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Self-Fulfilling Liquidity Dry-Ups

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ABSTRACT

I analyze a model in which holding cash imposes a negative externality: it worsens future adverse selection in markets for long-term assets, which impairs their role for liquidity provision. Adverse selection worsens when potential sellers of long-term assets hold more cash because then fewer sales reflect cash needs, and proportionally more sales reflect private information. Moreover, future market illiquidity makes current cash holding more appealing. This feedback effect may result in hoarding behavior and a market breakdown, which I interpret as a self-fulfilling liquidity dry-up. This mechanism suggests that imposing liquidity requirements on financial institutions may backfire.

A NUMBER OF POLICY makers and academics have pointed out unusual cash hoarding behavior by major financial institutions since the 2007 to 2009 financial crisis in general and a further surge in the euro area since the end of 2011.[1] Many have also expressed concerns that such behavior worsens economic outcomes,[2] a topic to which several recent academic studies have been

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[1] See Acharya and Merrouche (2013), Heider, Hoerova, and Holthausen (2010), Ashcraft, McAndrews, and Skeie (2011), and Pisani-Ferry and Wolff (2012), respectively.

[2] See, for instance, "The economic outlook," Fed Chairman Ben S. Bernanke's testimony before the Committee on the Budget, U.S. House of Representatives, January 17, 2008; the White House

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dedicated (Caballero and Krishnamurthy (2008), Acharya and Skeie (2011), Acharya, Shin, and Yorulmazer (2011), Diamond and Rajan (2012), Gale and Yorulmazer (2012)). The role of adverse selection during the crisis has also been highlighted (see, for instance, Bolton, Santos, and Scheinkman (2011), Morris and Shin (2012), and Tirole (2012)). However, the possibility that hoarding behavior and adverse selection may *reinforce* each other has received little attention so far.

Secondary markets are a source of liquidity provision for owners of long-term assets. Financial markets in which agents sell existing assets or issue claims to their payoffs are a good example. However, information asymmetry may result in adverse selection, which impairs market functioning and prevents gains from trade from being realized (Akerlof (1970)). Thus, adverse selection in these markets undermines their role in liquidity provision (Eisfeldt (2004)).

This paper develops such an adverse selection model of liquidity in which cash holding by some agents imposes a negative externality on others because it reduces future market liquidity. The intuition for why holding cash worsens adverse selection is best understood from a buyer's point of view: the more cash a seller is expected to have on hand, the less likely it is that he is trading because of a need to raise cash, and the more likely it is that he is trying to pass on a lemon.

The agents I study in the model make an investment decision. They can be thought of as entrepreneurs undertaking real projects or as banks issuing long-term loans. At an initial date, each agent allocates his funds between a long-term risky asset and a riskless short-term asset (which represents cash). There is a return-liquidity trade-off because long-term assets have a higher expected return, but agents need some cash before they pay off. At an interim date, they privately observe the idiosyncratic quality of their asset before they can trade in a competitive market. Because of information asymmetry, the market price is affected by the market's perceived motive for trading: either a need for cash or the private knowledge that the asset is a lemon. The model delivers Pareto-ranked multiple equilibria, which provides a striking illustration of how the externality operates.

In a first equilibrium, agents hoard enough cash that they do not need to participate in the interim market. This is well understood by the potential buyers, who infer that good assets will not be for sale. Therefore, assets can only trade at the lemons price. Hence, the interim market breaks down, it is illiquid, and no gains from trade are realized. Market illiquidity, in turn, justifies the initial hoarding decision.

In contrast, if agents decide to be fully invested in the long-term asset, they need to participate in the interim market to satisfy their cash needs. This is true irrespective of their asset quality and therefore some good assets will be for sale too. Volume and price improve and so does market liquidity. If the mixture of assets is good enough, the market price can be high enough that selling an

press release on October 28, 2008; and "Banks need to realise that hoarding cash is not the answer," *Financial Times*, August 17, 2008, for an example in the press.

asset yields a positive return. In that case, holding cash is dominated, which justifies the initial decision to be fully invested in the long-term asset.

The key mechanism is as follows: when agents decide to hold cash, the expected quality of their future sales decreases. This depresses the market price, which imposes an externality on other agents. Moreover, the lower the expected market price, the more appealing it is to hold cash. Thus, holding cash presents strategic complementarities. This may result in widespread hoarding behavior, which in turn causes the market to break down.

These results contrast with the common view that exposure to liquidity risk creates a negative externality (Acharya, Krishnamurthy, and Perotti (2011), Perotti and Suarez (2011)) and therefore financial institutions tend to hold too little liquidity. Indeed, excess reliance on short-term debt or excessive maturity mismatch can result in *fire sales*, a mechanism that has been pinpointed as a major magnifying factor of the recent financial crisis (Brunnermeier (2009), Krishnamurthy (2010)). Accordingly, new regulation will increase liquidity requirements for financial institutions (this is explicitly mentioned in the Basel Committee on Banking Supervision's recommendation (Basel Committee on Bank Supervision (2011)) and in the Dodd-Frank Act in the United States). An implication of my model is that, while an appropriate regulatory response to fire sale externalities, such policies are likely to have adverse unintended consequences when trades reflect private information: a liquidity requirement (such as the liquidity coverage ratio envisioned by Basel III) reduces the future need to raise cash and thus deters market participation for this motive, which impairs market liquidity. In fact, it may even cause a dry-up.

