TI 2015-101/VI
Tinbergen Institute Discussion Paper

# Liquidity Creation without Banks

*Simas Kucinskas*

*Faculty of Economics and Business Administration, VU University Amsterdam, Tinbergen Institute, the Netherlands.*

# Liquidity Creation Without Banks

Simas Kučinskas*
VU University Amsterdam and Tinbergen Institute

August 17, 2015

**Abstract**

I revisit the Diamond-Dybvig model of liquidity insurance in the presence of hidden trades. The key result is that in this environment deposit-taking banks are not necessary for the efficient provision of liquidity. Mutual funds are constrained efficient when supplemented with the same government liquidity regulation that is required to make a banking system constrained efficient. However, whereas banks are potentially subject to costly panics, mutual funds are not run-prone and hence superior from a welfare perspective if runs happen with a non-zero probability.

**Keywords:** liquidity creation, liquidity insurance, hidden trades, bank runs, mutual funds, narrow banking, financial stability.

**JEL Classification:** D91, E61, G21, G23, G28.

*E-mail: s.kucinskas@vu.nl; for the latest version of the paper, visit my website. I am grateful to my advisor Björn Brügemann for his constant help and guidance. Parts of this paper were written during my stay at De Nederlandsche Bank (DNB). I am thankful to everyone at the Research Department of DNB and in particular to Jakob de Haan and Neeltje van Horen for their hospitality. I thank Franklin Allen, Allen Berger, Piotr Denderski, Lucyna Górnicka, Michael Kumhof, Enrico Perotti, Florian Sniekers, Christian Stoltenberg, Uwe Thümmel, Razvan Vlahu, Chen Zhou, Marius A. Zoican, Makoto Watanabe, and Sweder van Wijnbergen, as well as seminar participants at De Nederlandsche Bank, Finance@VU, VU University Amsterdam Brown Bag Seminar, BiGSEM Doctoral Workshop on Economic Theory, INET Young Scholars Initiative, and DSF/TI PhD Seminar for useful comments and discussions. All mistakes are mine.

# 1 Introduction

The global financial crisis has reignited the debate over the best way to regulate banks. Commentators have offered — and policy makers worldwide put to practice — a range of suggestions, ranging from liquidity requirements and stress tests to separation of bank activities. Some observers, however, have argued that such measures treat the symptom rather than the cause, the fundamental problem being that finance is built upon too much run-prone debt. For example, Admati and Hellwig (2014) argue that capital requirements should be increased to 20–30% of total unweighted bank assets. Some economists have gone even further, suggesting to replace the current financial system with some form of narrow banking, eliminating maturity and liquidity mismatch altogether (Kotlikoff, 2010; Chamley, Kotlikoff, and Polemarchakis, 2012; Cochrane, 2013, 2014; Wolf, 2014).[1]

While more equity arguably makes the financial system safer, it may make liquidity creation, a key function of banks, more difficult (Diamond and Dybvig, 1986; Wallace, 1996). I shed light on the relationship between liquidity provision and financial stability by revisiting the classic Diamond and Dybvig (1983) model in the presence of hidden trades. The main result of this paper is that banks are not necessary for the efficient provision of liquidity in this environment. Mutual funds are constrained efficient when supplemented by appropriate government liquidity requirements. The liquidity regulation is exactly the same as that required to make deposit-taking banks create liquidity in a constrained-efficient manner. However, whereas banks are potentially subject to costly panics, mutual funds are run-proof and hence superior from a welfare perspective. With mutual funds, one can have the cake (liquidity insurance) and eat it too (no financial panics).

The model I use builds upon the recent work of Farhi, Golosov, and Tsyvinski (2009). The setup has two basic ingredients. First, as in the original Diamond-Dybvig model, consumers are uncertain about the timing of their consumption needs. Formally, consumers are hit by *liquidity shocks*, the realization of which is private information. Second, consumers can engage in *hidden trades*. After observing their liquidity shock, consumers can withdraw funds from an intermediary and trade in a private credit market. These trades are not observable and contracts cannot be made contingent on them. Hidden trades, arguably an increasingly important feature of modern markets (Diamond, 1997; Farhi, Golosov, and Tsyvinski, 2009; Chari and Phelan, 2012), limit the amount of liquidity insurance that can be provided by unregulated intermediaries.

[1]See Pennacchi (2012) for a historical overview of narrow banking type proposals. Thakor (2014, Section 5 D.) discusses narrow banking in the context of capital regulation.

I consider a system of financial intermediation based on competitive mutual funds. The type of mutual funds analyzed in this paper was originally proposed by Jacklin (1987). At the initial date, consumers exchange their endowment for an equity stake in the mutual fund. Consumers, as owners of the fund, become entitled to a stream of dividends. The mutual fund in turn invests its capital in an investment project to maximize profits. Importantly, after observing the realization of the liquidity shock, consumers can trade mutual fund shares on a Walrasian market. Selling the shares in the event of a liquidity shock allows the consumers to obtain partial liquidity insurance.

The main result that mutual funds are constrained efficient when combined with government regulation is driven by the interaction of two effects. First, hidden trades force the social planner to equate the present value of consumption — evaluated at the market interest rate — across all consumers. Since the consumers can retrade on the private credit market, they always choose the bundle with the highest market value. Incentive compatibility therefore dictates that the present value of consumption must be equal across all consumers. Second, in a competitive setting hidden trades lead to a market failure. Profit-maximization requires the mutual fund to offer a stream of dividends with the highest market value. As a result, mutual funds have an incentive to free ride on the liquidity provided by other funds and invest too much in the long-term project. Arbitrage among mutual funds makes the interest rate on the private market and the technological rate of return equal, and the resulting laissez-faire equilibrium is constrained inefficient. Unregulated intermediaries fail to provide any liquidity insurance.

By introducing a suitable liquidity requirement, the government solves the market failure arising from arbitrage among intermediaries. However, the constrained efficient allocation must still satisfy the present value constraint. As a result, one can achieve constrained efficiency by giving all consumers the same suitably chosen endowment and letting them trade at the socially optimal interest rate. The mutual fund mechanism does exactly this. It is not necessary to have intermediaries that offer a richer set of contracts because hidden trades dramatically shrink the set of incentive-compatible allocations. Although deposit-taking banks offer multiple consumption bundles to consumers, this provides no advantage over mutual funds when consumers have access to the private market and thus always select a bundle with the highest present value.

To further illustrate the claim that constrained efficiency does not call for a deposit-type contract, I show that a simple tax on investment also implements the constrained efficient optimum. The taxation result highlights the fact that the underlying failure of competitive markets in this environment is a pecuniary externality. Finally, I show that when hidden trades are *not allowed*, mutual funds are inefficient. Without hidden trades, therefore, a policy maker faces a trade-off between liquidity insurance and financial stability. Mutual funds are run-proof but induce a distortion in liquidity provision, while banks are better at providing liquidity but potentially subject to costly panics.

## Related Literature

A vast literature extends the original work of Diamond and Dybvig (1983); for an overview, see Gorton and Winton (2003). Von Thadden (1999) reviews the research on liquidity creation by banks and markets (including mutual funds) from the vantage point of Diamond-Dybvig type models. Bouwman (2013) summarizes the available empirical evidence.

The two most closely related papers to my work are Jacklin (1987) and Farhi, Golosov, and Tsyvinski (2009). In a classic study, Jacklin (1987) made several important contributions; I focus on the ones most directly related to my paper.[2] First, Jacklin introduced mutual funds as a way to provide liquidity insurance without risking a bank run. In a setting *with trading restrictions* (no hidden trades in modern terminology), Jacklin showed that mutual funds can implement the first-best allocation if the consumers have the original Diamond-Dybvig corner preferences (Jacklin, 1987, pp. 30–31). Such preferences are extreme: consumers hit by a liquidity shock only care about consumption today; the remaining consumers are indifferent about consuming today and tomorrow. With more plausible preferences, mutual funds are in general inefficient (Jacklin, 1987, Theorems 2 and 3).[3]

Furthermore, Jacklin proved that *with no trading restrictions* and *no government regulation*, mutual funds and banks are equivalent, i.e. give rise to the same allocation (Jacklin, 1987, Theorem 4). However, in that setting the comparison of banks and mutual funds is moot, as unregulated banks provide no liquidity insurance to begin with (von Thadden, 1999, Proposition 3; Allen and Gale, 2004, Theorem 3; Farhi, Golosov, and Tsyvinski, 2009, p. 980).[4] Jacklin did not investigate whether

[2] Haubrich and King (1990) explored many of the same questions in a related banking model. Cone (1982) is also often cited as being among the first to note that unrestricted trade leads to less liquidity provision.

[3] Formally, Jacklin showed that when incentive-compatibility constraints are not binding, mutual funds implement the first best if and only if the first best is a competitive equilibrium from equal endowments (Theorem 2). With binding incentive constraints, mutual funds cannot implement the second best (Theorem 3). However, Jacklin did not analyze whether competitive equilibria from equal endowments are compatible with liquidity insurance. Admittedly, that would have been a small step away from Jacklin's original analysis. Proposition 3 of the present paper fills in this gap.

