\varepsilon)R$. We view previous papers in the literature (that do not consider asset transfers) as implicitly setting $\varepsilon = 1$. Throughout the rest of the paper, for convenience, we refer to the effective depositor return R^a rather than the transfer cost ε.

2.2 Unconstrained Social Planner

Suppose there is a benevolent social planner who observes depositor types and directly controls allocations. The social planner maximizes welfare subject to the aggregate resource constraint, where welfare is depositors' period 0 expected util-

[2] There are no assets in period 2.

ity. Diamond and Dybvig (1983) show that the first best 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.

A depositor's type consists of their patience type $\theta \in \{I, P\}$, which they know but the planner does not, and their place in line s, which the planner knows but they do not. An outcome function specifies that the depositor at position s gets allocation

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

where a_s is the action of the depositor at place s in line, $\mathbf{a}$ is the vector of all depositors' actions, $c_t(a_s, s; \mathbf{a})$ 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 the intermediary transfers in period 1.[3] A mechanism consists of a set of actions available to each depositor,

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

and an outcome function. 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 is sequential service feasible if for all action profiles $\mathbf{a}$, 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.

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. The equilibrium concept is Bayes Nash: depositors maximize their expected utility, taking $\mathbf{a}$ 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 $h : \{I,P\} \to \mathbb{R}^3_+$. We say a mechanism **weakly implements** the social choice function h if there exists a Bayes Nash equilibrium of the game induced by the mechanism in which impatient depositors receive $h(I)$ and patient depositors receive $h(P)$. A mechanism **strongly implements** if in every Bayes Nash equilibrium, depositor allocations are given by h.

The canonical question in the Diamond and Dybvig (1983) 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 the environment is fundamentally unstable since we cannot achieve the first best without introducing the possibility of suboptimal equilibria.

2.4 Demand Deposit Mechanism

Diamond and Dybvig (1983) and most of the subsequent literature study the demand deposit mechanism, which is a direct mechanism.[4] Each depositor chooses from $\{\text{withdraw}, \text{wait}\}$, where "withdraw" represents withdrawing goods in period 1 and "wait" represents waiting to withdraw goods in period 2.[5] The outcome function is

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

where m_0 is the fraction of depositors who choose "wait" and

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

is the measure of the intermediary's holdings of the asset remaining at place s. In words, each depositor can withdraw c_1^* goods in period 1 as long as the intermediary has any assets remaining. If a depositor instead waits, then they split the return on the intermediary's balance sheet with all other waiting depositors in period 2.

Diamond and Dybvig (1983) prove that the mechanism is sequential service feasible and weakly implements the first best allocation. More specifically, they show that the induced game has a "truth telling" equilibrium as well as a "run" equilib-

[4]Notable exceptions are Andolfatto et al. (2017) and Cavalcanti and Monteiro (2016), who also propose indirect mechanisms.

[5]Technically, Diamond and Dybvig (1983) 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.

rium. In the former, impatient depositors withdraw in period 1, patient depositors wait, and the allocation is the first best. In the run, all depositors withdraw 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 that makes use of the intermediary's ability to transfer ownership of units of the asset. Each depositor chooses from three actions, $\{\text{withdraw}, \text{wait}, \text{transfer}\}$, where "withdraw" and "wait" are as before. If a depositor chooses the new action, "transfer", then the intermediary transfers κ units of the asset (not liquidated), where κ is a single number.[6] The outcome function is

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

where m_0 is again the fraction of depositors who choose "wait" and

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

[6] In Appendix A, we prove Lemma 1, which shows that restricting κ to be a single number does not affect whether the first best is strongly implementable.

is the measure of the intermediary's holdings of the asset left at place s.

By construction, the mechanism 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. The following theorem shows when we can design the asset transfer mechanism so that it is not subject to the same run problem as the demand deposit mechanism.

Theorem 1. *The asset transfer mechanism can strongly implement the first best allocation if and only if* $R^a > \frac{R}{c_2^*/c_1^*}$.

Proof. See Appendix A. □

To understand the theorem, it is helpful to recall why a run can occur in the demand deposit mechanism. The first best allocation is exactly budget feasible if impatient depositors withdraw goods in period 1 and patient depositors wait until period 2. 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. On the other hand, if a sufficiently large fraction of patient depositors withdraw goods in period 1, then the intermediary's holdings of the asset are depleted before all depositors have been served because $c_1^* > 1$. In that case, any depositors who wait until period 2 receive nothing. Thus, it is not incentive compatible for a patient depositor to wait if sufficiently many other patient depositors withdraw early.

Now consider the asset transfer mechanism when R^a is sufficiently high so that the intermediary can choose an asset transfer κ that satisfies $R^a\kappa > c_1^*$ and $\kappa \leq c_2^*/R$. For any depositor strategy profile, all impatient depositors strictly prefer to withdraw goods in period 1, and all patient depositors strictly prefer to take the asset transfer over withdrawing goods in period 1. Hence, the only possible incentive compatible deviation from truth telling is for patient depositors to take the asset transfer. Since $\kappa \leq c_2^*/R$, if a positive measure of patient depositors do so, then unlike if they were to withdraw goods, the intermediary is left at the end of period 1 with weakly *more* units of the asset per patient depositor who chose to wait. In this sense, the asset transfer is an off-equilibrium path option that, by strictly dominating withdrawing goods early for patient depositors, ensures that it is always incentive compatible for patient depositors to wait until period 2. As such, the asset transfer mechanism, which is indirect, is able to strongly implement the first best while the demand deposit mechanism, which is direct, cannot.[7]

Finally, if $R^a = R$ or equivalently, $\varepsilon = 0$, then a *direct* mechanism can strongly implement the first best: eliminate the option to wait, and set $\kappa = c_2^*/R^a$ so that patient depositors take the asset transfer in equilibrium. Intuitively, 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 depositors.[8]

We now show that even if the asset transfer mechanism cannot strongly implement the first best, the condition on the transferred asset return, R^a, is weaker for asset transfers to be useful. Specifically, the demand deposit mechanism cannot strongly implement *any* allocation that satisfies the resource constraint, which we refer to as "feasible", and provides insurance, i.e., such that impatient depositors receive $\bar{c}_1$ goods, patient depositors receive $\bar{c}_2$ goods, and $1 < \bar{c}_1 < \bar{c}_2 < R$. The first best is one of these allocations, but there is a continuum. The following corollary shows when the asset transfer mechanism can strongly implement such

[7]In this context, the revelation principle does not imply that restricting 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 a direct mechanism only weakly implements the first best.

[8]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 first best allocations without creating the possibility of a run.

an allocation.

Corollary 1. *Suppose an allocation $(\bar{c}_1, \bar{c}_2)$ is feasible and provides insurance. The demand deposit mechanism can weakly implement $(\bar{c}_1, \bar{c}_2)$, and there is an equilibrium in which all depositors run. The asset transfer mechanism can strongly implement $(\bar{c}_1, \bar{c}_2)$ if and only if $R^a > \frac{R}{\bar{c}_2/\bar{c}_1}$.*

The asset transfer mechanism can strongly implement some degree of insurance (asset transfers are useful) as long as it is more efficient to provide patient depositors with value by transferring assets than by liquidating assets, i.e., $R^a > 1$ or equivalently, the asset transfer cost is not prohibitive: $\varepsilon < 1 - 1/R$. The more insurance the allocation entails, i.e., the higher is $\bar{c}_1/\bar{c}_2$, the higher the required R^a. The first best entails the maximum desirable insurance.