Another implication concerns the design of public intervention should a crisis occur. In the model, the promise of future public intervention ensures efficiency because it makes hoarding unattractive and prevents a self-fulfilling liquidity dry-up. However, once agents have decided to hoard, it is "too late" and public intervention cannot restore efficiency. The key policy insights here are the following: First, participation constraints, not only participation in the market but also in public schemes (such as the asset buyback initially envisioned in the Troubled Asset Relief Program (TARP), depend on hoarding decisions. Hoarding behavior may thus affect the efficiency of public intervention. Second, flooding financial institutions with liquidity to foster new investment (which major central banks have arguably done recently) may exacerbate adverse selection in markets for legacy assets.

The paper belongs to the body of adverse selection models of market liquidity that build on Akerlof (1970). In particular, Eisfeldt (2004) develops the endogenous liquidity framework on which I build. She shows that higher productivity in the economy improves asset market liquidity because it increases investment, which makes income more risky. This makes agents more eager to share risk in the secondary market, which increases potential gains from trade and improves market liquidity. In my paper, risk-sharing does not drive asset sales since all uncertainty is resolved before the market opens. Other papers that study interactions between productivity and adverse selection in asset markets include Kurlat (2012) and Bigio (2011).

The paper is closely related to Plantin (2009), who presents a model where investment decisions depend on liquidity anticipation, and information is assumed to be more symmetric when many investors invest in the long-term risky asset. In Chari, Shourideh, and Zetlin-Jones (2011), another relevant paper, current selling decisions reveal information, that affects future adverse selection. In contrast to these two papers, in my setup adverse selection is affected by sellers' past investment decisions because they affect their current marginal rate of intertemporal substitution.

The paper shares with Bolton, Santos, and Scheinkman (2011) and Heider, Hoerova, and Holthausen (2010) the result that the fear of future illiquidity may trigger hoarding behavior. However, it differs on the effects that ex ante hoarding has on future market conditions. In particular, their models do not capture the negative externality I present here, but they do have *cash-in-the-market-pricing* effects, which they combine with adverse selection.

The cash-in-the-market-pricing literature builds on the general idea of an inelastic demand for financial assets. Focusing on other financial frictions, it yields quite opposite results from my model: investment decisions are typically strategic substitutes and holding liquidity usually imposes a positive externality. It is thus worth explaining the main mechanisms at play.

A cash-in-the-market-pricing episode is a case in which potential buyers do not have enough cash to clear the market at the "fundamental" value (Allen and Gale (1994), Allen and Carletti (2008)).[3] In that case, sellers can only obtain a fire sale price for their assets.[4] Therefore, when an agent decides to hold more cash ex ante, this increases the market price ex post, which reduces the incentive to hold cash for others. Investment decisions are thus strategic substitutes.

When cash-in-the-market-pricing is combined with another friction, for instance, a credit constraint due to moral hazard concerns (Hart and Moore (1994), Kiyotaki and Moore (1997), and Bernanke, Gertler, and Gilchrist (1999)), a collapse in prices may force agents to deleverage, which depresses prices further. When this effect is not internalized the competitive equilibrium is generally inefficient (Caballero and Krishnamurthy (2003), Lorenzoni (2008), Korinek (2011), Stein (2012)). In that case, holding liquidity has positive externalities and private agents tend to hold too little of it. Liquidity requirements or limits to maturity mismatch can therefore be socially beneficial. Whether the competitive equilibrium may imply socially excessive or insufficient holding of liquidity thus depends on the nature of the underlying friction (adverse

[3] The cash-in-the-market-pricing mechanism, or variations thereof, has been widely used to study liquidity dry-ups and related events (see, for instance, Diamond and Rajan (2011) and Gale and Yorulmazer (2012)). In the market microstructure literature, similar effects are obtained either with an exogenously downward-sloping demand for assets and arbitrageurs that face resource constraints that are functions of the market price (Gennotte and Leland (1990), Morris and Shin (2004)), or with limits-of-arbitrage constraints (Shleifer and Vishny (1997)), which create an endogenously inelastic supply of interim liquidity (Gromb and Vayanos (2002), Brunnermeier and Pedersen (2009)).

[4] See Shleifer and Vishny (2011) for a survey on fire sales.

selection or moral hazard, respectively). Which friction is most relevant in reality may vary over time and is an empirical question. I discuss the model's empirical predictions in Section III but their testing is beyond the scope of this paper.

Finally, other relevant work includes Perotti and Suarez (2011), Farhi and Tirole (2012), and Stein (2012) on liquidity regulation; Tirole (2012), Philippon and Skreta (2012), Chari, Shourideh, and Zetlin-Jones (2011), Chiu and Koeppl (2010), Guerrieri and Shimer (2012), and House and Masatlioglu (2012) on the design of public intervention in markets plagued by adverse selection; and, more generally, Brunnermeier (2009), for a chronology of the recent crisis and Tirole (2011) for a survey on the economics of liquidity.

The paper is organized as follows. Section I outlines the model. Section II solves the model and shows that it may admit multiple equilibria. Section III discusses the externality, considers the effects of liquidity requirements and public liquidity insurance, presents the empirical predictions, and highlights the key features of the model. Section IV concludes.

I. The Model

The model has three dates ($t = 0, 1, 2$) with a unique consumption good that is also the unit of account. The key elements of the timeline are as follows: at date 0, agents make an investment decision. At date 1, they privately learn information before they trade in a competitive market and choose how much they consume at that date. At date 2, investments pay off and final consumption takes place.

A. Agents, Technology, and Information

Let there be a measure one of ex ante (at $t = 0$) identical agents who are initially endowed with one unit of the consumption good and maximize

$$E[\ln c_1 + \ln c_2],$$

where c_t is their consumption at date t.