[4] Jacklin argued that when deposits can be traded, the resulting allocation must be a competitive equilibrium from equal endowments (Jacklin, 1987, p. 42). However, as discussed in Footnote 3, Jacklin did not explicitly characterize such equilibria.

government intervention could be welfare-improving, and whether banks would have an advantage over mutual funds once government regulation is put in place.

Farhi, Golosov, and Tsyvinski (2009) show that it is possible to provide liquidity insurance even in the presence of hidden trades. Whereas Jacklin was not very explicit about the informational frictions that rule out trading restrictions, Farhi, Golosov, and Tsyvinski formally define the social planner's problem when consumers can engage in hidden trades. Farhi, Golosov, and Tsyvinski then employ tools of mechanism design to characterize the constrained efficient allocation and show that it involves liquidity insurance (Farhi, Golosov, and Tsyvinski, 2009, Theorem 1). Hidden trades need not destroy risk sharing. Importantly, Farhi, Golosov, and Tsyvinski show that it is possible to decentralize the constrained efficient optimum with competitive banks by introducing a liquidity requirement (Farhi, Golosov, and Tsyvinski, 2009, Proposition 1). However, Farhi, Golosov, and Tsyvinski do not investigate whether banks have an advantage over mutual funds in their environment. This is an important open question because deposit-taking banks are potentially subject to costly runs.

To sum up, existing work has not answered whether run-prone banks are necessary for the efficient provision of liquidity in a setting with hidden trades. The current paper shows that banks are, in fact, not necessary for the efficient provision of liquidity. With government regulation, mutual funds can provide optimal liquidity insurance without any associated risks to financial stability.

# 2 Model

I study a Diamond-Dybvig type model with hidden trades, following the setup of Farhi, Golosov, and Tsyvinski (2009) closely.

## 2.1 Primitives

**Environment.** There are three periods: $t = 0, 1, 2$. The economy is populated by a unit measure of ex ante identical consumers. Consumers are endowed with $e$ units of an infinitely divisible consumption good at the initial date, and maximize expected utility. At the beginning of period one consumers experience a preference shock. The shock is private information and so traditional insurance contracts are not feasible. Utility of consumption is state-dependent:

$$U(c_1, c_2; \theta) = \begin{cases} U(c_1, c_2; E) & \text{with probability } \pi(E) \\ U(c_1, c_2; L) & \text{with probability } \pi(L) \end{cases} \tag{1}$$

In words, with probability $\pi(E)$ the consumer is an *early type* and places more weight on consumption in period one. With complementary probability, the consumer is a *late type* and cares relatively more about consumption in period two. I write $\pi(\theta)$ to denote the probability of being type $\theta$ and let $\Theta \equiv \{E, L\}$ denote the set of possible types.[5] Following Jacklin (1987) the idea that early consumers value period one consumption more than the late types is formally captured by the single-crossing condition

$$\frac{U_1(c_1, c_2; E)}{U_2(c_1, c_2; E)} > \frac{U_1(c_1, c_2; L)}{U_2(c_1, c_2; L)} \tag{2}$$

for all $(c_1, c_2) \in \mathbb{R}^2_{++}$. Utility function $U(c_1, c_2; \theta)$ is well-defined on $\mathbb{R}^2_{+}$, except possibly when $c_t$ is equal to zero, twice continuously differentiable, weakly increasing in both arguments and strictly increasing in at least one, and strictly concave.[6] To rule out pathological cases, I assume that the following Inada conditions hold:

$$\lim_{c_j \downarrow 0} U_j(c_1, c_2; \theta) = +\infty \text{ for all } j \text{ and some } \theta \in \Theta. \tag{3}$$

Note that this condition does not rule out the original Diamond-Dybvig corner preferences, as the condition only needs to hold for some type $\theta$. Finally, a law of large numbers for a continuum of i.i.d. random variables holds, so that there is no risk about the measure of early consumers in the aggregate.

**Technology.** Two technologies are available in the economy: storage and a productive long-term technology. The long-term technology is deterministic and yields $\widehat{R} > 1$ units of consumption good in period two per one unit invested in period zero. A fraction of the long-term investment may be liquidated after the realization of the liquidity shocks in period one. Liquidation is costless: for each unit of the long-term investment liquidated, agents receive one unit of the consumption good, as in the original Diamond and Dybvig setup. In addition, there is a storage technology that transfers consumption across periods. Storage is available in both period zero and period one, while one can invest in the long-term technology only in period zero.

[5] The assumption of two types is for simplicity only. The results generalize straightforwardly to the case of finitely many types.

[6] This specification is general enough to nest all of the cases typically considered in the literature, including those in Farhi, Golosov, and Tsyvinski (2009). It is important to allow for general utility functions because of the implementability result of Jacklin (1987) discussed earlier: mutual funds are efficient when hidden trades are not feasible and consumers have Diamond-Dybvig preferences. With hidden trades and optimal regulation, one would expect mutual funds to do well with the original Diamond-Dybvig preferences but not necessarily otherwise.

## 2.2 Efficiency and Welfare

An *allocation* is a collection of consumption bundles for both types $\{(c_{1\theta}, c_{2\theta})\}_{\theta\in\Theta}$ where $c_{t\theta}$ is consumption of type $\theta$ at time $t$. An allocation is said to be *feasible* if

$$\sum_{\theta} \pi(\theta) \left( c_1(\theta) + \frac{c_2(\theta)}{\widehat{R}} \right) \leq e$$

and all consumption levels are weakly positive. Since all consumers are identical in period zero, *ex ante welfare* is well-defined, and given by

$$\sum_{\theta} \pi(\theta) U\left(c_1(\theta), c_2(\theta); \theta\right).$$

By the Revelation Principle, it is without loss of generality to only focus on allocations that satisfy the following *incentive-compatibility* constraints:[7]

$$U\left(c_1(\theta), c_2(\theta); \theta\right) \geq U\left(c_1(\theta'), c_2(\theta'); \theta\right) \text{ for all } \theta, \theta' \in \Theta. \tag{4}$$

The definitions of first- and second-best efficiency are standard. The definition of constrained (third-best) efficiency in the environment with hidden trades is provided in the next section.

**Definition 1.** *A feasible allocation is said to be* first best *if it maximizes ex ante welfare. A feasible allocation is said to be* second best *if it maximizes ex ante welfare subject to incentive-compatibility constraints in Eq.* (4)*.*

It turns out to be useful to define the following benchmark allocation. Consider a world in which consumers have no access to financial markets or intermediaries, but can invest in the long-term technology on their own. Following the literature, I will call this the *autarkic* allocation (see, e.g., Freixas and Rochet, 2008, pp. 21–22).

**Problem 1** (Autarky)**.**

$$\begin{aligned} \max_{c_1, c_2} \ & U(c_1, c_2; \theta) \\ \text{s.t. } & c_1 + \frac{c_2}{\widehat{R}} = e \\ & c_1, c_2 \geq 0 \end{aligned}$$

[7]Strictly speaking, one should allow for the possibility of consumers using storage after receiving the consumption bundle from the planner, see, e.g., Allen and Gale (2004, p. 1029). Since introducing storage does not affect any of the results below and complicates notation, I abstract from it. The effects of storage are well-understood: introducing storage leads to worse risk sharing (Allen, 1985; Cole and Kocherlakota, 2001; von Thadden, 1997, 1998, 1999).

We obtain the autarkic allocation by collecting the consumption bundles from the individual optimization programs. Note that by construction, there is no risk sharing in autarky.

### 2.3 Decentralization

Can the second-best allocation be decentralized via a system of competitive banks? The answer, under certain assumptions, is yes, as has been shown in seminal papers by Prescott and Townsend (1984) and Allen and Gale (2004). Two assumptions are key for the result to obtain. First, consumption must be observable. Consumers cannot engage in *hidden trades* as otherwise liquidity insurance would be arbitraged away. Second, there cannot be any *panic-based runs*. If these assumptions hold, competitive banks are second-best efficient and there is no role for government intervention. In the remainder of the paper, I investigate whether competitive banks are still optimal when these assumptions are relaxed.

## 3 Hidden Trades

I now introduce hidden trades and give the definition of constrained efficiency in the environment with hidden trades. The basic idea is that after making the announcement to the planner or an intermediary, consumers can trade in a private credit market. The social planner can neither shut down the market, nor observe the trades that take place. Trade in the private market increases the scope for possible deviations by the consumers and thereby imposes additional constraints on the amount of risk sharing that can be provided. In this section I first define equilibrium in the private market and then define and partially characterize the constrained efficient allocation.

### 3.1 Private Markets

Each consumer observes her type at the beginning of period one. The consumer then announces her type to the social planner (or some private agent or firm); the announcement need not be truthful. After receiving the consumption bundle the consumer can trade in the private market. These trades are *unobservable*: contracts cannot be made contingent on the trades of the consumers on the private market.

To sum up, the timing is as follows:

1. Consumers observe their type (liquidity shock).

2. Consumers make an announcement to the planner (or some other private agent or firm) and get a consumption bundle.
3. Consumers trade in a private credit market.
4. Consumption takes place.