One interpretation for the asset liquidation value is a market price. If it is better to transfer assets to patient depositors than to sell assets and give the proceeds to those depositors, then a natural question is why don't patient depositors want to withdraw goods to purchase assets in this market? We take up this question in Section 4.1.

2.6 Inevitable Runs

So far, we have focused on whether the asset transfer mechanism can strongly implement an allocation that provides insurance. The truth telling equilibrium, in which patient depositors wait until period 2 to withdraw, is always present, and the asset transfer serves as an off-equilibrium-path option to eliminate an additional suboptimal equilibrium. We now consider whether asset transfers are useful if a shock to the asset liquidation value eliminates the truth telling equilibrium. Indeed, it is reasonable to suggest that such a shock is what happened to spark the Silicon Valley Bank run, which we discuss in more detail in Section 3.

Formally, we suppose there is an unanticipated fall in the asset's liquidation value to $p < \bar{p}$, where

$$\bar{p} := \lambda c_1^* / (1 - (1 - \lambda) c_1^* / R)$$

is the "crisis threshold" below which it is no longer possible to give impatient depositors c_1^* goods in period 1 and patient depositors c_1^* goods in period 2 (not to mention c_2^* goods), even if all patient depositors wait to withdraw in period 2. The intermediary cannot adjust the promised period 1 goods withdrawal c_1^*, so a patient depositor strictly prefers to withdraw in period 1 regardless of the actions of other patient depositors. We can think of $\bar{p}$ as the threshold below which the intermediary is "insolvent" in the Diamond and Dybvig (1983) model. The following theorem demonstrates that asset transfers cannot bring back the truth telling equilibrium, but can improve welfare in the inevitable run.

Theorem 2. *Fix (c_1^*, c_2^*) to be the first best allocation with an asset liquidation value of 1, and suppose the liquidation value falls to $p < \bar{p}$, where $\bar{p}$ is the crisis threshold, so that it is infeasible to give all depositors c_1^*. The following are true:*

1. *If a demand deposit mechanism weakly implemented the first best before the crisis, then it has a unique equilibrium during the crisis.*
2. *If an asset transfer mechanism strongly implemented the first best before the crisis, then it has a unique equilibrium during the crisis, with welfare strictly greater than in the demand deposit mechanism.*
3. *If $R^a > p$, then there exists an asset transfer mechanism with goods withdrawal c_1^* that has a unique equilibrium during the crisis, with welfare strictly greater than in the demand deposit mechanism.*

Proof. See Appendix A. □

Unlike before, assets transfers are now useful only if they are actually taken in equilibrium. Patient depositors run by taking the asset transfer rather than by withdrawing goods, and as a result the intermediary can serve more depositors. Intuitively, this is not so different from the function of asset transfers already discussed. It is the ability of asset transfers to improve the intermediary's balance sheet in a run that allows them to prevent self-fulfilling runs.

Theorem 2 considers both the case in which the asset transfer κ cannot respond to the fall in the asset liquidation value, and the case in which it can. The latter is in line with the notion that the intermediary negotiates asset transfers with depositors once a run is underway. The second result in the theorem states that if the asset transfer mechanism strongly implemented the first best before the crisis and the asset transfer cannot respond to the crisis, then the asset transfer continues to be useful. The third result states that even if the effective depositor return on intermediary assets, R^a, was too low before the crisis for preventing runs, but the asset transfer can respond to the crisis, then asset transfers can become useful as long as it is more efficient to provide patient depositors value by transferring assets than by liquidating assets. This is the same condition from Corollary 1 for the asset transfer mechanism to be able to strongly implement some degree of insurance.

3 Asset Transfers in Practice

We highlight two key takeaways from our theoretical analysis for when asset transfers are useful. They apply to whether the asset transfer mechanism can strongly implement the first best, can strongly implement any degree of insurance, or can improve welfare in an inevitable run.

Takeaway 1: *Asset transfers are more likely to be effective if depositors are sophisticated and have particular knowledge about, preference for, or ability in holding their intermediary's assets.*

In this case, the effective return depositors earn on the intermediary's assets, R^a, is higher, so the condition in Theorem 1 or Corollary 1 is more likely to be met.

Takeaway 2: *Asset transfers are more likely to be effective if the intermediary has a few large depositors.*

The proof of Theorem 1 demonstrates that asset transfers do not need to be offered to all depositors to stop a run. They prevent the run equilibrium as long as they are offered to enough depositors so that if patient depositors offered the transfer take it, and other patient depositors withdraw goods early, then the intermediary does not run out of resources before the end of period 1. Thus, if a significant portion of deposits are held by a few depositors, then asset transfers can be effective as long as those depositors are interested in taking them. This may be particularly relevant for two reasons. First, asset transfers may entail fixed costs, for example, negotiating an appropriate selection of assets or size of the transfer. Second, larger depositors may be more able to hold intermediary assets because the transfers to them are larger and thus entail less idiosyncratic risk, or because larger depositors are more able to bear idiosyncratic risk. We discuss idiosyncratic risk in more detail in Section 4.3.

The Silicon Valley Bank Run: We now argue that asset transfers would have been useful during the run on Silicon Valley Bank. Just prior to the run in March 2023, Silicon Valley Bank satisfied the two criteria discussed above for asset transfers to be effective. First, many deposits were held by sophisticated investors, and the industries in which they worked were the same as the industries to which Silicon Valley Bank had made loans.[9] Such depositors were likely to derive a high return from holding the bank's assets, and so transferring assets to them would have given Silicon Valley Bank more resources than liquidating. Second, many deposits were

[9] See the next footnote for a description of the depositors. Regarding bank assets, Chernova (2023) writes: "As of March 31, SVB had a loan book of $66 billion, with about a quarter of that issued to technology and healthcare companies and 55% to venture and private-equity funds." For context, the Fed reports that Silicon Valley Bank had total assets of $209 billion (FRS (2023)).

held by a few large depositors.[10] It would have been worthwhile for Silicon Valley Bank to pay fixed costs to negotiate asset transfers with such depositors, and it would have been possible to offer large enough packages of bank loans to avoid idiosyncratic risk.

Finally, although we do not incorporate it into our analysis, another feature of Silicon Valley Bank's situation just prior to the run in March 2023 made it particularly costly to liquidate assets for patient depositors: doing so would force it to reclassify much of its portfolio from "held-to-maturity" to "available-for-sale", and thus mark the value of those assets to market.[11] As such, asset transfers are useful also because they prevent this reclassification.

Lessons For Regulators: The spirit of introducing asset transfers is that financial intermediaries are not the only potential holders of intermediary assets, especially during a run. This offers practical lessons for policy makers:

1. It is unnecessary and unwise to extend deposit insurance to large sophisticated depositors because they are most able to impose scrutiny on intermediaries and to accept asset transfers during a run.

2. Financial contracts should be set up in advance that allow large depositors and financial intermediaries to "negotiate" over who holds intermediary assets when a run occurs. This is particularly important given the speed at which recent runs occurred.

3. Stress tests should consider the feasibility of transferring assets to depositors.

[10] FRS (2023) reports that 94% of Silicon Valley Bank deposits were uninsured because they were in excess of $250,000 in their respective accounts. For example, Chapman and Leopold (2023) reports that this included $1 billion deposits from Sequoia (the investment firm famous for backing Apple, Google, and WhatsApp), $902.9 million deposits from Kanzhun, $608 million deposits from Altos Labs Inc., and $634.5 million deposits from Marqeta Inc.