At dates 0 and 1, they have access to a risk-free one-period storage technology that represents cash; it yields a zero rate of return. At date 0, they also have access to a risky long-term technology that consists of projects, undertaken at date 0, that only pay off at date 2. These projects succeed with probability $\pi < 1$. In the case of success, the projects yield a return R_H per unit invested. In the case of failure, the return is R_L, with $0 \le R_L < R_H$. I assume $R_L < 1 < \pi R_H + (1-\pi)R_L$: on average, long-term projects are more productive than storage, but they yield less than storage in the case of failure. Investment decisions are not observable.

At the beginning of date 1, agents privately observe their projects' quality, that is, whether the projects are going to succeed or fail. Quality is common to all the projects of a given agent. One can thus think of each agent as owning only one project of variable size. However, quality is independent across agents and, assuming a law of large numbers, average quality is deterministic. If projects are stopped at date 1, they yield nothing. However, at that date, agents may issue claims to the payoff of their projects in a competitive market, which I describe later.

Let there also be a measure one of risk-neutral "deep-pocket" *buyers* (the term *agent* refers exclusively to the ones described earlier). Their existence ensures that the market clears at the expected value of the underlying payoffs.

To prevent agents from circumventing date-1 market incompleteness by trading at date 0 (i.e, before they are privately informed), I rule this possibility out by assuming that agents are needed to initiate their own projects and that they cannot commit to properly invest on behalf of a date-0 buyer.[5]

B. Interim Market

I consider a competitive market in which agents trade perfectly divisible shares of their projects. The market opens at date 1. There is no other means to borrow against future income than to issue shares of ongoing projects, and issuance is limited to existing projects. Short sales are thus ruled out. In line with most of the literature, I assume that all trades take place at the same price.[6] It would be a natural outcome of an anonymous market in which buyers cannot infer quality from quantities because sellers can split their sales.

Henceforth, I call shares of high-quality projects "good assets," and shares of low-quality projects "bad assets" or lemons interchangeably.

C. Demand for Shares and Market Price

Buyers do not have access to the long-term technology. They only have access to storage and to the interim market. I assume that they have, on aggregate, enough resources available at date 1 to clear the market at the expected value of the underlying payoffs.

When asset quality is private information, the expected value of an asset depends on the average quality of traded assets (Akerlof (1970)). Therefore, the market unit price p is given by

$$p(q) = R_L + q(R_H - R_L), \tag{1}$$

where q, which is inferred by the buyers at equilibrium, denotes the proportion of good assets in the market.

[5] A way to justify this would be that proper project initiation is not verifiable and not observable before date 1 and improper initiation makes the project fail for sure but provides investors with a private benefit.

[6] This is assumed, for instance, in Akerlof (1970), Eisfeldt (2004), Bolton, Santos, and Scheinkman (2011), and Chari, Shourideh, and Zetlin-Jones (2011). However, when it is assumed that buyers quote prices, assets of different qualities can trade at different prices. This is the case, for instance, in Wilson (1980), and more recently in Guerrieri and Shimer (2012).

D. Market Liquidity

A unit invested in the long-term asset, and then sold, yields p units of consumption goods at date 1. The interim market is thus a source of liquidity provision, and, the higher the price, the better the liquidity provision. Equation (1) states that p increases with q. Therefore, adverse selection undermines liquidity provision: the more severe the adverse selection (the lower the q), the poorer the liquidity provision by the market.

Since the alternative way to obtain consumption goods at date 1 is holding cash, it is convenient to use the following definition:

DEFINITION 1 (Illiquid market): *The market is said to be illiquid if* $p < 1$. *This happens when* $q < \frac{1-R_L}{R_H-R_L}$.

II. Equilibria

In this section, I show that the model may deliver multiple rational expectations equilibria, one of them being a self-fulfilling liquidity dry-up.

A. The Problem of the Agent

From a date-0 perspective, agents need to choose how much of their initial endowment to invest in the long-term technology. The variable $y \in [0, 1]$ captures this initial investment decision. Agents also have to make contingent consumption plans for the subsequent dates. Letting the index $i \in \{L, H\}$ reflect variable state contingency (i.e., the realization of R_i for the agent), they have to choose how much of the long-term asset to sell (x_i) at date 1 at the market price (p), and how much to store (s_i) until date 2.

Formally, agents seek to maximize

$$E[\ln(c_{1i}) + \ln(c_{2i})],$$

subject to the contingent budget constraints

$$\begin{cases} c_{1i} = 1 - y + px_i - s_i \\ c_{2i} = (y - x_i)R_i + s_i, \end{cases} \tag{2}$$

and the boundary conditions $s_i \geq 0$ and $0 \leq x_i \leq y$.

The budget constraints state the following: date-1 resources consist of storage from date 0, plus the revenue from asset sales. These resources can be consumed or stored until date 2. At date 2, resources available for consumption consist of the output from the share of long-term investment that has not been sold, plus storage from date 1.

In the following paragraphs, I solve this problem by backward induction.

B. Contingent Optimal Sale of Long-Term Assets (Date 1)

The realization of R_i is learned at the beginning of the period, y is predetermined, and p is taken as given. At date 1, agents therefore face a simple intertemporal consumption problem: maximize $\ln(c_{1i}) + \ln(c_{2i})$, subject to the pair of realized budget constraints (2).