Formally, let $\mathbf{C} = \{(c_1(\theta), c_2(\theta))\}_{\theta \in \Theta}$ denote the menu of contracts offered by the planner, and $R$ be the interest rate faced on the private market. Consider the following problem.[8]

**Problem 2** (Optimal Trades and Announcement)**.**

$$V(\mathbf{C}, R; \theta) = \max_{x_1, x_2, \theta'} U(x_1, x_2; \theta)$$
$$\text{s.t. } x_1 + \frac{x_2}{R} = c_1(\theta') + \frac{c_2(\theta')}{R}$$
$$\theta' \in \Theta, x_1, x_2 \geq 0.$$

The consumer faces a menu of contracts. After picking the bundle $(c_1(\theta'), c_2(\theta'))$ with the highest market value, the consumer chooses her actual *after-trade consumption $x_t$*. After-trade consumption $x_t$ may differ from consumption $c_t$ originally assigned by the planner. Since we are in a complete markets setting in period one, we can separate the optimal consumption decision from the optimal announcement: all consumers simply pick the consumption bundle with the highest market value $c_1(\theta) + c_2(\theta)/R$.

We can now define equilibrium in the private market.

**Definition 2** (Mixed Equilibrium in the Private Market)**.** *A* mixed equilibrium *in the private market for a given menu of contracts* $\mathbf{C}$ *is an allocation* $\{(x_1^{eq}(\theta), x_2^{eq}(\theta))\}_{\theta \in \Theta}$*, a probability measure* $\{\rho^{eq}(\theta)\}_{\theta \in \Theta}$*, and an interest rate* $R^{eq}$ *such that:*

- *Consumers optimize: for all* $\theta \in \Theta$, $(x_1^{eq}(\theta), x_2^{eq}(\theta), \theta^{eq}(\theta))$ *solve Problem 2, taking the interest rate* $R^{eq}$ *as given, and the probability measure* $\{\rho^{eq}(\theta)\}_{\theta \in \Theta}$ *is consistent with individual optimization:* $\rho^{eq}(\theta) > 0 \Rightarrow \theta \in \arg\max_{\theta'} c_1(\theta') + \frac{c_2(\theta')}{R^{eq}}$ *for all* $\theta \in \Theta$.
- *Markets clear:* $\sum_\theta \pi(\theta) x_t^{eq}(\theta) = \sum_\theta \rho^{eq}(\theta) c_t(\theta)$ *for* $t = 1, 2$.

The definition of equilibrium borrows from Allen and Gale (2004) to allow for the possibility of ex post identical consumers making different announcements to the planner. The reason for doing so is a technical one: some economies may fail to have non-mixed equilibria because aggregate endowment is not a continuous

[8] As in Farhi, Golosov, and Tsyvinski (2009), I only consider equilibria for which the gross interest rate is weakly greater than one. Taking storage — and the resulting zero lower bound on interest rates — seriously would not change any of the results.

function of the interest rate. Equilibrium existence is ensured once we allow for mixing.

### 3.2 Constrained Efficiency

We are now equipped to give a formal definition of constrained efficiency in the presence of hidden trades. The social planner chooses a feasible allocation in order to maximize ex ante welfare, subject to incentive-compatibility constraints. The incentive constraints state that the consumers must prefer reporting their type truthfully to possibly lying and then trading in the private market. The social planner solves

**Problem 3** (Constrained Efficient Allocation)**.**

$$\max_{\{(c_1(\theta),c_2(\theta))\}_{\theta\in\Theta}} \sum_\theta \pi(\theta)U(c_1(\theta),c_2(\theta);\theta)$$
$$\text{s.t. } \sum_\theta \pi(\theta)\left(c_1(\theta)+\frac{c_2(\theta)}{\widehat{R}}\right)=e$$
$$U(c_1(\theta),c_2(\theta);\theta)\geq V(\mathbf{C},R;\theta) \text{ for all } \theta\in\Theta$$
$$c_1(\theta),c_2(\theta)\geq 0 \text{ for all } \theta\in\Theta,$$

where $R$ is an equilibrium interest rate on the private market according to Definition 2. The solution to to the problem $\{(c_1^*(\theta),c_2^*(\theta))\}_{\theta\in\Theta}$ is the *constrained efficient* or *third-best* allocation. Clearly, the incentive constraints above are as least as tight as the incentive constraints in Eq. (4). As a result, welfare achieved in the third best is weakly smaller than welfare in the second best: markets act as constraints on risk sharing (Hammond, 1979, 1987).

While Problem 3 appears quite difficult, Farhi, Golosov, and Tsyvinski (2009) show that it is possible to dramatically reduce the dimensionality of the problem. First, define an auxiliary problem; $SP$ stands for "social planner".

**Problem 4** (Marshallian Demands)**.**

$$V_{SP}(I,R;\theta)=\max_{x_1,x_2} U(x_1,x_2;\theta)$$
$$\text{s.t. } x_1+\frac{x_2}{R}=I$$
$$x_1,x_2\geq 0,$$

Denote the solutions by $x_1(I,R;\theta)$ and $x_2(I,R;\theta)$. These solutions are simply Marshallian demands when the consumer has an income $I$ and faces an interest rate $R$. Now consider the problem of a social planner who directly chooses the interest rate on the private market $R$ and an income $I$ to maximize ex ante welfare.

**Problem 5** (Constrained Efficient Allocation: Equivalent Formulation)**.**

$$\max_{I,R} \sum_{\theta} \pi(\theta) V_{SP}(I,R;\theta)$$
$$\text{s.t.} \sum_{\theta} \pi(\theta) \left( x_1(I,R;\theta) + \frac{x_2(I,R;\theta)}{\widehat{R}} \right) = e$$

Call the solution to this problem $(I^*, R^*)$. Farhi, Golosov, and Tsyvinski (2009, Lemma 1) show that the two problems above, Problem 3 and Problem 5, are equivalent. Intuitively, since consumers have access to a private market, everyone picks the bundle with highest market value, i.e. the bundle that solves $\max_{\theta} c_1(\theta) + c_2(\theta)/R$. The constrained efficient allocation therefore satisfies the *present value condition*

$$c_1^*(\theta) + \frac{c_2^*(\theta)}{R^*} = c_1^*(\theta') + \frac{c_2^*(\theta')}{R^*} \text{ for all types } \theta, \theta' \tag{PV}$$

where $R^*$ is the socially optimal interest rate. At first sight it would seem that little can be done to provide insurance against liquidity shocks. However, the planner can influence the market interest rate by changing aggregate consumption in different periods. By distorting the market interest rate away from the technological rate of return, the social planner provides some liquidity insurance even in the presence of hidden trades. As a result, while the market value of consumption is equalized across types (i.e. $c_1^*(\theta) + c_2^*(\theta)/R^* = c_1^*(\theta') + c_2^*(\theta')/R^*$), physical resources allocated to the types are not (i.e. $c_1^*(\theta) + c_2^*(\theta)/\widehat{R} \neq c_1^*(\theta') + c_2^*(\theta')/\widehat{R}$).

# 4 Mutual Funds: Constrained Efficiency Result

This section contains the main result of the paper: I show that a system of mutual funds can implement the constrained efficient allocation without risking a banking panic. I first describe how the mutual fund economy works and characterize the resulting allocation in the absence of government intervention. Without any government intervention competitive equilibrium is inefficient as individual mutual funds do not internalize the effects of their liquidity holdings on the market interest rate. However, I then show that the government can restore constrained efficiency by introducing a suitable liquidity requirement. Importantly, the resulting allocation is run-proof under weak conditions, implying that mutual funds are superior to banks when hidden trades are possible and bank runs happen with a non-zero probability.

## 4.1 Competitive Equilibrium

There is a competitive mutual fund sector with free entry. Mutual funds compete by offering the consumers bundles of the form $\mathbf{c} = (c_1, c_2)$ in exchange for their endowment. All consumers at the same mutual fund, irrespective of their type, get the same consumption bundle. The bundle provides the consumers with $c_1$ units of consumption good in period one and $c_2$ units of consumption good in period two. Consumers sign a contract with the mutual fund whose contract yields the highest expected utility. In turn, mutual funds invest their capital to maximize discounted profits. Mutual funds also pay out dividends $d_t$ to their owners and trade bonds $b$ at a price $q$ among themselves in an "inter-fund" market. After the realization of liquidity shocks in period one, consumers can borrow and lend in a Walrasian credit market at an interest rate $R$.[9]

The formulation above is rather abstract. However, it is equivalent to the following mechanism, originally proposed by Jacklin (1987). A mutual fund raises capital by issuing shares to the consumers in return for their endowment. In period one, the mutual funds pays out a dividend $\delta$ to each consumer; the remainder is placed in the long-term technology. In period one, the consumers trade *ex*-dividend shares between themselves at some market-clearing price $p$. That is, after receiving the dividend, consumers can decide to buy or sell some shares at the market price. In period two, a consumer holding a share of the mutual fund is entitled to $\widehat{R}(e-\delta)$ of consumption good. Evidently, the two mechanisms are equivalent with $c_1 = \delta$ and $c_2 = \widehat{R}(e-\delta)$, while the price of the mutual fund shares is related to the interest rate by $R = \widehat{R}(e-\delta)/p$.