[11] FRS (2023) states that almost 50% of Silicon Valley Bank's assets were classified this way, and that selling some would force a reclassification of large portions of its portfolio.

Regulation should consider how to make assets more transferable to large depositors.

4 Model Extensions / Robustness

In this final section, we conduct three exercises to illustrate further when asset transfers are effective, and how they compare to other solutions to the self-fulfilling run problem. We first show that asset transfers can remain effective in the presence of an asset market. Second, we formalize extensions to our baseline environment in which asset transfers outperform suspension mechanisms. Third, we show that idiosyncratic return risk on investments can limit the usefulness of asset transfers.

4.1 Asset Market

We have interpreted the asset liquidation value as the price the intermediary can get in an asset market. It is thus natural to ask what happens if depositors can access this market as well, especially following a drop in the price of the intermediary's assets—as occurred in the Silicon Valley Bank run—which suggests a high return for buyers in the market.

We find that asset transfers remain effective as long as it is more efficient to transfer assets directly to depositors than indirectly through the asset market by selling and giving the proceeds to depositors, who then purchase assets. For this to be the case, depositors must have a relative preference for the intermediary's assets over other assets in the market, and there must be asset market frictions that make it difficult for depositors to purchase the assets the intermediary sells into the market. This can be due to the existence of different types of assets that are hard to distinguish, or to limited asset market participation so that a buyer cannot always find the asset they want.

We make the following adjustments to the environment from Section 2.1. We impose that intermediaries are no longer able to liquidate assets in period 1. Instead, throughout period 1, an anonymous Walrasian market is open for trading goods and assets. The buyers of assets in this market are a large measure of agents that have goods, and can consume in either period 1 or 2. The intermediary and depositors are small relative to these agents, and so take the price in this market as given. As before, an intermediary earns return R period 2 goods per unit of the asset it holds.

We suppose there are a variety of asset types sold in this market, and each buyer has a different distribution of holding returns across these types. A buyer in the market can purchase a representative mixture of the asset types at price p per unit of asset because asset types are ex-ante indistinguishable. The intermediary has a single type of asset, which it can sell in the market at price p. We suppose all depositors have the same distribution of holding returns across asset types; they earn return R^a period 2 goods per unit of the intermediary's asset (this is inclusive of any transfer cost ε), and return R^b period 2 goods per unit of the representative mixture of market assets. We impose that $R/p > 1$ so that as in the original setup, it is cheaper for the intermediary to provide goods to patient depositors than to impatient ones. For there to be any difference from the original setup, we impose throughout that $R^b/p > 1$ so that if patient depositors have goods in period 1, they will use them to purchase assets in the market. Finally, we impose that $R > R^b$ so that it is possible for the intermediary to provide liquidity insurance without tempting patient depositors to take the impatient depositor allocation.[12] To be clear, depositors can buy and sell assets but cannot trade claims to future withdrawals from the intermediary.

We consider allocations that are feasible and provide liquidity insurance as before, i.e., characterized by (c_1^*, c_2^*) so that $(1-\lambda)c_2^* = R(1-\lambda c_1^*/p)$ and $1 < c_1^* < c_2^* < R/p$, where the intermediary's effective ability to convert period 1 goods into period 2 goods now reflects the asset market price p. Moreover, we restrict attention to allocations that satisfy the new incentive compatibility constraint that pa-

[12] Otherwise, the intermediary cannot provide insurance, reminiscent of Jacklin (1987).

tient depositors do not prefer to withdraw goods and purchase assets in the market: $(R^b/p)c_1^* < c_2^*$.

The following proposition, comparable to Theorem 1 and Corollary 1, provides a condition on asset market returns and prices so that the asset transfer mechanism can deliver liquidity insurance without self-fulfilling runs.

Proposition 1. *Suppose (c_1^*, c_2^*) is feasible, provides insurance, and is incentive compatible. The demand deposit mechanism can weakly but not strongly implement (c_1^*, c_2^*). The asset transfer mechanism can strongly implement (c_1^*, c_2^*) if and only if $R^a > \frac{R/p}{c_2^*/c_1^*} R^b$.*

Proof. See Appendix B. □

The threshold in the proposition for the return on transferred assets, R^a, consists of two terms. First, $(R/p)/(c_2^*/c_1^*)$ measures the degree of insurance the intermediary provides. This term is the threshold $R/(c_2^*/c_1^*)$ in Theorem 1, except that now the rate at which the intermediary can effectively convert period 1 goods into period 2 goods is R/p rather than R. Second, R^b reflects that now when a patient depositor withdraws goods, they are effectively investing in an asset with holding return R^b.

We next compare to the crisis scenario in Theorem 2. We suppose the asset market price begins at 1, and then falls to a sufficiently low value p so that if the intermediary cannot adjust the goods withdrawal c_1^*, a run is inevitable. Specifically, we define the "crisis threshold" to be the price below which patient depositors prefer to take c_1^* goods over waiting, regardless of the actions of other patient depositors:

$$\hat{p} := ((1-\lambda)R^b + \lambda)c_1^*/R.$$

The threshold $\hat{p}$ is different from the crisis threshold before Theorem 2, $\bar{p}$, because with the asset market, as the price falls, a run becomes inevitable for two reasons. First, as before, providing impatient depositors with c_1^* becomes more costly. Second, patient depositors become more tempted to take the goods withdrawal because the effective return they earn in the market, R^b/p, increases.

We focus on the case in which the intermediary can choose the asset transfer κ conditional on the price p. Otherwise, since the value of taking a goods withdrawal to patient depositors increases in a run, even if the asset transfer mechanism originally strongly implemented (c_1^*, c_2^*), the transfer may not be sufficient to stop patient depositors from taking goods following a drop in the asset market price.

Proposition 2. *Fix (c_1^*, c_2^*) to be a feasible allocation that provides insurance and is incentive compatible with an asset market price of 1. Suppose the asset market price falls to $p < \hat{p}$, where $\hat{p}$ is the crisis threshold below which truth telling is no longer an equilibrium. The following are true:*

1. *If a demand deposit mechanism weakly implemented (c_1^*, c_2^*) before the crisis, then it has a unique equilibrium during the crisis.*

2. *If $R^a > R^b$, then there exists an asset transfer mechanism with goods withdrawal c_1^* that has a unique equilibrium during the crisis, with welfare strictly greater than in the demand deposit mechanism.*

Proof. See Appendix B. □

The proposition states that asset transfers are useful as long as the holding return depositors get from transferred assets is greater than the holding return they get from assets purchased in the market. In that case, it is more efficient to transfer assets to patient depositors than to sell assets and give patient depositors goods, which they then use to purchase assets in the market. This does not depend on the asset market price. As the price falls, patient depositors become more tempted to withdraw goods early. But the cost of them doing so goes up as well, so it is optimal for the intermediary to increase its asset transfer offer by enough to stop them.