First, let me consider the agents with low-quality assets, whom I call *agents L*. If $p > R_L$, they obviously sell all their assets. For simplicity, I assume that they do the same when $p = R_L$, and I restrict the analysis to prices that are consistent with equation (1): $p \in [R_L, R_H]$. Accordingly, letting $x_i(p, y)$ denote agents i's optimal asset sale for a given pair (p, y), I have

$$x_L(p, y) = y\ . \tag{3}$$

To equate their marginal utility of consumption over time, agents then set $s_L(p, y)$ so as to split their resource equally across the two dates. Hence, their optimal consumption plan given (p, y) is

$$c_{1L}(p, y) = c_{2L}(p, y) = \frac{1 - y + py}{2}\ . \tag{4}$$

Let me now turn to *agents H*. First, observe that equation (3) implies that $p < R_H$. Therefore, it is not optimal to have both $x_H > 0$ and $s_H > 0$. It follows that the first-order conditions yield

$$\begin{cases} x_H(p, y) = \max\left\{0; \dfrac{py - 1 + y}{2p}\right\} \\ s_H(p, y) = \max\left\{0; \dfrac{1 - y - yR_H}{2}\right\} \end{cases}, \tag{5}$$

which determines their optimal consumption plan given (p, y). A simple derivation of $x_H(p, y)$ establishes the following:

LEMMA 1 (Market participation): *$x_H(p, y)$, the quantity of assets sold by agents H, increases with y and strictly increases if $y \geq \frac{1}{1+p}$.*

The polar cases convey the main intuition. If $y \leq \frac{1}{1+p}$, agents H have enough cash to avoid selling their good assets at a discount. If $y = 1$, they have no cash, and participating in the market is their only means to obtain current consumption goods. They therefore sell some assets (in particular, given that utility is logarithmic, they sell half of them). Essentially, the less cash they have at hand, the more they need to sell assets. This first result is important because it establishes the channel through which initial investment decisions affect the mixture of assets that will be traded at date 1.

C. Optimal Investment Decision (Date 0)

Let me define $U_i(p, y) \equiv \ln c_{1i}(p, y) + \ln c_{2i}(p, y)$, the state-contingent level of utility achieved in state i for a given pair (p, y). Then the optimal date-0 investment policy given p corresponds to:

$$y(p) \equiv \arg\max_{y} \;\; \pi\, U_H(p, y) \;+\; (1-\pi)\, U_L(p, y)\,.$$

PROPOSITION 1 (Optimal investment):

$$y(p) \in \begin{cases} \left[0, \tfrac{1}{2}\right[& ; p < 1 \\ \left[\tfrac{1}{2}, 1\right] & ; p = 1 \\ \{1\} & ; p > 1\,. \end{cases}$$

Sketch of the proof (see Appendix A for a complete proof): For $p < 1$, considering the marginal utility of y separately in the two states provides the most intuitive proof that the optimal y is strictly smaller than $\frac{1}{2}$. First, in state L, consumption at both dates is $\frac{1-y+py}{2}$, and the marginal utility of y is therefore strictly negative. Second, in state H, while a strictly positive y is desirable because the asset yields a high payoff if held to maturity, it is more efficient to provide for date-1 consumption through storage rather than selling the long-term asset (since $p < 1$). This implies that maximizing $U_H(p, y)$ boils down to maximizing $\ln(1-y) + \ln(yR_H)$, which is strictly concave in y, and reaches a maximum at $y = \frac{1}{2}$. Summing up, when $p < 1$, the marginal utility of y is strictly negative in state L and can only be strictly positive for $y < \frac{1}{2}$ in state H. Therefore, expected utility maximization implies that the optimal y be strictly smaller than $\frac{1}{2}$. When $p > 1$, investment dominates storage irrespective of realized quality, and $y = 1$ is always optimal.

D. Implied Asset Sales

I can now evaluate the state-contingent asset sale functions (3) and (5) at the optimal investment level given by Proposition 1:

$$x_L(p, y(p)) = y\,;$$

$$x_H(p, y(p)) \in \begin{cases} \{0\} & ; p < 1 \\ \left\{\tfrac{1}{2}\right\} & ; p > 1 \\ \left[0, \tfrac{1}{2}\right] & ; p = 1\,. \end{cases} \tag{6}$$

DEFINITION 2 (Hoarding): *Agents are said to be hoarding when they decide to fully cover date-1 consumption needs with cash holdings, rather than relying on market liquidity provision. That is, when $c_{1i} \leq 1 - y$, for $i = L, H$.*

PROPOSITION 2 (Hoarding): *The anticipation of an illiquid market ($p < 1$) leads to hoarding.*

Proof: First, from equation (6), $p<1$ implies that $x_H=0$, and therefore $c_{1H}\leq 1-y$. Second, from Proposition 1, $p<1$ implies $y(p)<\frac{1}{2}$, which implies $\frac{1-y(p)+py(p)}{2}<1-y(p)$. Since the left-hand term corresponds to $c_{1L}(p,y)$ (equation (4)), this establishes the result. Q.E.D.

E. Average Quality

Assuming a law of large numbers, I can now define and compute $q(p,y(p))$, the proportion of good assets for a given p, at the investment level y, which is itself consistent with p:

$$q(p,y(p))\equiv\frac{\pi x_H\left(p,y(p)\right)}{(1-\pi)x_L\left(p,y(p)\right)+\pi x_H\left(p,y(p)\right)}\in\begin{cases}\{0\} & ;p<1\\ \left\{\frac{\pi}{2-\pi}\right\} & ;p>1\\ \left[0,\frac{\pi}{2-\pi}\right] & ;p=1\,.\end{cases}\tag{7}$$

F. Equilibrium Definition

A triple (y^*,q^*,p^*) is a rational expectations equilibrium for this economy if and only if:

(i) y^* is an optimal investment decision given p^*;
(ii) q^* is the proportion of good assets in the market implied by a price p^* when the initial investment decision was y^*;
(iii) $p^*=R_L+q^*(R_H-R_L)$, that is, p^* is the expected asset payoff given q^*.