Each consumer in the mutual fund economy solves the following problem.

**Problem 6** (Individual Problem in the Mutual Fund Economy)**.**

$$V_{MF}(\mathbf{c}, R; \theta) \equiv \max_{x_1, x_2 \geq 0} U(x_1, x_2; \theta) \text{ s.t. } x_1 + \frac{x_2}{R} = c_1 + \frac{c_2}{R}.$$

Following Farhi, Golosov, and Tsyvinski (2009), I only allow intermediaries to invest in the long-term technology. This assumption is relaxed in Section 5.1.

A representative mutual fund maximizes profits, discounted at the rate $\widehat{R}$, subject to a participation constraint.[10] Call the equilibrium level of expected utility

[9] To minimize on notation, I do not introduce a separate market for mutual fund shares. If there are no trading restrictions, such a market is equivalent to a credit market and hence there is no loss of generality in assuming that there is only one credit market. The formulation of the mutual fund economy is similar to that used in Bhattacharya and Gale (1987, Section 2).

[10] Following Farhi, Golosov, and Tsyvinski (2009) I focus on symmetric equilibria only. There is no real loss of substance in doing so. Because of the constant returns to scale investment technology, equilibrium size distribution of mutual funds is indeterminate. Moreover, trades of bonds are indeterminate. Nevertheless, these indeterminacies do not influence the equilibrium allocation, price

by $\underline{U}$. The participation constraint states that the expected utility obtained by the shareholders of the fund must be at least $\underline{U}$. Since consumers choose the contract with the highest expected utility, a mutual fund that offered a contract with lower utility would get no customers.

**Problem 7** (Mutual Fund Problem: Primal Formulation)**.**

$$\max_{c_1,c_2,d_1,d_2,b} \; d_1 + \frac{d_2}{\widehat{R}} + qb - \frac{b}{\widehat{R}}$$
$$\text{s.t. } c_1 + \frac{c_2}{\widehat{R}} + d_1 + \frac{d_2}{\widehat{R}} + qb - \frac{b}{\widehat{R}} = e$$
$$\sum_{\theta} \pi(\theta) V_{MF}(\mathbf{c}, R; \theta) \geq \underline{U}$$
$$c_1, c_2 \geq 0.$$

We can simplify the problem by noting that in equilibrium the dividends are zero, and the price of bonds is $q = \widehat{R}^{-1}$ by no arbitrage, so that the dual problem to Problem 7 is given by

**Problem 8** (Mutual Fund Problem: Dual Formulation)**.**

$$\max_{c_1,c_2} \sum_{\theta} \pi(\theta) V(\mathbf{c}, R; \theta)$$
$$\text{s.t. } c_1 + \frac{c_2}{\widehat{R}} = e$$
$$c_1, c_2 \geq 0.$$

The essential difference from a system of competitive banks is that a mutual fund offers a single bundle to its shareholders, whereas traditional banks offer two bundles and consumers self-select the appropriate one; I sketch the competitive equilibrium with banks in Appendix B.

Let us now define equilibrium in this economy.

**Definition 3** (Symmetric Equilibrium in the Mutual Fund Economy)**.** *An* equilibrium *in the mutual fund economy is an allocation* $\{(x_1^{MF}(\theta), x_2^{MF}(\theta))\}_{\theta \in \Theta}$ *together with a price system* $(q^{MF}, R^{MF})$*, optimal contract* $(c_1^{MF}, c_2^{MF})$*, and a market utility* $\underline{U}^{MF}$ *such that:*

- *Consumers optimize:*
  - *For all* $\theta \in \Theta$, $(x_1^{MF}(\theta), x_2^{MF}(\theta))$ *solves Problem 6 taking* $R^{MF}$ *as given.*
  - *Consumers choose the mutual fund contract that gives them the highest expected utility.*

system or market utility.

- *Firms optimize:*
  - *The optimal mutual fund contract* $(c_1^{MF}, c_2^{MF})$ *solves Problem 8 taking* $q^{MF}$, $\underline{U}^{MF}$ *and* $R^{MF}$ *as given.*
  - *Optimal entry: the representative mutual fund makes zero profits.*
- *Markets clear:*
  - *Consumption:* $\sum_\theta \pi(\theta) x_1^{MF}(\theta) = c_1^{MF}$ *and* $\sum_\theta \pi(\theta) x_2^{MF}(\theta) = c_2^{MF}$.
  - *Bond market:* $b = 0$.

## 4.2 Constrained Efficiency Result

I first show that *unregulated* competitive mutual funds, just like unregulated banks (Farhi, Golosov, and Tsyvinski, 2009), cannot provide any liquidity insurance.

**Proposition 1.** *The equilibrium allocation in the mutual fund economy with no regulation is equal to the autarkic allocation.*

*Proof.* In the Appendix. □

Since consumers can borrow and lend freely, the mutual fund maximizes expected utility of its shareholders by maximizing the market value of the consumption bundle. This equalizes the equilibrium interest rate with the technological rate of transformation, i.e. $R^{MF} = \widehat{R}$. At such an interest rate, of course, consumers in the mutual fund economy face the same consumption possibilities as in autarky and mutual funds fail to provide any liquidity insurance. Intuitively, each mutual fund has an incentive to free ride on the liquidity provided by other funds. Collectively, however, this leads to a complete breakdown of liquidity provision.[11]

At this point matters look grim. However, the government can restore constrained efficiency by imposing a suitable liquidity requirement. It is not obvious that this should be the case. In principle, banks operate on a richer space of contracts. Banks offer a choice between two consumption bundles and rely on incentive compatibility for self-selection. In contrast, the mutual fund offers a single consumption bundle. It would seem that banks should do a better job at providing liquidity insurance. However, with hidden trades the restriction on the set of contracts turns out to be without loss of generality. Access to the credit market at the interim date dramatically shrinks the set of incentive-compatible allocations.

[11] Bhattacharya and Gale (1987) provide a similar intuition in a model of interbank lending.

To ensure that liquidity requirements indeed work I make the following monotonicity assumption. The monotonicity assumption is necessary for liquidity requirements to work for banks, too, and as such is not specific to mutual funds.[12]

**Assumption 1** (Monotonicity)**.** *Let $R^*$ denote the equilibrium interest rate in the constrained efficient allocation. Then*

$$R^* \le \widehat{R} \Rightarrow \sum_{\theta} \pi(\theta) c_1^*(\theta) \ge \sum_{\theta} \pi(\theta) c_1^{aut}(\theta)$$
$$R^* \ge \widehat{R} \Rightarrow \sum_{\theta} \pi(\theta) c_1^*(\theta) \le \sum_{\theta} \pi(\theta) c_1^{aut}(\theta),$$

*where* "aut" *denotes the autarkic allocation and asterisks denote the constrained efficient allocation.*

Intuitively, the assumption says that when the socially optimal interest rate is smaller than the technological rate of return, competitive intermediaries underprovide liquidity, and vice versa for the case when the socially optimal interest rate is higher than the technological rate of return. All of the preference specifications commonly considered in the literature satisfy this intuitive requirement. In particular, the condition holds under Diamond-Dybvig corner preferences, discount factor shocks, liquidity shocks, and valuation-neutral shocks (Farhi, Golosov, and Tsyvinski, 2007, 2009). It is possible to microfound the assumption by assuming that consumption in both periods is a normal good, and the substitution effect weakly dominates the income effect, that is, $x_1(I, R; \theta)$ is weakly increasing in $I$ and weakly decreasing in $R$ for all $\theta \in \Theta$.

Following Allen and Gale (2004) and Farhi, Golosov, and Tsyvinski (2009) I consider liquidity requirements as a way to restore efficiency. If $R^* \le \widehat{R}$ (socially efficient interest rate smaller than the technological rate of return), the government imposes a *liquidity floor*:

$$c_1 \ge \ell.$$

If $R^* \ge \widehat{R}$ (socially efficient interest rate greater than the technological rate of return), the government imposes a *liquidity cap*:

$$c_1 \le \ell.$$

The following Theorem, which is the key result of the paper, shows that with such liquidity requirements, mutual funds implement the constrained efficient optimum.

[12] In Section 5.1 I show that the constrained efficient optimum can also be implemented by taxing long-term investment. With taxes, Assumption 1 is not necessary.