4.2 Comparison to Suspension

There is a long history of researchers and policy makers proposing or implementing suspension mechanisms to try to eliminate bank runs. These policies have worked better in theory than in practice, and have frequently been controversial due to concerns over their legality, fairness, feasibility, and sub-optimality. We focus on the latter two, and formalize reasons why the asset transfer mechanism is preferable to suspension. Specifically, we consider three extensions to our baseline environment: limited commitment, repeat visits to the intermediary during period 1, and aggregate return risk. In the first two, suspension may fail to stop self-fulfilling runs because it does not alleviate the concerns of anxious patient depositors, whereas the asset transfer mechanism remains effective. In the final extension, a run may be inevitable, in which case suspension makes the problem even worse, whereas asset transfers have no effect.

We focus on feasible allocations that provide insurance, i.e., that provide $(c_1^*, 0)$ to impatient depositors and $(0, c_2^*)$ to patient depositors, where $(1-\lambda)c_2^* = R(1-\lambda c_1^*)$ and $1 < c_1^* < c_2^* < R$. A suspension mechanism offers depositors the options to withdraw or wait in period 1, as in the demand deposit mechanism, but only allows a maximum measure γ of depositors to withdraw. After γ withdrawals, all remaining depositors in period 1 must wait. We suppose that if an impatient depositor shows up in period 1 after withdrawals are suspended, then they come back in period 2 to receive their share of the return on the intermediary's assets.[13] We impose that $\gamma \in [\lambda, (R/c_1^* - 1)/(R-1))$. The lower bound implies that suspension weakly implements (c_1^*, c_2^*) in our baseline setup by allowing all impatient depositors to withdraw in period 1. The upper bound implies that suspension strongly implements (c_1^*, c_2^*) in our baseline setup because even if all depositors attempt to withdraw in period 1, a depositor who waits will receive strictly more than c_1^* in

[13]This is justified by supposing that impatient depositors receive a small amount of utility from consuming in period 2.

period 2. Finally, for simplicity, we suppose asset transfers are frictionless, i.e., $R^a = R$ or equivalently, $\varepsilon = 0$.

4.2.1 Commitment

As highlighted by Ennis and Keister (2009, 2010), the suspension mechanism faces a potential commitment problem: after suspension is imposed, a benevolent intermediary or government wants to lift the suspension and dispense goods to remaining impatient depositors. This may leave little enough left for remaining patient depositors that it was indeed optimal to run in the first place. In this section, we formalize the commitment issue in a way that allows a comparison of the suspension mechanism and the asset transfer mechanism. We show that the asset transfer mechanism is not subject to the same criticism.

Consider the environment from Section 2.1 but now allow for limited commitment. Suppose after a measure λ of depositors interact with the intermediary in period 1 (the earliest the intermediary would suspend withdrawals), the intermediary sets a new mechanism to maximize the expected utility of its depositors. When the intermediary sets its initial mechanism, it is common knowledge that the intermediary cannot commit to the mechanism it will choose in the middle of period 1. The equilibrium concept is subgame perfect Nash: given the initial mechanism, agents act optimally based on accurate beliefs about the mechanism that the intermediary will optimally choose in the middle of period 1 and the equilibrium that mechanism will induce.

Proposition 3. *As in Ennis and Keister (2009), there are depositor preferences such that the suspension mechanism cannot strongly implement the first best allocation. On the other hand, the asset transfer mechanism can always strongly implement the first best.*

Proof. See Appendix C. □

The intermediary may have difficulty committing to suspension because if a run occurs, then when it is time to suspend, there are impatient depositors left to serve. Moreover, since the running patient depositors depleted the intermediary's resources more than usual, when the intermediary is tempted to lift the suspension, it wants to reduce payouts to remaining depositors, both impatient and patient. Thus, it is optimal for a patient depositor to run and take goods before the suspension if possible. The asset transfer mechanism does not face the same commitment problem for two reasons. First, impatient depositors are never turned away, so the intermediary does not feel the same temptation to abandon protocol. Second, patient depositors are never tempted to take goods early, and instead take the asset if they fear a run. Since the asset transfer depletes the intermediary's resources *less* than usual, if a run pushes the intermediary to change its mechanism, it wants to *increase* payouts to remaining depositors.

4.2.2 Repeat Visits

The classic Diamond and Dybvig (1983) setup imposes the stark assumption that a depositor's lifetime liquidity needs are revealed to them the first time they visit the intermediary. Engineer (1989) demonstrates that if we relax this assumption, then suspension may no longer stop runs. Intuitively, when depositors first visit, they *all* fear they may be impatient, and so want to withdraw before withdrawals are suspended. In this section, we consider an extension of our baseline setup that resembles the model in Engineer (1989). We show that asset transfers are more effective than suspension.

Consider the environment from Section 2.1 but now allow for repeat visits during period 1. Each agent draws two independent places in line, $s_1 \in [0, 0.5]$ and $s_2 \in (0.5, 1]$. At the beginning of the interval $[0, 0.5]$, a measure $\zeta\lambda$ of depositors learn they are impatient, where $\zeta \in [0, 1]$. At the beginning of the interval $(0.5, 1]$, of the remaining $1 - \zeta\lambda$ depositors who do not yet know whether they are impatient, a measure $(1-\zeta)\lambda$ learn they are impatient, and the other $1-\lambda$ depositors are patient. Thus, a depositor who does not learn they are impatient at the beginning of the first interval believes they will turn out to be impatient with probability $(1-\zeta)\lambda/(1-\zeta\lambda)$. As before, a measure λ of depositors end up being impatient.

This extension captures the idea that depositors may have an opportunity to interact with the intermediary before they know whether they are impatient. ζ indexes the amount of information depositors have when they first visit the intermediary. In one extreme, if $\zeta = 1$, then we are in the baseline model except in period 1, each depositor interacts with the intermediary twice after learning their type. In the other extreme, if $\zeta = 0$, then in period 1, each depositor interacts with the intermediary once before they learn their type, and once after.

We maintain that mechanisms are as in our baseline environment: suspension is characterized by a single threshold of withdrawals γ, after which no more depositors can withdraw in period 1, and the goods withdrawal and asset transfer size (c_1^* and κ) are fixed throughout period 1.[14] The following proposition states that the asset transfer mechanism dominates suspension in the sense that it strongly implements for a wider range of ζ.

Proposition 4. *Suppose (c_1^*, c_2^*) is feasible and provides insurance. There exist $\zeta_A \leq \zeta_S$ such that the suspension mechanism can strongly implement (c_1^*, c_2^*) if and only if $\zeta > \zeta_S$, and the asset transfer mechanism can strongly implement if and only if $\zeta > \zeta_A$. Moreover, $\zeta_A < 1$ and if the degree of insurance, c_1^*/c_2^*, is sufficiently large, then $\zeta_S > 0$ and $\zeta_A < \zeta_S$, i.e., there is a non-empty interval of ζ for which asset transfers can strongly implement (c_1^*, c_2^*) but suspension cannot.*

Proof. See Appendix C. □

[14]This contrasts with Engineer (1989) in which withdrawals can be suspended after one threshold is breached during the first round of visits, then allowed at the beginning of the second round of visits until another threshold is breached. If we allowed for these multiple suspension thresholds, then it would also make sense to allow for the size of the goods withdrawal (as in Engineer (1989)) and of the asset transfer to vary during the second round of visits as a function of depositor actions during the first round. For the sake of simplicity, we do not allow this level of generality.

If a depositor takes the asset during their first visit and turns out to be impatient, then they can liquidate it for positive value. On the other hand, if a depositor does not withdraw during their visit and turns out to be impatient after suspension is triggered, then they receive nothing. Suspension thus ends up looking like asset transfers that cannot be liquidated by depositors in period 1. As a result, asset transfers are more effective.