G. Equilibria

To find the equilibria of this economy, I combine the buyers' no-arbitrage condition (1) with equation (7) to define the implied price correspondence:

$$p^{'}(p)\equiv R_L+q(p,y(p))[R_H-R_L],\tag{8}$$

where $p^{'}(p)$ is the market price corresponding to a proportion of good assets $q(p,y(p))$. Therefore, when $y(p)$ is a singleton,[7] a fixed point $p^{'}(p)=p$ pins down an equilibrium for the economy. The corresponding values of y^* and q^* are then given by Proposition 1 and equation (7), respectively.[8]

H. Example of a Self-Fulfilling Liquidity Dry-Up

Figure 1 illustrates that, in this economy, the same fundamentals $(\pi,\ R_H,\ R_L)$ might lead to multiple equilibria that differ by their level of market liquidity.

In a first equilibrium (E_{liq}), agents expect the market to be liquid ($p>1$). Accordingly, they invest only in the long-term asset. Given that they have

[7] This is true in the interesting cases, that is, when $p\neq 1$.

[8] Defined over $[R_L,R_H]$, the correspondence $p^{'}(p)$ is nonempty, convex, and has a closed graph. The existence of a fixed point is thus guaranteed by Kakutani's theorem.

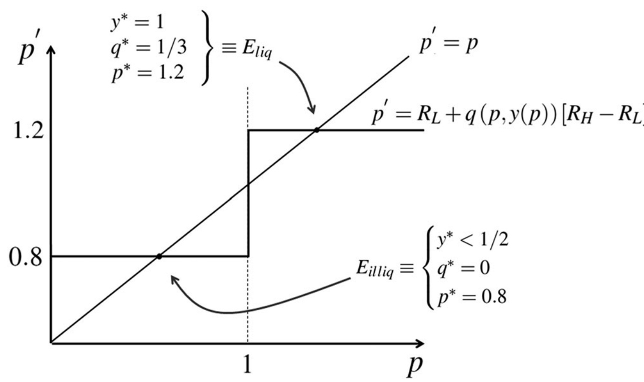

Figure 1. Example of multiple equilibria. This picture depicts the implied price correspondence (expression (8)) with parameter values $\pi = 0.5$, $R_H = 2$, and $R_L = 0.8$. Equilibria of the model are given by fixed points of the correspondence, which are at its intersection with the identity line $p' = p$.

no cash, agents H need to participate in the market to provide for current consumption. This sustains a relatively high average quality ($q^* = 1/3$) and ensures market liquidity ($p^* = 1.2$). However, if agents anticipate an illiquid market ($p < 1$), they initially choose to hoard. Accordingly, agents H do not need to sell their assets, and the market breaks down: only lemons are for sale ($q^* = 0$). The market is thus illiquid ($p^* = R_L$), which justifies the initial hoarding decision. Equilibrium E_{illiq} is thus a self-fulfilling liquidity dry-up.

Both equilibria are locally stable in the sense that best responses to any small perturbation to the equilibrium price would bring the price back to equilibrium. There are also equilibria corresponding to $p = 1$, but they are unstable.[9]

I have assumed that agents L sell all their lemons when $p = R_L$. Without this assumption, the quantity they sell in the low-liquidity equilibrium is indeterminate (it is given by $x_L \in [0, y]$), but the equilibrium allocation of resources is unchanged. This allocation is unique given the initial investment decision and, since there are no gains from trade, it is equivalent to a market freeze (which, strictly speaking, corresponds to $x_L = 0$). Given initial investment decisions, the high-liquidity equilibrium is also unique. It is a pooling equilibrium (in prices, not in quantities) in the sense that agents L pretend they are of the H type and get the same price, even though they sell larger quantities.[10]

The example depicted in Figure 1 is not an exception. In fact, a low-liquidity equilibrium always exists, and, if the long-term asset is sufficiently productive,

[9] There is a single symmetric equilibrium with $p = 1$, but since $y(p)$ is not a singleton in that case, there is also an infinity of asymmetric equilibria.

[10] If quantity sold were observable, a high-liquidity pooling equilibrium (in price and quantity) would exist under similar conditions. The analysis could be done on the basis of this equilibrium. However, a separating equilibrium in which different types trade different (and strictly positive) quantities at different prices might also exist.

a high-liquidity equilibrium exists too. Formally, for each pair (π, R_L), there is a threshold for R_H from which there are multiple equilibria.[11]

PROPOSITION 3 (Self-fulfilling liquidity dry-ups): *If $R_H \geq \frac{(2-\pi)}{\pi} - 2\frac{(1-\pi)}{\pi}R_L$, both a low-liquidity equilibrium (i.e., with $p^* < 1$) and a high-liquidity equilibrium (i.e., with $p^* > 1$) exist. The low-liquidity equilibrium can thus be interpreted as a self-fulfilling liquidity dry-up.*

Proof: Straightforward. Q.E.D.

III. Discussion

In this section, I first discuss the externality whose identification is the main contribution of the paper. Second, I provide a concrete application, where I show that imposing liquidity requirements on financial institutions (a policy response to the recent financial crisis) may have unintended consequences. Third, I explain how public liquidity insurance can prevent agents from coordinating on the Pareto-dominated equilibrium of the model. I then highlight the relevant contexts to which the results apply, and I discuss the novel empirical predictions. Finally, I highlight the key ingredients required to obtain the externality and relate them to the main assumptions of the model.

A. The Externality

At date 1, the "true" value of an asset is $R_i \in \{R_L, R_H\}$ per unit. Hence, a trade at a unit price of $p \neq R_i$ implies a transfer of value from the seller to the buyer (the transfer is negative if $p > R_i$). At equilibrium, the price adjusts so that the buyers break even on expectation. Therefore, an increase in the sale of good assets increases the market price, which is beneficial to other sellers. This is the standard pecuniary externality linked to adverse selection.