**Theorem 1.** *Suppose that Assumption 1 holds. Then if $R^* \leq \widehat{R}$ (resp. $R^* \geq \widehat{R}$) the government can implement the social optimum by setting a liquidity floor (resp. liquidity cap) with $\ell = \sum_\theta \pi(\theta) c_1^*(\theta)$.*

*Proof.* In the Appendix. □

Intuitively, since consumers have the ability to engage in hidden trades, incentive compatibility forces the social planner to equalize the market value of the consumption bundles allocated to early and late consumers. In the world with mutual funds, the government manipulates the amount of period one consumption by choosing a suitable liquidity requirement. Manipulating the level of period one consumption in turn influences the equilibrium interest rate via a general equilibrium channel. Once aggregate consumption is fixed at its constrained efficient level, we see that the socially efficient interest rate $R^*$ is an equilibrium interest rate in the mutual fund economy, i.e. $R^{MF} = R^*$. Hence, we have arranged things in such a way that trade in the credit market allocates the consumption good across types in a constrained efficient manner. It is not necessary to have intermediaries that offer a richer set of contracts because the present value constraint (PV) dramaticaly shrinks the set of incentive-compatible allocations.

## 4.3 Mutual Funds and Financial Stability

Mutual funds are constrained efficient when supplemented with a suitable liquidity requirement. But so are deposit-taking banks (Farhi, Golosov, and Tsyvinski, 2009). Why would a financial system of mutual funds be preferred to that based on banks?

The answer is that banks are potentially subject to costly panic-based runs, while mutual funds are not (Diamond and Dybvig, 1983; Jacklin, 1987). Formally, a constrained efficient contract is said to be *run-prone* if it is a best response for a late consumer to withdraw her deposit if everyone else also withdraws; for simplicity, I do not consider partial runs. I follow the same bankruptcy procedure as in Diamond and Dybvig (1983). Consumers are served sequentially until the bank runs out of the consumption good. Since I use a more general specification of preferences, I make the following additional assumption: if the bank can make good on its commitments in the first period, payments are made in the same order in period two. Trade in the private market takes place after all of the consumers have been served or the bank has run out of resources.

Evidently the constrained efficient contract is run-prone if either (a) $c_1(E) > e$; or (b) $c_1(E) \leq e$ and $c_2(E) > \widehat{R}(e - c_1(E))$. In the first case, the bank is already bust in period one if all consumers claim to be early. In the second case, the bank can honour its commitments in period one, but is no longer able to do so in period two.[13] For example, with original Diamond-Dybvig preferences ($U(c_1, c_2; E) = u(c_1)$ and $U(c_1, c_2; L) = \rho u(c_2)$ with $\widehat{R}^{-1} < \rho < 1$), the constrained efficient allocation is run-prone and runs are type (a) if relative risk aversion is strictly greater than one. In the event of a run, ex ante welfare is, of course, strictly smaller than that in the constrained efficient allocation. As a result, whenever runs happen with a non-zero probability, welfare in the banking economy is strictly smaller than welfare in an economy with mutual funds.

Note that it may be possible to amend the demand deposit contract to rule out runs. If the bank can commit ex ante to suspend payments whenever the fraction of consumers withdrawing at the interim date exceeds the population frequency of the early types, the bank can implement the constrained efficient allocation uniquely. As pointed out by Ennis and Keister (2009a), such suspension of convertibility schemes may not be time-consistent. However, the discussion of whether or not it is possible to rule out runs with deposit-type contracts becomes largely irrelevant once we realize that banks are not necessary for the efficient provision of liquidity to begin with.[14]

Is the Walrasian equilibrium unique in the mutual fund economy? Quite trivially, if there is a unique interest rate that clears the private market when the social planner chooses $\{(c_1^*(\theta), c_2^*(\theta))\}_{\theta\in\Theta}$, then the equilibrium is unique in the mutual fund economy with optimal liquidity requirements as well. In other words, whenever the Walrasian equilibrium is unique in the social planner's problem, it is also unique in the mutual fund economy. However, we can say a bit more. Since consumers have identical endowments, we can appeal to the powerful uniqueness result of Mityushin and Polterovich (Polterovich and Mityushin, 1978; Mas-Colell et al., 1995, Proposition 4.C.3). Suppose that utility functions for both types are separable in consumption in different periods, i.e., $U(c_1, c_2; \theta) = g(c_1; \theta) + h(c_2; \theta)$. Then, if

$$\frac{-g''(x;\theta)x}{g'(x;\theta)} < 4 \text{ and } \frac{-h''(x;\theta)x}{u'(x;\theta)} < 4 \text{ for all } x \text{ and } \theta \in \Theta,$$

[13] Runs of type (b) can be easily prevented even in the absence of suspension of convertibility by stipulating that the claims of the early types are subordinate in the event of insolvency. That is, in period two payments are first made to the late types. The early types get repaid only if there are enough resources left after paying back the late types.

[14] Relatedly, there is a large literature that investigates whether runs can actually happen with fully optimal contracts and rational consumers when the sequential service constraint is taken as a feature of the environment. As pointed out by Green and Lin (2003), if sequential service is incorporated into the contracting problem in the original Diamond-Dybvig model, runs cannot happen in equilibrium. Subsequent research has clarified that the result depends on the specific details of the environment (Peck and Shell, 2003; Andolfatto, Nosal, and Wallace, 2007; Ennis and Keister, 2009b; Sultanum, 2014; Andolfatto, Nosal, and Sultanum, 2014). My paper does not contribute to this important literature.

equilibrium in the mutual fund economy is unique. This condition on the curvature of the utility function is rather weak and seems to be satisfied empirically, see the discussion in Section 5 of Mas-Colell (1991).

# 5 Discussion and Extensions

In this section I provide a few results that are useful for getting a better sense of the underlying economics and extend the analysis to the case without hidden trades. First, I show that the constrained efficient allocation can be implemented by taxing long-term investment. The result illustrates the fact that constrained efficiency does not call for a deposit-type contract and points to a specific pecuniary externality as the source of the market failure. Second, I show that without hidden trades, mutual funds are not second-best efficient.

## 5.1 Implementation via Taxes

I have so far assumed that only mutual funds can invest in the long-term technology. If consumers have access to the long-term technology, then they should also be subject to liquidity regulation. Indeed, Jacklin (1987, p. 42) points out that direct access to the long-term technology leads to unravelling of liquidity provision when ex post trade is feasible. Hence, in a world in which consumers have direct access to the long-term technology, it may be more plausible to consider taxation of investment as a means to restore constrained efficiency.

To that end, suppose that each consumer operates her own long-term investment technology (as in the benchmark autarky problem defined in Problem 1) but the government imposes a linear tax on investment. Tax proceeds are given back to the consumers via a lump-sump transfer in period zero. Since liquidity shocks are unobservable to the government, the transfer cannot be made contingent on type. One may easily allow for trade among consumers but that does not change the resulting allocation.[15] Hence, it is without loss of generality to assume that there is no credit market at the interim date.

The consumers choose a feasible consumption bundle to maximize utility. The only difference from the decision problem in autarky (Problem 1) is that the long-term investment is taxed at rate $\tau$. As a result, the consumers face a gross interest rate of $\widehat{R}/(1+\tau)$ instead of $\widehat{R}$.

[15] Again, as with bond trades among mutual funds in Section 4.1, trades among the consumers are indeterminate. If we restrict attention to symmetric equilibria, then there must be no trade in equilibrium.

**Problem 9** (Investment with Taxation)**.**

$$V_{tax}(\tau, T; \theta) = \max_{c_1, c_2} \; U(c_1, c_2; \theta)$$
$$\text{s.t. } c_1 + \frac{c_2(1+\tau)}{\widehat{R}} = e + T$$
$$c_1, c_2 \geq 0.$$

Denote the solutions to this problem by $c_1^{tax}(\tau, T; \theta)$ and $c_2^{tax}(\tau, T; \theta)$.

The government chooses the tax rate on investment $\tau$ and the lump-sum transfer $T$ to maximize welfare, taking the endogenous response of the consumers into account. The government budget constraint is given by

$$T = \sum_{\theta} \pi(\theta) \tau (e - c_1^{tax}(\tau, T; \theta)). \tag{5}$$

We can now prove the following result.

**Proposition 2.** *The government can implement the constrained efficient allocation by setting $\tau^* = \widehat{R}/R^* - 1$ and $T^* = \sum_\theta \pi(\theta)\tau^*(e - c_1^*(\theta))$.*

*Proof.* In the Appendix. □

Proposition 2 is useful for getting a better understanding of the constrained efficient allocation. An application of the envelope theorem shows that the effect of changing the tax rate on the utility of type $\theta$ is

$$\frac{\mathrm{d}\, V_{tax}(\tau; T(\tau); \theta)}{\mathrm{d}\,\tau} = \mu(\theta) \Bigg( \underbrace{\left( e - \sum_{\theta'} \pi(\theta') c_1(\theta') - \frac{c_2(\theta)}{\widehat{R}} \right)}_{\text{Redistribution}} - \underbrace{\tau \sum_{\theta'} \pi(\theta') \frac{\mathrm{d}\, c_1(\theta')}{\mathrm{d}\,\tau}}_{\text{Intertemporal distortion}} \Bigg),$$

where $\theta' \in \Theta$ and $\mu_\theta$ is the marginal utility of an additional unit of resources (Lagrange multiplier on the intertemporal budget constraint).[16] There are two effects of increasing $\tau$. First, there is an *intertemporal distortion*. Increasing the tax rate introduces a wedge between the technological rate of return and the return faced by the consumers, thereby decreasing welfare. However, there is also a *redistributional effect*, which can be positive or negative for a given consumer. The effect

[16] Here is the algebra. Let $\mathcal{L}$ denote the Lagrangian and $\mu(\theta)$ the Lagrange multiplier on the intertemporal budget constraint, evaluated at the optimum. Then,

$$\frac{\partial \mathcal{L}}{\partial \tau} = -\mu(\theta) \left( \frac{c_2(\theta)}{\widehat{R}} - \frac{\mathrm{d}\, T}{\mathrm{d}\,\tau} \right) = -\mu(\theta) \left( \frac{c_2(\theta)}{\widehat{R}} - \left( e - \sum_{\theta'} \pi(\theta') c_1(\theta') - \tau \sum_{\theta'} \pi(\theta') \frac{\mathrm{d}\, c_1(\theta')}{\mathrm{d}\,\tau} \right) \right),$$

with $\mathrm{d}\, c_1(\theta)/\mathrm{d}\,\tau = \partial c_1(\theta)/\partial\tau + (\partial c_1(\theta)/\partial T)(\mathrm{d}\, T/\mathrm{d}\,\tau)$. The envelope theorem then gives the result.

arises because increasing $\tau$ redistributes resources from those consumers who invest heavily in the long-term technology to those who invest less. Note that if all consumers are identical, the redistributive effect is zero and only the investment distortion remains, justifying the choice of terminology.