4.2.3 Aggregate Return Risk

So far, we have studied environments in which the efficient way for the intermediary to provide goods to patient depositors is to hold assets to maturity. We now allow for the possibility that it is efficient to liquidate assets because of a fall in the return. Suspension then leads to a worse outcome than the demand deposit and asset transfer mechanisms because it forces assets to remain on the intermediary's balance sheet.

One interpretation is that the intermediary is not benevolent and wants to survive until period 2. It uses suspension to stop depositors from forcing the liquidation of its assets. This is in the spirit of a number of papers that demonstrate that giving depositors the right to force liquidation may be a powerful disciplining device on intermediary behavior (for example, Calomiris and Kahn (1991) and Diamond and Rajan (2001)). We show that the asset transfer mechanism prevents runs, and unlike suspension, still allows depositors to play this disciplining role. Along with the previous discussion of commitment, this shows that asset transfers perform better than suspension whether or not the intermediary is benevolent.

Consider the environment from Section 2.1 but now allow for aggregate return risk. Suppose that with probability $\theta \in (0,1)$, the long-term return on the asset is R, and with probability $1-\theta$, the return is 0. Regardless of the return, the asset can be liquidated in period 1 for 1 good, as before. The value of the long-term return is realized at the beginning of period 1 and is common knowledge. We restrict attention to mechanisms in which the options offered do not depend on the realization of the long-term return.[15]

Proposition 5. *Suppose (c_1^*, c_2^*) is feasible and provides insurance when the long-term return is R. Set the asset transfer to be $\kappa = c_2^*/R$ in the asset transfer mechanism. When the long-term return is R, both the asset transfer and suspension mechanisms strongly implement the first best. When the long-term return is 0, the unique equilibrium under the asset transfer mechanism has strictly higher welfare than the unique equilibrium under the suspension mechanism.*

Proof. See Appendix C. □

Suspension is worse than the demand deposit mechanism because it prevents the forced, yet efficient, liquidation of the intermediary's assets; patient depositors run, but suspension kicks in and closes the intermediary until period 2. By contrast, the asset transfer mechanism is equivalent to the demand deposit mechanism; patient depositors withdraw goods early, and force the intermediary to liquidate its assets.

4.3 Idiosyncratic Return Risk

A clear economic implication of our results thus far 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 Diamond and Dybvig (1983) environment. In this section, we suppose the intermediary holds a diversified portfolio with a deterministic return, but can only transfer units of the asset that carry unobservable idiosyncratic risk. We show that if this risk is sufficiently large, then the asset transfer mechanism is no longer effective because an asset transfer that patient depositors prefer over the risk free withdrawal of goods is too expensive. Compared to the asset transfer cost ε in our baseline model, this provides a more direct motivation for

[15]This captures that the intermediary cannot contract on the long-term return, and that giving the intermediary discretion does not work—possibly because the intermediary and depositors have a conflict of interest over how to respond if the return is 0.

assets to remain with the intermediary rather than with depositors between periods 1 and 2, even though the intermediary's only ability is aggregation.

4.3.1 Environment Changes

Consider the environment from Section 2.1, but replace the investment technology with the following. In period 0, an agent chooses a number of investments, and the size of each. An investment of x units of the endowment yields an asset that generates x units of the good if interrupted in period 1 and Rx units of the good if held until period 2, where R is randomly drawn at the beginning of period 2 and is i.i.d. across investments:

$$R = \begin{cases} R_H & \text{with probability } q \\ R_L & \text{with probability } 1-q \end{cases}$$

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 a decreasing relationship between the size of an investment and its average cost, perhaps due to a fixed cost of starting a new investment.[16] It implies that each depositor can only make finitely many investments, leaving them exposed to not only liquidity preference risk (as before) but also idiosyncratic return risk. An intermediary, by contrast, can make uncountably many investments, and so will create a fully diversified portfolio with non-random period 2 return $\bar{R}$.

We further impose that each asset and the ownership of each asset are perfectly indivisible; all the intermediary can do with an asset is liquidate, transfer, or hold it until period 2 *in its entirety*. In particular, the intermediary cannot create a new, diversified, and transferable asset by mixing together fractions of assets. Thus, even

[16] The minimum size makes our investment technology similar to the one in Diamond (1984) and Williamson (1986), although for them, it plays a different role of justifying costly monitoring.

though the intermediary fully diversifies its portfolio, it can only transfer assets that bear the same idiosyncratic risks a depositor would have faced had they invested on their own. We interpret this as allowing the intermediary to provide insurance by pooling resources but limiting its ability to securitize its portfolio.[17]

Finally, for simplicity, we suppose asset transfers are frictionless, i.e., $R^a = R$ or equivalently, $\varepsilon = 0$. For technical reasons, we impose the additional restriction on preferences that $\lim_{c \to 0} u(c) = -\infty$.

4.3.2 Intermediary Problem

We now characterize when the asset transfer mechanism can strongly implement the first best allocation in this setting. The constrained planner problem and the first best allocation are the same as in Section 2.3 but 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 asset of size κ to each depositor and, when choosing κ, the constraint $\kappa \geq \bar{x}$ does not bind.[18] Hence, the intermediary makes a measure $1/\kappa$ of investments, each of size κ.

The following theorem states that for fixed preferences and a fixed average return, the asset transfer mechanism can strongly implement the first best allocation if and only if the dispersion of idiosyncratic returns is sufficiently low.

Theorem 3. *Vary $\eta \equiv R_H/R_L$, and adjust the return realizations R_H and R_L so that the average return, $\bar{R}$, and the probability of a high return, q, are constant. There exists a $\bar{\eta} \in (1, \infty)$ such that the asset transfer mechanism can strongly implement*

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

[18] Specifically, we suppose parameters are such that 1) if the intermediary can strongly implement the first best by offering, as its asset transfer, a single asset of size κ, then $\kappa \geq \bar{x}$; and 2) if the intermediary cannot strongly implement the first best with any such asset transfer, then $\bar{x}$ is sufficiently large that the intermediary also cannot strongly implement the first best by offering to transfer two or more assets to any depositors.

the first best allocation if and only if $\eta < \bar{\eta}$.

Proof. See Appendix D. □

A patient depositor that takes the asset transfer now faces idiosyncratic return risk. Hence, if return dispersion η is higher, then the intermediary must offer a higher transfer size κ to maintain patient depositors' preference for the risky asset transfer over the risk free early withdrawal of goods. As η increases, the required κ is eventually so large that a new type of run equilibrium emerges in which all patient depositors take the asset transfer, and the intermediary runs out of resources before the end of period 1. In this sense, idiosyncratic return risk plays the same role as the asset transfer cost ε.

As with the asset transfer cost in Corollary 1, even if $\eta \geq \bar{\eta}$, the asset transfer mechanism may still be able to strongly implement some degree of insurance, unlike the demand deposit mechanism.

5 Conclusion

We showed that a benevolent intermediary facing the classic Diamond and Dybvig (1983) 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 showed that this mechanism is particularly relevant for the most recent crisis in which a significant portion of deposits were held by large, sophisticated investors with knowledge about the sectors into which their banks were lending. We also showed that this mechanism dominates suspension if policy makers have limited commitment, depositors repeatedly interact with the intermediary, and/or there is aggregate return risk. An important implication of our results 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.