Whether an agent with a good asset chooses to trade, and therefore provides a positive externality, hinges on his private valuation of this asset being lower than the market price. The key point in the model is that his private valuation depends on his date-0 investment decision. The larger his position in the long-term asset, the less cash he has on hand, and the more he needs to sell assets to cover current needs. Formally, from Lemma 1, we have that $x_H(p, y)$, the quantity of assets sold by type-H agents, is increasing in y. Consequently, changes in y affect the expected quality of future sales.

The expected quality of an asset (the probability that it is a good one) sold by an agent who faces a price p and has invested y is given by

$$q^e(p, y) \equiv \frac{\pi x_H(p, y)}{(1-\pi)x_L(p, y) + \pi x_H(p, y)}.$$

[11] Note that equilibrium multiplicity does not depend on the choice of the distribution of project quality, on the return to storage, or on the specific form of the utility function. See the working paper version of the model for a proof of equilibrium multiplicity under more general assumptions (Malherbe (2010)).

The numerator is his expected sales of good assets, and the denominator is his expected total sales.[12] A simple derivation establishes that $\frac{\partial q^e(p,y)}{\partial y} \geq 0$, with strict inequality when $y \geq \frac{1}{1+p}$. An increase in y thus improves the expected quality of future sales, which provides a nice intuition for how the externality works. However, an increase in y also increases the quantity of lemons to be sold. To establish the externality, one must look at the expected net effect.

Let me restrict the analysis to prices that are between the two equilibrium prices (including them), and let me define $t(p, y)$ as the expected transfer implied by future sales of an agent that invests y in the long-term asset and faces a price p, that is,

$$t(p, y) \equiv \pi x_H(p, y)(R_H - p) + (1 - \pi)x_L(p, y)(R_L - p)\,.$$

An increase in $t(p, y)$ increases the market price, which implies a positive externality. Similarly, a decrease in $t(p, y)$ implies a negative externality.

PROPOSITION 4 (Externality): *Provided that y is not already too low, the decision to hold more cash (i.e., to decrease y) imposes a negative externality on other agents. That is,* $\frac{\partial t(p,y)}{\partial y} > 0,\ \forall y \in \left[\frac{1}{1+p}, 1\right]$.

Proof: See Appendix A. Q.E.D.

Note that, when $y \in [\frac{1}{1+p}, 1]$, $x_H(p, y)$ is strictly increasing in y (Lemma 1). The result is then obvious when $p = R_L$, and it can be easily generalized to the high-liquidity equilibrium price and to any price in between.

Given the externality, it is not surprising that the high-liquidity equilibrium Pareto dominates the low-liquidity one. This is because: (i) no resource is wasted in the storage technology; (ii) agents H enjoy better consumption smoothing (these are the direct gains from trade); and (iii) there is a cross-subsidy from agents H to agents L, which is desirable from an ex ante insurance perspective.

Note finally that the feedback effect that leads to equilibrium multiplicity comes from strategic complementarities[13] in initial investment decisions. To see how these strategic complementarities work and how they are linked to the externality, consider the range of actions analyzed in Proposition 4. These actions decrease the market price. But a lower market price makes the long-term asset less attractive (because a lower price decreases the option value to sell at the interim date, without changing the cost of the investment) and thus makes holding cash more attractive. These actions therefore present strategic complementarities.[14] This is another important difference with

[12] In a symmetric equilibrium, $q^e(p, y)$ is equal to $q(p, y(p))$, the proportion of good assets in the market.

[13] In game theory, an action presents strategic complementarities if the incentive for an agent to take this action increases when others take it.

[14] Note, however, that strategic complementarities are not global: at a high initial level of cash holdings, a further increase no longer decreases the price and can even increase it. See Appendix B for further discussion.

the cash-in-the-market-pricing literature, where cash-holding decisions are typically strategic substitutes.

B. Liquidity Requirement

In reaction to the recent crisis, regulators seem determined to require that financial institutions hold more liquidity (the Basel Committee on Banking Supervision has recommended the imposition of a liquidity coverage ratio (Basel Committee on Banking Supervision (2011)), and the Dodd-Frank Act stipulates that liquidity requirements should be taken into account for setting prudential standards for systemically important financial institutions). While this is a sensible thing to do to mitigate fire sale externalities, my results suggest that such requirements may have adverse unintended consequences when trades reflect private information.

I present here a very simple exercise that illustrates the above point. Specifically, I consider a liquidity requirement imposed by a regulator on date-0 investment decisions:

$$1 - y \geq \rho, \tag{9}$$

which simply means that a fraction ρ of the initial endowment should be kept in cash (i.e., should be stored).

The first implication is that it puts an upper bound on agents' maturity mismatch, which can only reduce their future needs to raise cash. Hence, it deters market participation for this motive and makes adverse selection more severe.

PROPOSITION 5 (Unintended consequences): *A liquidity requirement strictly reduces welfare at the high-liquidity equilibrium and may even cause a liquidity dry-up.*

Proof: See Appendix A. Q.E.D.

First, observe that, in a high-liquidity equilibrium, the liquidity buffer requirement (condition (9)) is binding: when the market is liquid, storage is dominated and is kept at a minimum ($y = 1 - \rho$). By Lemma 1 (market participation), setting an upper bound to y can only deter market participation of agents H: at a given p, x_H increases with y; it thus decreases with ρ. Average quality at the high-liquidity equilibrium (assuming it still exists) is thus lower, and so is the price. Both types of agents are ex post worse off because they are forced to invest in a dominated technology, and this has no beneficial effect since the interim market price is actually depressed. Second, because a higher ρ deters market participation of agents H and depresses the price, there is, for a given parameter set (R_H, R_L, π), a ρ from which a market price greater than or equal to one is not sustainable and market liquidity must dry up. In other words, an increase in ρ shrinks the parameter region compatible with a high-liquidity equilibrium.