Taking the expectation over $\theta$ and evaluating at $\tau = 0$ (assuming that the partials are bounded), we get the welfare effect of introducing a small tax

$$\sum_{\theta} \pi(\theta) \left. \frac{\mathrm{d}\, V_{tax}(\tau; T(\tau); \theta)}{\mathrm{d}\, \tau} \right|_{\tau=0} = \sum_{\theta} \pi(\theta)\mu(\theta) \Big( e - \sum_{\theta'} \pi(\theta')c_1(\theta') - \frac{c_2(\theta)}{\widehat{R}} \Big). \qquad (6)$$

The expression is zero if and only if the marginal utility of income in autarky is the same for both types. Eq. (6) is the Greenwald-Stiglitz formula for the present environment (Greenwald and Stiglitz, 1986). If the marginal utilities of income are not equal, which is the general case, taxes on long-term investment improve welfare. The intuition is familiar: the effect of taxation on redistribution has a first-order effect, while the distortion on investment is only of second order. Whether the optimal tax is negative or positive depends on the specification of preferences. If the marginal utility of income in autarky is greater for the early types, the government imposes a tax on investment. Otherwise, the government imposes an investment subsidy.

The result in Proposition 2 is not entirely new. Farhi, Golosov, and Tsyvinski (2009) argue, but do not provide an explicit proof, that the constrained efficient optimum can be achieved by imposing a linear tax of investment. In an underappreciated paper, Sussman (1992) shows that when the government taxes investment optimally, competitive equilibrium in the original Diamond-Dybvig model delivers the first-best allocation. Proposition 2 explains why: in the environment of Diamond-Dybvig, the constrained efficient allocation coincides with the second-best allocation, which in turn coincides with the first best, a key insight from Farhi, Golosov, and Tsyvinski (2009). The taxation result also gives the precise reason why the constrained efficient allocation with Diamond-Dybvig preferences coincides with first best: since consumers are at a corner solution, the intertemporal wedge does not distort consumption decisions, and hence does not affect the equilibrium allocation.

## 5.2 Mutual Funds Without Hidden Trades

I now reconsider the welfare properties of mutual funds in a world in which hidden trades are not allowed. A shareholder of a mutual fund is contractually prohibited from trading with shareholders of other mutual funds. Intuitively, think of each mutual fund as being located on a separate island. The consumers choose which island to go to at the initial date. At the interim date, consumers on the island can trade with consumers located on the same island. However, the consumers cannot leave the island and trade with consumers located on other islands. I assume that mutual funds commit to the contract offered at the initial date so that there are no hold-up problems.

With these assumptions at hand, we see that the equilibrium definition in Definition 3 remains almost the same, except that now mutual funds choose the contract taking the effect on the interest rate into account. Formally, the representative mutual fund solves

**Problem 10** (Mutual Fund Problem Without Hidden Trades)**.**

$$\max_{c_1, c_2} \sum_{\theta} \pi(\theta) V(\mathbf{c}, R; \theta)$$
$$\text{s.t. } c_1 + \frac{c_2}{\widehat{R}} = e$$
$$c_1, c_2 \geq 0,$$

where $R$ is the island-specific market clearing interest rate, meaning that

$$\sum_{\theta} \pi(\theta) x_1(\mathbf{c}, R; \theta) = c_1.$$

To streamline the exposition, I assume that the utility functions of the consumers satisfy the following Inada conditions:

$$\lim_{c_j \downarrow 0} U_j(c_1, c_2; \theta) = +\infty \text{ for all } j \text{ and } \theta \in \Theta. \tag{7}$$

The following proposition characterizes the welfare properties of the mutual fund economy without hidden trades and relates the efficiency properties of mutual funds to the need for liquidity insurance. In doing so, I extend the work of Jacklin (1987, Theorems 2 and 3) who did make the relationship between efficiency and the scope for liquidity provision fully explicit.

**Proposition 3** (No Hidden Trades)**.** *Suppose that the first-best allocation is incentive compatible. Then, the mutual fund can implement the first best if and only if the first-best and autarky allocations coincide. If the first-best allocation is not incentive compatible, the mutual fund economy can never implement the second best. In both cases, the mutual fund economy improves on autarky.*

*Proof.* In the Appendix. □

As discussed in Section 5.1, the mutual fund provides liquidity insurance by distorting the market rate of return. Introducing an intertemporal wedge partially mitigates the welfare loss from missing markets for liquidity shocks and allows for the mutual fund to improve on autarky. However, since consumers are at an interior solution at the first-best allocation, the wedge between the private and social rates of return gives rise to the standard efficiency cost of taxation. As a result, the mutual fund allocation is typically not only ex ante (before the realization of liquidity shocks) but also ex post inefficient. Mutual funds are only efficient in the knife-edge case when the autarkic allocation is equal to the first best. In this situation, there is no scope for liquidity insurance to begin with.

If the first best is not incentive compatible, the mutual fund can never implement the second best. The incentive-compatibility constraint drives a wedge between the marginal rates of substitution for the different types at the second-best allocation. However, the marginal rates of substitution are equalized in the mutual fund economy. As a result, if an incentive constraint is binding at the second-best allocation, the mutual fund is never second-best efficient.

**The Role of Competition**

As discussed in the Introduction, Theorem 1 is driven by the interaction of the present value condition (PV) and the existence of pecuniary externalities. Proposition 3 is useful because it considers a setting in which (PV) holds — by assumption — but there is no pecuniary externality. This way, we can cleanly identify the role of competition. We see that although mutual funds are typically not inefficient, they do improve on autarky.[17] Another economic interpretation of Proposition 3, then, is that hidden trades only destroy liquidity insurance when combined with competition among intermediaries. For example, if there is only one mutual fund in the economy, it will take the possibility of hidden trades into account when choosing the optimal contract and still provide some liquidity insurance. If such a mutual fund is a profit-maximizing monopolist, it will internalize the pecuniary externality but also cause a monopoly distortion. Of course, that is a general feature of models with pecuniary externalities in which grouping all individual firms into a single entity gets rid of the externality.

[17] This result stands in contrast to the analysis of Wallace (1996). Wallace analyzes welfare properties of narrow banking, defined as a banking system that is always run-proof, in the Diamond and Dybvig model. Wallace shows that any allocation implementable by narrow banking is achievable under autarky. The reason for the disparity is that Wallace assumes consumers are *spatially separated* at the interim date, implicitly ruling out the mutual fund mechanism. As emphasized by Jacklin (1993, p. 246), even if consumers are spatially separated, it is not clear why a market maker could not at least partially substitute for a centralized market.

# 6 Conclusions

In the aftermath of the global financial crisis, many commentators have suggested significantly increasing capital requirements for banks. While more equity is likely to increase financial stability, it could also have detrimental effects on liquidity creation.

In this paper I analyzed the relationship between liquidity creation and financial stability in a canonical Diamond-Dybvig model with hidden trades. The key result of the paper is that with hidden trades, there is no trade-off between liquidity provision and financial stability. Run-prone liabilities are not necessary for the efficient provision of liquidity. Mutual funds, when supplemented with appropriate liquidity requirements, are constrained efficient and run-proof. As a result, if bank runs happen with a non-zero probability, mutual funds are strictly superior to deposit-taking banks from a welfare perspective.

What should a policy maker make of these results? At the risk of venturing too far from the model, I provide some speculations. One may dismiss the results by taking the view that the model is missing something of first-order importance, or that hidden trades are not an important concern in reality. For example, the model abstracts from a number of important reasons why banks may be best funded with demandable liabilities, including models of informationally-insensitive debt (Gorton and Pennacchi, 1990) and synergies between deposit-taking and credit lines (Kashyap, Rajan, and Stein, 2002). Introducing trading frictions as in Diamond (1997) or Allen, Carletti, and Marquez (2015) may also tilt the results in favour of banks, although the basic forces of the current model should remain present.