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A Proofs for Section 2.1

Lemma 1. *Define a mechanism* Γ *that offers depositors three options: "withdraw", "wait", and "transfer", where the first two are as in the demand deposit mechanism, and if a depositor chooses "transfer", then they only receive units of the asset.*

If there does not exist a constant κ *such that the asset transfer mechanism strongly implements the first best, then* Γ *does not strongly implement the first best.*

Proof. Suppose the asset transfer mechanism cannot strongly implement the first best allocation. It follows from Theorem 1 that $R^a \leq \frac{R}{c_2^*/c_1^*}$. We now show that under the mechanism Γ, a suboptimal equilibrium exists. Suppose impatient depositors "withdraw" and patient depositors choose whichever they prefer of "withdraw" and "transfer", breaking ties in favor of the former. In this equilibrium, if no depositors are offered an asset transfer $\kappa > c_1^*/R^a$, then a traditional run equilibrium exists, and we are done. Suppose instead that a fraction $\beta > 0$ of depositors are offered an asset transfer $\kappa > c_1^*/R^a$, which they take if patient. Define $\bar{\kappa}$ to be the average value of κ offered to such depositors. It follows that $\bar{\kappa} > c_1^*/R^a \geq c_2^*/R$. Hence, the intermediary runs out of resources strictly before the end of period 1 because if not, its resources remaining at the end of period 1 would be

$$1 - \lambda c_1^* - (1-\lambda)(1-\beta)c_1^* - (1-\lambda)\beta\bar{\kappa},$$

which is strictly less than 0 since $\lambda c_1^* + (1-\lambda)c_2^*/R = 1$ and $c_1^* > c_2^*/R$. As such, a depositor who waits would receive nothing in period 2, so 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. □

Proof of Theorem 1. Necessity: We show the contrapositive: if $R^a \leq \frac{R}{c_2^*/c_1^*}$, then the asset transfer mechanism cannot strongly implement the first best allocation, i.e., a suboptimal equilibrium exists. Suppose $R^a \leq \frac{R}{c_2^*/c_1^*}$. We consider three cases. First, suppose $\kappa \leq c_1^*/R^a$. Then, both impatient and patient depositors weakly prefer to withdraw goods in period 1 over taking the asset transfer. It follows that the traditional run equilibrium in which all depositors withdraw goods in period 1 exists.

Next, suppose $\kappa \geq c_1^*$. We show that there is a suboptimal equilibrium in which all depositors take the asset transfer. Both impatient and patient depositors weakly prefer to take the asset transfer over withdrawing goods in period 1. In the proposed equilibrium, the intermediary runs out of resources strictly before the end of period 1 because the transfer requires at least as many assets as a goods withdrawal. Formally, if the intermediary did not run out of resources by some place $s < 1$ in line, then its asset holdings remaining at the end of period 1 would be $1 - \kappa < 1 - c_1^* < 0$. Thus, the proposed equilibrium is an equilibrium because as in a traditional run, any depositor who waits receives 0 goods. Moreover, the equilibrium is suboptimal because as in a traditional run, a positive measure of depositors receive 0 goods.

Finally, suppose $c_1^*/R^a < \kappa < c_1^*$. We show that there is a suboptimal equilibrium in which impatient depositors withdraw goods in period 1, and patient depositors take the asset transfer. Impatient depositors strictly prefer to withdraw goods in period 1 over taking the asset transfer, and patient depositors strictly prefer to take the asset transfer over withdrawing goods in period 1. Moreover, since $R^a \leq \frac{R}{c_2^*/c_1^*}$, it follows that $\kappa > c_2^*/R$. As such, in the proposed equilibrium, the intermediary runs out of resources strictly before the end of period 1 because the transfer requires more assets than must be used to supply a depositor with c_2^* goods in period 2. Formally, if the intermediary did not run out of resources by some place $s < 1$ in line, then its asset holdings remaining at the end of period 1 would be

$$1 - \lambda c_1^* - (1-\lambda)\kappa < 1 - \lambda c_1^* - (1-\lambda)c_2^*/R = 0.$$

Thus, the proposed equilibrium is an equilibrium because as in a traditional run, any depositor who waits receives 0 goods. Moreover, the equilibrium is suboptimal because as in a traditional run, a positive measure of depositors receive 0 goods.

Sufficiency: We show that if $R^a > \frac{R}{c_2^*/c_1^*}$, then there exists an asset transfer κ such that the asset transfer mechanism strongly implements the first best allocation. Specifically, set $\kappa = c_2^*/R$. Since $\kappa < c_1^*$, impatient depositors strictly prefer to withdraw goods in period 1 over taking the asset transfer. Moreover, they also do not want to wait to withdraw until period 2. Since $\kappa > c_1^*/R^a$, patient depositors strictly prefer to take the asset transfer over withdrawing goods in period 1. It follows that in any equilibrium, impatient depositors withdraw goods in period 1, and patient depositors mix between taking the asset transfer and waiting to withdraw goods in period 2. Suppose patient depositors take the asset transfer with probability β. Then, at the end of period 1, the measure of the intermediary's asset holdings remaining is

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

where the last equality follows from the fact that the resource constraint binds in the first best. As such, a depositor who waits receives c_2^* goods in period 2.

There are two cases. If $R^a < R$, then patient depositors strictly prefer to wait than to take the asset transfer because the former generates c_2^* goods and the latter generates $R^a\kappa = \frac{R^a}{R}c_2^*$ goods. Thus, there is a unique equilibrium, and it entails impatient depositors withdrawing goods in period 1, and patient depositors waiting to withdraw goods in period 2. This equilibrium yields the first best allocation. On the other hand, if $R^a = R$, then patient depositors are indifferent between taking the asset transfer and waiting to withdraw in period 2. Thus, any degree of mixing β is an equilibrium, and they all yield the first best allocation.

As an aside, the above arguments show that if the asset transfer mechanism strongly implements the first best allocation, then the first best is also the unique outcome that survives the iterated deletion of strictly dominated strategies. $\square$

Proof of Theorem 2. The crisis threshold $\bar{p}$ is defined by

$$R(1-\lambda c_1^*/\bar{p})/(1-\lambda) = c_1^*.$$

Rearranging yields

$$\bar{p} := \lambda c_1^*/(1-(1-\lambda)c_1^*/R) < 1.$$

Suppose $p < \bar{p}$ for the remainder of the proof.

For the first statement, under the demand deposit mechanism, as always, impatient depositors all withdraw early. Thus, patient depositors withdraw early as well because regardless of their actions, each patient depositor receives less than c_1^* goods from waiting. Thus, there is a unique equilibrium. A fraction $1/(c_1^*/p)$ of depositors get c_1^* goods, and the rest get 0.

For the second and third statement, we prove that if an asset transfer has a goods withdrawal c_1^* and asset transfer κ that satisfies $c_1^*/R^a < \kappa \leq c_1^*/p$, then there is a unique equilibrium, and it has welfare strictly greater than under the demand deposit mechanism. With $\kappa > c_1^*/R^a$, patient depositors strictly prefer to take the asset transfer over withdrawing goods in period 1. They also strictly prefer to take the asset transfer over waiting because $\kappa > c_1^*/R^a$ implies that the more patient depositors take the asset transfer, the less remains per patient depositor who waited in period 2. Thus, there is a unique equilibrium. A fraction $1/(\lambda c_1^*/p + (1-\lambda)\kappa)$ of depositors get goods, which is weakly greater than $1/(c_1^*/p)$ since $\kappa \leq c_1^*/p$. Of these depositors, a fraction λ get c_1^* goods, and the rest $R^a\kappa > c_1^*$ goods. Thus, welfare is strictly higher than under the demand deposit mechanism.