C. Coordination Failure and Public Liquidity Insurance

In this model, a self-fulfilling liquidity dry-up is a coordination failure: if agents expect others to hoard, their best response is to hoard too, even though they know that a high-liquidity equilibrium is possible.

In this simple setup, the coordination failure can, however, be easily prevented with public intervention. For instance, the government can guarantee at date 0 a date-1 floor price of one. In that case, cash becomes a dominated asset, no one hoards, and the only possible outcome is the Pareto-preferred equilibrium. This intervention can be interpreted as a public liquidity insurance and is very similar in spirit to the demand deposit insurance in Diamond and Dybvig (1983).

In more elaborate setups, however, the design of public intervention that aims at overcoming adverse selection in financial markets is a complex issue. One reason is that agents' participation constraints depend on expected public intervention (Philippon and Skreta (2012), Tirole (2012)). But my results suggest an additional layer of complexity: market participation also depends on cash positions, which themselves depend on expected public intervention. An example is that the public liquidity insurance mentioned earlier would only be effective if credibly announced ex ante. Once agents have decided to hoard, guaranteeing a floor price is still feasible ex post, but it would no longer be a Pareto improvement. Hoarding behavior may thus seriously impact the efficiency of public interventions such as those considered by Tirole (2012) and Philippon and Skreta (2012). It would therefore be interesting to study this question in a dynamic setup that allows for ex ante hoarding decisions.

D. Relevant Context and Empirical Predictions

The model applies to markets that may be subject to adverse selection on the sellers' side. For example, this can be the case for markets for financial securities, such as common stocks or asset-backed securities, or for corporate assets.[15]

The model first delivers empirical predictions related to the severity of adverse selection in contexts where sellers' "liquidity positions" are hard to assess by outsiders. Thus, these predictions are more likely to apply when sellers are large and complex companies with opaque balance sheets rather than small companies operating a single line of business (see Tirole (2011) on the difficulty of assessing liquidity positions). A worsening of adverse selection in a given market is characterized by lower prices, lower volumes, and lower average quality of the assets that are traded (compared to those that are not) and by higher incentives to invest in costly information acquisition about these assets.

[15] See, for instance, Downing, Jaffee, and Wallace (2009) for evidence of adverse selection in the market for mortgage-backed securities, and Rhodes-Kropf, Robinson, and Viswanathan (2005) for evidence of adverse selection in equity issuance linked to corporate acquisition.

PREDICTION 1: *Adverse selection intensifies in periods of high cash holdings.*

The unusual and widespread hoarding behavior that has been observed in the aftermath of the recent financial crisis makes it an interesting context for testing this prediction.[16] A case in point could be asset-backed securities. While their design is supposed to alleviate adverse selection (Demarzo and Duffie (1999) and DeMarzo (2005)), these securities had largely become "toxic" in the fall of 2008, a phenomenon widely associated with adverse selection (Morris and Shin (2012), Tirole (2012)). However, the economy had also entered a recession that was likely to be severe. Bad news about fundamentals increases the information sensitivity of debt-like assets and makes them more prone to adverse selection (Gorton and Pennacchi (1995), Dang, Gorton, and Holmström (2012)). But this second channel is not incompatible with the cash holding one. In fact, the two effects are likely to reinforce each other and would probably be hard to disentangle during this period. Still, issuance in securitization markets has, by and large, not recovered (Gorton and Metrick (2013)), while macroeconomic fundamentals have arguably improved (at least in the United States). This provides support for the economic significance of the cash-holding channel.

PREDICTION 2: *When sellers' cash needs decrease (increase), or when other sources of cash become more (less) easily available to them, adverse selection intensifies (abates).*

This prediction relates directly to my discussion on liquidity requirements. It applies, for instance, to markets in which financial institutions are natural sellers/issuers. An example of changing refinancing conditions could be an increase in the range of collateral eligible for borrowing at the central bank or a change in the class of institutions that can access central bank lending. Such changes have been made during the recent crisis to ease the short-term funding of financial institutions. The model suggests that they may actually have worsened adverse selection in other markets (such as those for asset-backed securities, for example). The same must be said of the European Central Bank's recent launch of long-term refinancing operations (LTRO), since it implies a protracted period of easy refinancing for financial institutions in the euro area.

PREDICTION 3: *Sellers of assets that are prone to adverse selection are relatively more likely to release information on cash needs and to report reasons for selling that are allegedly unrelated to the quality of the assets they sell.*

Divesting firms often publicly announce that the assets they sell are "noncore" (or "nonstrategic") and/or that the divestiture is driven by cash needs. Informing investors about corporate strategy could be the purpose of such announcements, but it may also be an attempt to alleviate suspicions of an

[16] Since August 2007, U.K. banks have substantially increased their liquidity buffers (Acharya and Merrouche (2013)); since September 2008, there has been a dramatic increase in the excess reserves of European banks (Heider, Hoerova, and Holthausen (2010), Pisani-Ferry and Wolff (2012)), and of U.S. major deposit institutions. Keister and McAndrews (2009), however, point out that a substantial part of the increase could be due to factors other than hoarding.

opportunistic sale.[17] A large body of literature studies the impact of divestiture on firm performance. Some papers study the motives for selling (Hite, Owers, and Rogers (1987), John and Ofek (1995), and Lang, Poulsen, and Stulz (1995), for example) but, to the best of my knowledge, the interaction between alleged selling motives and adverse selection has been rather overlooked. If such communication arises more often when the assets for sale are prone to adverse selection, and/or is associated with smaller lemons discounts, this would provide support for the model.

The model also delivers predictions related to contexts in which the seller's cash position is easier to assess by outsiders. The first is the counterpart of Prediction 3.