Alternatively, results of this paper may provide a rationale for significantly increasing capital requirements for banks who are vulnerable to hidden trades. After all, in the model intermediaries work very well with no debt at all. The model also suggests that one size capital requirements do not fit all. Capital requirements arguably should be higher for banks that are more vulnerable to retrade, possibly contingent on observable risk characteristics of bank loans. In practice, banks that hold informationally intensive loans that are difficult to securitize and have few close substitutes (perhaps because banks act as delegated monitors as in Diamond (1984) or engage in relationship lending) may have lower capital requirements.

More work, especially on the empirical side of things, is necessary to distinguish between the two views, but the idea that more equity may come at no social cost seems intriguing. Investigating these issues further seems a fruitful research avenue.

# References

Admati, A., Hellwig, M., 2014. The Bankers' New Clothes: What's Wrong With Banking and What to Do About It. Princeton, NJ: Princeton University Press.

Allen, F., 1985. Repeated principal-agent relationships with lending and borrowing. Economics Letters 17 (1), 27–31.

Allen, F., Carletti, E., Marquez, R., 2015. Deposits and bank capital structure. Journal of Financial Economics, forthcoming.

Allen, F., Gale, D., 2004. Financial intermediaries and markets. Econometrica 72 (4), 1023–1061.

Andolfatto, D., Nosal, E., Sultanum, B., 2014. Preventing bank runs. Working Paper, Federal Reserve Bank of Chicago.

Andolfatto, D., Nosal, E., Wallace, N., 2007. The role of independence in the Green–Lin Diamond–Dybvig model. Journal of Economic Theory 137 (1), 709–715.

Bhattacharya, S., Gale, D., 1987. Preference shocks, liquidity, and central bank policy. In: Barnett, W. A., Singleton, K. J. (Eds.), New Approaches to Monetary Economics. Cambridge: Cambridge University Press, pp. 69–88.

Bouwman, C. H., 2013. Liquidity: How banks create it and how it should be regulated. In: Berger, A., Molyneux, P., Wilson, J. (Eds.), The Oxford Handbook of Banking. Oxford: Oxford University Press, pp. 184–218.

Chamley, C., Kotlikoff, L. J., Polemarchakis, H., 2012. Limited-purpose banking: Moving from "trust me" to "show me" banking. The American Economic Review P&P 102 (3), 113–119.

Chari, V., Phelan, C., 2012. What assets should banks be allowed to hold? Federal Reserve Bank of Minneapolis Economic Policy Paper.

Cochrane, J. H., 2013. Stopping bank crises before they start. *The Wall Street Journal*, 23 June. URL: http://goo.gl/UU6S4z.

Cochrane, J. H., 2014. Toward a run-free financial system. Working Paper, University of Chicago.

Cole, H. L., Kocherlakota, N. R., 2001. Efficient allocations with hidden income and hidden storage. Review of Economic Studies 68 (3), 523–542.

Cone, K. R., 1982. Regulation of depository financial institutions. PhD Thesis, Stanford University.

Diamond, D. W., 1984. Financial intermediation and delegated monitoring. The Review of Economic Studies 51 (3), 393–414.

Diamond, D. W., 1997. Liquidity, banks, and markets. Journal of Political Economy 105 (5), 928–956.

Diamond, D. W., Dybvig, P. H., 1983. Bank runs, deposit insurance, and liquidity. Journal of Political Economy 91 (3), 401–419.

Diamond, D. W., Dybvig, P. H., 1986. Banking theory, deposit insurance, and bank regulation. Journal of Business 59 (1), 55–68.

Ennis, H. M., Keister, T., 2009a. Bank runs and institutions: The perils of intervention. The American Economic Review 99 (4), 1588–1607.

Ennis, H. M., Keister, T., 2009b. Run equilibria in the Green–Lin model of financial intermediation. Journal of Economic Theory 144 (5), 1996–2020.

Farhi, E., Golosov, M., Tsyvinski, A., 2007. A theory of liquidity and regulation of financial intermediation. Working Paper, NBER.

Farhi, E., Golosov, M., Tsyvinski, A., 2009. A theory of liquidity and regulation of financial intermediation. The Review of Economic Studies 76 (3), 973–992.

Freixas, X., Rochet, J.-C., 2008. Microeconomics of Banking. Cambridge: The MIT Press.

Gorton, G., Pennacchi, G., 1990. Financial intermediaries and liquidity creation. The Journal of Finance 45 (1), 49–71.

Gorton, G., Winton, A., 2003. Financial intermediation. In: Constantinides, G., Harris, M., Stulz, R. (Eds.), The Handbook of the Economics of Finance: Corporate Finance. Elsevier, pp. 431–552.

Green, E. J., Lin, P., 2003. Implementing efficient allocations in a model of financial intermediation. Journal of Economic Theory 109 (1), 1–23.

Greenwald, B. C., Stiglitz, J. E., 1986. Externalities in economies with imperfect information and incomplete markets. The Quarterly Journal of Economics 101 (2), 229–264.

Hammond, P. J., 1979. Straightforward individual incentive compatibility in large economies. The Review of Economic Studies 46 (2), 263–282.

Hammond, P. J., 1987. Markets as constraints: multilateral incentive compatibility in continuum economies. The Review of Economic Studies 54 (3), 399–412.

Haubrich, J. G., King, R. G., 1990. Banking and insurance. Journal of Monetary Economics 26 (3), 361–386.

Jacklin, C. J., 1987. Demand deposits, trading restrictions and risk sharing. In: Prescott, E. D., Wallace, N. (Eds.), Contractual Arrangements for Intertemporal Trade. Minnesota: University of Minnesota Press, pp. 26–47.

Jacklin, C. J., 1993. Market rate versus fixed rate demand deposits. Journal of Monetary Economics 32 (2), 237–258.

Kashyap, A. K., Rajan, R., Stein, J. C., 2002. Banks as liquidity providers: An explanation for the coexistence of lending and deposit-taking. The Journal of Finance 57 (1), 33–73.

Kotlikoff, L. J., 2010. Jimmy Stewart is Dead: Ending the World's Ongoing Financial Plague with Limited Purpose Banking. New Jersey: John Wiley & Sons.

Mas-Colell, A., 1991. On the uniqueness of equilibrium once again. In: Barnett, W. A., Cornet, B., D'Aspremont, C., Gabszewicz, J., Mas-Collel, A. (Eds.), Equilibrium Theory and Applications. Cambridge: Cambridge University Press, pp. 275–296.

Mas-Colell, A., Whinston, M. D., Green, J. R., 1995. Microeconomic Theory. Oxford: Oxford University Press.

Peck, J., Shell, K., 2003. Equilibrium bank runs. Journal of Political Economy 111 (1), 103–123.

Pennacchi, G., 2012. Narrow banking. Annual Review of Financial Economics 4 (1), 141–159.

Polterovich, V., Mityushin, L., 1978. Criteria for monotonicity of demand functions. URL: http://goo.gl/nIFkbr.

Prescott, E. C., Townsend, R. M., 1984. Pareto optima and competitive equilibria with adverse selection and moral hazard. Econometrica 52 (1), 21–45.

Sultanum, B., 2014. Optimal Diamond–Dybvig mechanism in large economies with aggregate uncertainty. Journal of Economic Dynamics and Control 40, 95–102.

Sussman, O., 1992. A welfare analysis of the Diamond-Dybvig model. Economics Letters 38 (2), 217–222.

Thakor, A. V., 2014. Bank capital and financial stability: An economic tradeoff or a Faustian bargain? Annual Review of Financial Economics 6, 185–223.

von Thadden, E.-L., 1997. The term-structure of investment and the banks' insurance function. European Economic Review 41 (7), 1355–1374.

von Thadden, E.-L., 1998. Intermediated versus direct investment: Optimal liquidity provision and dynamic incentive compatibility. Journal of Financial Intermediation 7 (2), 177–197.

von Thadden, E.-L., 1999. Liquidity creation through banks and markets: Multiple insurance and limited market access. European Economic Review 43 (4), 991–1006.

Wallace, N., 1996. Narrow banking meets the Diamond-Dybvig model. Federal Reserve Bank of Minneapolis Quarterly Review 20 (1), 3–13.

Wolf, M., 2014. Strip private banks of their power to create money. *The Financial Times*, 24 April, URL: http://goo.gl/uRFNV6.

# Appendix A Proofs

## Proof of Proposition 1

Since $R$ is taken as given, maximizing the objective function in Problem 8 is equivalent to solving

$$\max_{c_1,c_2\geq 0} c_1 + \frac{c_2}{R} \text{ s.t. } c_1 + \frac{c_2}{\widehat{R}} = e.$$

The solution to this linear problem is:

- If $R < \widehat{R}$, $\mathbf{c} = (0, \widehat{R}\,e)$.
- If $R > \widehat{R}$, $\mathbf{c} = (e, 0)$.
- If $R = \widehat{R}$, $\mathbf{c} = (z, \widehat{R}(e-z))$ where $z$ is any number in $[0, e]$.