The third statement follows immediately. The second statement follows because from the proof of Theorem 1, the asset transfer satisfies $c_1^*/R^a < \kappa \leq c_2^*/R$, and because $c_2^*/R < c_1^* < c_1^*/p$. □

B Proofs for Section 4.1

Proof of Proposition 1. The intermediary problem is the same as before except now the asset liquidation value is p, and the incentive compatibility constraint for patient depositors accounts for the possibility that they withdraw goods in period 1 to purchase assets in the market.

The proof is thus the same as the proof of Theorem 1, except that for the asset transfer to be preferred by patient depositors over withdrawing goods, it must be that $R^a\kappa > (R^b/p)c_1^*$ instead of $R^a\kappa > c_1^*$. It follows that the asset transfer mechanism can strongly implement if and only if $R^a > \frac{R}{c_2^*/c_1^*}R^b/p$, which is the inequality in the proposition. □

Proof of Proposition 2. The crisis threshold $\hat{p}$ is defined by

$$R(1-\lambda c_1^*/\hat{p})/(1-\lambda) = (R^b/\hat{p})c_1^*.$$

Rearranging yields

$$\hat{p} := ((1-\lambda)R^b + \lambda)c_1^*/R < 1.$$

Suppose $p < \hat{p}$ for the remainder of the proof.

Under the demand deposit mechanism, by construction as in the proof of Theorem 2, there is a unique equilibrium: all depositors withdraw goods early. A fraction $1/(c_1^*/p)$ of depositors get goods. A fraction λ of those are impatient and get c_1^*, and a fraction $1-\lambda$ are patient, so they purchase assets in the market and get $(R^b/p)c_1^*$ goods.

Under the asset transfer mechanism, since $R^a > R^b$, it is possible to choose an asset transfer κ that satisfies $R^a\kappa > (R^b/p)c_1^*$ and $\kappa \leq c_1^*/p$. The rest of the proof is the same as in the proof of Theorem 2. □

C Proofs for Section 4.2

Proof of Proposition 3. For the suspension mechanism, the proof is as in Ennis and Keister (2009, 2010). Note that the proof is the same for any value of the suspension threshold above its minimum, i.e., $\gamma \geq \lambda$ because after a measure λ of depositors, the intermediary chooses a new mechanism.

Consider the asset transfer mechanism. Suppose the asset transfer is $\kappa = c_2^*/R$ at first. Regardless of the mechanism that the intermediary will choose after interacting with a measure λ of depositors, a patient depositor strictly prefers to take the asset transfer rather than withdraw goods in period 1; each yields a value independent of the intermediary and other depositors, and the asset transfer yields a strictly higher value for patient depositors. On the other hand, an impatient depositor always strictly prefers to withdraw goods rather than take the asset transfer or wait until period 2. Suppose a fraction α of patient depositors in the first λ measure of depositors take the asset transfer, and the rest wait until period 2. Then, when the intermediary chooses their new mechanism, the measure of assets remaining on their balance sheet is

$$1-\lambda^2 c_1^* - \lambda(1-\lambda)\alpha c_2^*/R.$$

A measure $1-\lambda$ of depositors remain to interact with the intermediary in period 1, a fraction λ of whom are impatient, and a measure $\lambda(1-\lambda)(1-\alpha)$ of patient depositors have already decided to wait until period 2 to withdraw. Thus, the new first best allocation consists of a c_1^{**} and c_2^{**} that satisfy the First Order Condition:

$$u'(c_1^{**}) = Ru'(c_2^{**}),$$

and the budget constraint:

$$R[1-\lambda^2 c_1^* - \lambda(1-\lambda)\alpha c_2^*/R - (1-\lambda)\lambda c_1^{**}] = [\lambda(1-\lambda)(1-\alpha) + (1-\lambda)^2]c_2^{**}.$$

We can see that $c_1^{**} = c_1^*$ and $c_2^{**} = c_2^*$ because patient depositors who took the asset transfer used up as many units of the asset as they would had they waited and received c_2^*, leaving the intermediary in effectively the same position as at the beginning of period 1. It follows that the intermediary strongly implements the new first best, which is the same as the old first best, with the asset transfer mechanism. Thus, a patient depositor in the initial measure λ of depositors is indifferent between taking the asset transfer and waiting, either of which yields c_2^* goods. It follows that the asset transfer mechanism strongly implements the first best. □

Proof of Proposition 4. Set the asset transfer to be $\kappa \in (c_1^*/R, c_2^*/R]$, so that patient depositors strictly prefer taking the transfer over withdrawing goods and so that the transfer requires less resources than providing a depositor with c_2^* goods in period 2. As in the baseline model, a depositor who knows they are impatient always chooses to withdraw goods in period 1, which we take as given throughout the proof. We first show there is an equilibrium that yields the allocation (c_1^*, c_2^*), and then turn to whether there is also a run equilibrium.

Suppose depositors believe other depositors are not running under either suspension or the asset transfer mechanism. The decision problem for a patient depositor visiting the intermediary for the second time in period 1 is the same as in the baseline model, so they wait (or if $\kappa = c_2^*/R$, it is equivalent for them to take the asset transfer). A depositor visiting for the first time who does not know whether they are impatient faces the payoffs:

$$\begin{aligned}
\mathbb{E}[u(\text{withdraw})] &= u(c_1^*) \\
\mathbb{E}[u(\text{wait})] &= \frac{(1-\zeta)\lambda}{1-\zeta\lambda} u(c_1^*) + \frac{1-\lambda}{1-\zeta\lambda} u(c_2^*) \\
\mathbb{E}[u(\text{transfer})] &= \frac{(1-\zeta)\lambda}{1-\zeta\lambda} u(\kappa) + \frac{1-\lambda}{1-\zeta\lambda} u(R\kappa),
\end{aligned}$$

where the last option is only available in the asset transfer mechanism. The weights in the latter two options reflect the probability of ending up impatient vs. patient, and the arguments of u in the last option reflect that a depositor who takes the asset transfer will liquidate in period 1 if they turn out to be impatient and will hold until maturity if they turn out to be patient. Such a depositor prefers waiting over withdrawing because $c_2^* > c_1^*$. They also prefer waiting over taking the transfer because $\kappa \leq c_2^*/R < c_1^*$. Thus, there is an equilibrium in which depositors who do not know their type when they first visit wait, impatient depositors withdraw c_1^*, and patient depositors ultimately get c_2^*.

Now, the only possible run is one in which depositors visiting for the first time who do not know whether they are impatient withdraw goods. Specifically, under the suspension mechanism, a depositor who knows they are patient during the second round of visits in period 1 strictly prefers to wait. This is because the suspension threshold is sufficiently strict ($\gamma < (R/c_1^* - 1)/(R-1)$) so that a depositor who waits always receives strictly more than c_1^* in period 2. Similarly, under the asset transfer mechanism, a depositor who knows they are patient during the second round of visits in period 1 strictly prefers to take the asset transfer over withdrawing goods. Since transfers are frictionless ($R = R^a$) and the transfer is c_2^*/R, this provides such a depositor with c_2^* goods.