By the Inada conditions in Eq. (3), only the last case $R = \widehat{R}$ can be an equilibrium. Thus, $x_1 + x_2/R = x_1 + x_2/\widehat{R} = e$, where the second equality comes from the feasibility constraint of the mutual fund. Therefore, Problem 6 coincides with Problem 1. Thus, the only contract consistent with market clearing is the one with $z = \sum_\theta \pi(\theta)c_1^{aut}(\theta)$, where $(c_1^{aut}(\theta), c_2^{aut}(\theta))$ is the solution to Problem 1.

## Proof of Theorem 1

I only consider the case $R^* \leq \widehat{R}$ in the proof, as the other case is completely symmetric. With the liquidity requirement, mutual funds solve

$$\max_{c_1,c_2\geq 0} c_1 + \frac{c_2}{R} \text{ s.t. } c_1 + \frac{c_2}{\widehat{R}} = e \text{ and } c_1 \geq \ell.$$

The solution is:

- If $R < \widehat{R}$, $\mathbf{c} = (\ell, \widehat{R}(e-\ell))$.
- If $R > \widehat{R}$, $\mathbf{c} = (e, 0)$.
- If $R = \widehat{R}$, $\mathbf{c} = (z, \widehat{R}(e-z))$ where $z$ is any number in $[\ell, e]$.

By the Inada conditions in Eq. (3), the second case cannot be an equilibrium. By Assumption 1 the last case can only be an equilibrium if $z = \sum_\theta \pi(\theta)c_1^{aut}(\theta) = \ell$. Specifically, by the same argument as in the proof of Proposition 3, we know that the market can only clear if $z = \sum_\theta \pi(\theta)c_1^{aut}(\theta)$ , where $(c_1^{aut}(\theta), c_2^{aut}(\theta))$ is the solution to Problem 1. Since $R^* \leq \widehat{R}$, Assumption 1 gives that $\sum_\theta \pi(\theta)c_1^*(\theta) \geq \sum_\theta \pi(\theta)c_1^{aut}$. Therefore, for $z = \sum_\theta \pi(\theta)c_1^{aut}(\theta)$ to be consistent with the liquidity requirement one needs to have $\sum_\theta \pi(\theta)c_1^{aut}(\theta) = \ell$. Hence, the only candidate contract is $(\ell, R(e-\ell))$.

I now claim that $R^{MF} = R^*$ is an equilibrium interest rate and that

$$\left\{\left(x_1^{MF}(\theta), x_2^{MF}(\theta)\right)\right\}_{\theta\in\Theta} = \{(c_1^*(\theta), c_2^*(\theta))\}_{\theta\in\Theta}$$

is the equilibrium allocation. This is immediate as the solution to the social planner's problem in Problem 5 constitutes an equilibrium in the private market at the interest rate $R^*$.

## Proof of Proposition 2

I claim that with these choices by the government $(c_1^*(\theta), c_2^*(\theta))$ solves the individual maximization problem in Problem 9 for all $\theta$. To show this, we only need to prove that $e + T^* = I^*$. From the analysis of the constrained efficient allocation,

$$I^* = \sum_\theta \pi(\theta)\left(c_1^*(\theta) + \frac{c_2^*(\theta)}{R^*}\right).$$

But then

$$\begin{aligned}
e + T^* &= (1+\tau^*)e - \tau^* \sum_\theta \pi(\theta) c_1^*(\theta) \\
&= (1+\tau^*)\underbrace{\sum_\theta \pi(\theta)\left(c_1^*(\theta) + \frac{c_2^*(\theta)}{\widehat{R}}\right)}_{=e \text{ by feasibility}} - \tau^* \sum_\theta \pi(\theta) c_1^*(\theta) \\
&= \sum_\theta \pi(\theta)\left(c_1^*(\theta) + \frac{c_2^*(\theta)}{\widehat{R}}(1+\tau^*)\right) = I^*.
\end{aligned}$$

Finally, the government budget constraint in Eq. (5) holds by construction.

## Proof of Proposition 3

*First part: comparison with first best.* A quick calculation shows that at the first-best allocation the following Euler equation holds:

$$U_1(c_1^{FB}(\theta), c_2^{FB}(\theta); \theta) = U_2(c_1^{FB}(\theta), c_2^{FB}(\theta); \theta)\,\widehat{R}\,.$$

In the mutual fund economy, the consumers satisfy the Euler equation at the market interest rate:

$$U_1(c_1^{MF}(\theta), c_2^{MF}(\theta); \theta) = U_2(c_1^{MF}(\theta), c_2^{MF}(\theta); \theta) R.$$

Suppose that the mutual fund and first-best allocations are identical. Then from above we must have that $\widehat{R} = R$. But since

$$c_1^{MF}(\theta) + \frac{c_2^{MF}(\theta)}{R} = c_1^{MF}(\theta) + \frac{c_2^{MF}(\theta)}{\widehat{R}} = e = c_1^{FB}(\theta) + \frac{c_2^{FB}(\theta)}{\widehat{R}}$$

autarky and first-best allocations coincide. For the other direction, note that the mutual fund can always implement the autarkic allocation by $c_1 = \sum_\theta \pi(\theta) c_1^{aut}(\theta)$ and $c_2 = \widehat{R}(e - c_1)$ and the resulting equilibrium interest rate is $R^{MF} = \widehat{R}$.

*Second part: comparison with second best.* The proof is by contradiction. Assume that the mutual fund can implement the second-best allocation. By virtue of the single-crossing property in Eq. (2) at most one incentive constraint can be binding at the second-best allocation. Without loss of generality, suppose that the constraint for the early types is binding (the other case is completely symmetric). Then, the first-order conditions with respect to $c_1(E)$ and $c_2(E)$ are given by

$$\pi(E)U_1(c_1(E), c_2(E); E) - \pi(E)\mu + \gamma U_1(c_1(E), c_2(E); E) = 0$$
$$\pi(E)U_2(c_1(E), c_2(E); E) - \pi(E)\frac{\mu}{\widehat{R}} + \gamma U_2(c_1(E), c_2(E); E) = 0$$

where $\mu$ is the Lagrange multiplier on the resource constraint and $\gamma$ is the Lagrange multiplier on the incentive compatibility constraint. Note that $\gamma > 0$ by assumption. A quick manipulation of the first-order conditions shows that the Euler equation remains valid for the early types, i.e.

$$U_1(c_1(E), c_2(E); E) = U_1(c_1(E), c_2(E); E)\,\widehat{R}\,.$$

Since the Euler condition holds, we can use the same technique as in the first part of the proof to show that the second-best allocation coincides with autarky. But that contradicts the assumption that the incentive constraint is binding at the second-best allocation, as the autarky allocation is incentive compatible.

# Appendix B Competitive Banks

I sketch the equilibrium definition when intermediation is done by competitive banks; for a more detailed discussion, see Farhi, Golosov, and Tsyvinski (2009). The representative bank chooses a menu of contracts $\mathbf{C} = \{(c_1(\theta), c_2(\theta))\}_{\theta\in\Theta}$, dividends $d_t$ and bond trades with other banks $b$ to maximize discounted profits, subject to feasibility, participation and incentive-compatibility constraints.

**Problem 11** (Bank's Problem: Primal Formulation)**.**

$$\max_{\{(c_1(\theta),c_2(\theta))\}_{\theta\in\Theta},d_1,d_2,b} d_1 + \frac{d_2}{\widehat{R}} + qb - \frac{b}{\widehat{R}}$$

$$\text{s.t. } \sum_\theta \pi(\theta)\left(c_1(\theta) + \frac{c_2(\theta)}{\widehat{R}}\right) + d_1 + \frac{d_2}{\widehat{R}} + qb - \frac{b}{\widehat{R}} = e$$

$$\sum_\theta \pi(\theta)V(\mathbf{C}, R; \theta) \geq \underline{U}$$

$$U(c_1(\theta), c_2(\theta); \theta) \geq V(\mathbf{C}, R; \theta) \text{ for all } \theta \in \Theta$$

$$c_1(\theta), c_2(\theta) \geq 0 \text{ for all } \theta \in \Theta.$$

The value function $V(\mathbf{C}, R; \theta)$ used in the participation and incentive-compatibility constraints is defined in Problem 2. Hence, the key differences from the mutual fund is that (i) the bank offers two consumption bundles instead of one; and (ii) the contract offered by the bank must satisfy incentive compatibility. In equilibrium, $q = \widehat{R}^{-1}$ by no arbitrage and $d_1 + d_2/\widehat{R} = 0$ by free entry. As in the analysis of the mutual fund economy, it is easier to analyze the dual to this problem, which is "choose a feasible menu of contracts to maximize expected utility subject to the incentive compatibility constraints". The equilibrium definition given in Definition 3 needs to be adjusted to take into account the different problem solved by the intermediaries and the fact that the equilibrium supply of the consumption good is now $\sum_\theta \pi(\theta)c_1(\theta)$ and $\sum_\theta \pi(\theta)c_2(\theta)$ in period one and two, respectively.