Thus, under the suspension mechanism, suppose depositors believe other depositors are running when they first visit the intermediary. In this case, withdrawals will be suspended after a fraction $\gamma < 1$ of depositors first visit, and so before any depositors visit for the second time in period 1. A depositor visiting for the first time who does not know whether they are impatient faces the payoffs:

$$\mathbb{E}[u(\text{withdraw})] = u(c_1^*)$$
$$\mathbb{E}[u(\text{wait})] = \frac{(1-\zeta)\lambda}{1-\zeta\lambda}u(0) + \frac{1-\lambda}{1-\zeta\lambda}u(\tilde{c}_2)$$

because they will be unable to withdraw at their second visit, and where $\tilde{c}_2 = R(1-\gamma c_1^*)/(1-\gamma) \le c_2^*$. The run is not an equilibrium if and only if the value of withdrawing is strictly less than the value of waiting. The latter is decreasing in the suspension threshold γ (through $\tilde{c}_2$), so the suspension mechanism can strongly implement (c_1^*, c_2^*) if and only if the value of withdrawing is strictly less than the value of waiting when γ is at its minimum value of λ. In that case, $\tilde{c}_2 = c_2^*$, so the value of waiting is an average of $u(0)$ and $u(c_2^*)$, where the weight on the former is strictly decreasing in ζ. Therefore, suspension strongly implements (c_1^*, c_2^*), if and only if $\zeta > \zeta_S$ for some ζ_S. Moreover, as the degree of insurance, c_1^*/c_2^*, increases to 1, ζ_S must eventually be strictly positive because $u(c_2^*)$ goes to $u(c_1^*)$, and at $\zeta = 0$, the weight on $u(0)$ in the value of waiting is still strictly positive.

Next, under the asset transfer mechanism, suppose depositors believe other depositors are running when they first visit the intermediary. In this case, the intermediary will run out of resources after a fraction $1/c_1^* < 1$ of depositors first visit, and so before any depositors visit for the second time in period 1. A depositor visiting for the first time who does not know whether they are impatient faces the payoffs:

$$\begin{aligned}
\mathbb{E}[u(\text{withdraw})] &= u(c_1^*) \\
\mathbb{E}[u(\text{wait})] &= u(0) \\
\mathbb{E}[u(\text{transfer})] &= \frac{(1-\zeta)\lambda}{1-\zeta\lambda}u(\kappa) + \frac{1-\lambda}{1-\zeta\lambda}u(R\kappa)
\end{aligned}$$

because they will be unable to withdraw at their second visit, and if they turn out to be impatient, they will liquidate any asset holdings. The run is not an equilibrium if and only if the value of taking the transfer is strictly greater than the value of withdrawing; this is the case from the proof of Theorem 1 because $\kappa \leq c_2^*/R < c_1^*$ implies that the resources used for the asset transfer are less than the resources used on average in the first best for a depositor who does not know whether they are impatient. Thus, the asset transfer mechanism can strongly implement (c_1^*, c_2^*) if and only if the value of taking the transfer is strictly greater than the value of withdrawing when κ is at its maximum value of c_2^*/R. This is the case if and only if $\zeta > \zeta_A$ for some ζ_A. The threshold ζ_A is strictly less than 1 because $c_2^* > c_1^*$ and at $\zeta = 1$, the value of taking the transfer is $u(c_2^*)$. Moreover, if the ζ threshold for suspension, ζ_S, is strictly greater than 0, then it must be that $\zeta_A < \zeta_S$, i.e., there is a range of ζ for which asset transfers strongly implement but suspension does not, because the expected utility from withdrawing is the same in both cases, but the expected utility from a transfer is strictly greater than the expected utility from waiting under suspension. □

Proof of Proposition 5. If the return realization is R, then suspension works as in Diamond and Dybvig (1983), and the asset transfer mechanism works as in Theorem 1. For the remainder of the proof, we suppose the long-term return is 0.

In the suspension mechanism, there is a unique equilibrium: all depositors withdraw goods in period 1. A fraction γ (the suspension threshold) of depositors each receive c_1^* in period 1, and the remaining depositors each receive 0. In the asset transfer mechanism, there is a unique equilibrium: all depositors withdraw goods in period 1. A fraction $1/c_1^*$ of depositors each receive c_1^* in period 1, and the remaining depositors each receive 0. Since the ability of suspension to strongly implement when the return realization is R implies that $1/c_1^* > \gamma$, this allocation yields higher welfare than the allocation in the unique equilibrium under suspension. □

D Proofs for Section 4.3

Proof of Theorem 3. Note that as we vary the return dispersion η, the first best allocation (c_1^*, c_2^*) is constant because we adjust R_H and R_L to keep the average return $\bar{R}$ fixed.

Rearranging the inequality in Theorem 1 shows that in our baseline model, the asset transfer mechanism can strongly implement the first best if and only if $c_2^*/R > c_1^*/R^a$. The proof of Theorem 1 demonstrates that this is the case because the asset transfer mechanism can strongly implement the first best if and only if there is an asset transfer κ that 1) requires less asset than must be used to supply a depositor with c_2^* goods in period 2 ($\kappa \leq c_2^*/R$); and 2) is strictly preferred by patient depositors over withdrawing c_1^* goods in period 1 ($R^a\kappa > c_1^*$). Translating this logic into our setting with idiosyncratic return risk, 1) becomes $\kappa \leq c_2^*/\bar{R}$, and 2) becomes

$$qu(R_H\kappa) + (1-q)u(R_L\kappa) > u(c_1^*).$$

Since the left-hand side is strictly increasing in κ, it follows that the asset transfer mechanism can strongly implement the first best if and only if the inequality holds at $\kappa = c_2^*/\bar{R}$:

$$qu(R_H c_2^*/\bar{R}) + (1-q)u(R_L c_2^*/\bar{R}) > u(c_1^*).$$

We now show that there exists a $\bar{\eta} \in (1, \infty)$ such that this inequality holds if and only if $\eta < \bar{\eta}$, where $\eta \equiv R_H/R_L$. Note that if we vary η while keeping $\bar{R}$ and q fixed, then c_1^* is constant.

Using $R_H = \eta R_L$ and $\bar{R} = (q\eta + 1 - q)R_L$, we can write

$$qu(R_H c_2^*/\bar{R}) + (1-q)u(R_L c_2^*/\bar{R}) = qu\left(\frac{\eta c_2^*}{q\eta + 1 - q}\right) + (1-q)u\left(\frac{c_2^*}{q\eta + 1 - q}\right),$$

which we call $U(\eta)$ because we are varying η while keeping $\bar{R}$ (and so c_2^*) and q fixed. Since $U(\cdot)$ is differentiable, it is sufficient to show that $U(\eta)$ is strictly decreasing in η, that $U(1) > u(c_1^*)$, and that $\lim_{\eta \to \infty} U(\eta) < u(c_1^*)$. First,

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

which is equal to 0 at $\eta = 1$, and strictly negative for all $\eta > 1$ because u is strictly concave. Hence, $U(\eta)$ is strictly decreasing in η. Second, $U(1) = u(c_2^*)$, which is strictly greater than $u(c_1^*)$. Finally, as η goes to infinity, $U(\eta)$ goes to negative infinity (strictly less than the $u(c_1^*)$) because the argument of u in the second term goes to 0, and we made the additional technical assumption on preferences in Section 4.3.1 that $\lim_{c \to 0} u(c) = -\infty$. □