PREDICTION 4: *Cash-rich firms are relatively more likely to invest in costly disclosure of information on the quality of the assets they sell (pay certification fees, for instance) and to report reasons for selling that are allegedly unrelated to their quality.*

When selling assets equally prone to adverse selection, firms with more cash on hand are indeed more likely to try to alleviate suspicions that their sales are driven by private information.

Proposition 4 implies that the average quality of sold assets is decreasing with initial cash holdings. The model therefore predicts that, when buyers observe large cash holdings held by a seller, they should assign high probability to the sale being driven by private information, and they should offer a low price. Accordingly:

PREDICTION 5: *Cash-rich firms are likely to face relatively larger lemons discounts.*

Empirical studies on the relationship between cash positions and lemons discounts are scarce. However, Gao (2011) finds empirical evidence for an adverse selection effect of corporate cash reserves in the context of acquisitions that are financed by stocks. In particular, he finds that announcement returns are lower for bidders with higher excess cash reserves, which is consistent with my prediction.

If they face larger lemons discounts, cash-rich firms should be more reluctant to sell information-sensitive assets. Hence:

PREDICTION 6: *Cash-rich firms are relatively less likely to sell assets that are prone to adverse selection.*

This prediction has to be contrasted with the prediction of Myers and Majluf (1984) that larger financial slack makes a firm more likely to issue equity. The difference comes mostly from their assumption of a fixed-size investment opportunity. In their paper, more financial slack means that less capital needs to be raised to seize the opportunity. Since the net present value of the project

[17] After all, as pointed out by Tirole (2011), this is not so different from having ads for used cars or houses mentioning exogenous reasons for selling (move abroad, family extension, etc.).

is constant, the marginal return to raising capital is increasing in financial slack. In my model, in contrast, the marginal utility of cash obtained from the sale decreases with the cash that was already available.

E. Key Features of the Model

This paper makes the point that holding cash can impose a negative externality as it worsens adverse selection in markets for long-term assets. While the point is made in the context of a simple and very stylized model, it applies quite generally to contexts where cash positions are not easily observable. In these cases, one should expect it to be relevant in most situations in which both private information and a need to raise cash are potential motives for selling assets.

If cash positions were observable in the model, an increase in an agent's cash holdings would still decrease the average quality of his future sale but would not impose an externality on others because the market perception of the agent's trading motive could be based on his own cash position. The combination of the two motives for selling is the other key feature of the model. Individually, these motives are of course quite common. To illustrate that they do not hinge on very specific assumptions, I identify where they come from in the model and I provide examples of alternate relevant situations.

First, to have private information as a potential selling motive, I simply assume that agents privately observe their project quality at the beginning of date 1, and I rule out contracts that would make private information irrelevant at that date. The underlying specific restrictions are not important. What matters is that sellers have relevant private information when the market opens. Holmström and Tirole (2011) confirm this in a version of the model where agents can trade at date 0 but are already privately informed.

Second, the potential need to raise cash comes, in the model, from agents deriving utility from date-1 consumption. Any other reasons cash would be valuable at date 1 (an investment opportunity or a refinancing need, for instance) would also yield such a selling motive.

Finally, note that it is essential that holding more cash attenuates the need for cash. It may seem trivial, but cash needs should be endogenous. This is usually not the case in models that, in the tradition of Diamond and Dybvig (1983), assume that a fraction of agents are hit by a shock that gives them an *absolute* preference for cash.[18] By contrast, in my model the decreasing marginal utility of date-1 consumption ensures that the need to raise cash decreases with cash holdings. This would also be the case if the need for cash came from an (possibly random) investment opportunity with a concave return function (with some strict concavity), but not in the case of an investment

[18] This special case usually yields corner solutions for sale decisions, in which case the severity of adverse selection is likely to be uniquely determined by the fraction of agents hit by the shock. See Parlour and Plantin (2008) for an example.

opportunity with linear return and infinite possible scale (as is sometimes implicitly assumed in the security design literature).[19]

IV. Conclusion

I present a model in which holding cash imposes a negative externality. This model sheds light on a new channel through which hoarding behavior may impair the efficient allocation of resources.

By and large, the results contrast with those of the cash-in-the-market/fire-sale literature, in which liquidity holding imposes a positive externality. Whether private agents tend to hold too much or too little liquidity thus depends on the nature of the underlying friction, that is, whether there is an adverse selection or moral hazard problem. The respective policy implications are opposite. In particular, my model suggests that imposing liquidity requirements on financial institutions, a policy that mitigates fire-sale externalities, is likely to have adverse unintended consequences in markets prone to adverse selection.

The regulatory response to the recent crisis suggests that fire sales are indeed seen as most relevant. However, given the current amount of excess reserves of financial institutions in Europe and in the United States, it is difficult to argue that private agents always tend to hold too little liquidity and that hoarding behavior is only a remote theoretical possibility. Regulators should therefore not overlook the mechanism highlighted in this paper.

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Appendix A: Proofs

Proof of Proposition 1:

(i) The case in which $p > 1$ is trivial as holding cash is a dominated means of transfering resources to dates 1 and 2. Thus, $y(p)\mid_{p>1} = 1$.

(ii) When $p = 1$, holding cash is equivalent to investing and then selling, and it is straightforward to show that the optimal contingent consumption plan corresponds to $c_{2H} = \frac{R_H}{2}$ and $c_{1H} = c_{1L} = c_{2L} = \frac{1}{2}$. This plan is feasible if and only if $y \in [\frac{1}{2}, 1]$.

(iii) Consider now $p < 1$. From equation (4), I have $U_L(p < 1, y) = 2\ln(\frac{1+y(p-1)}{2})$ and, from equation (5),

[19] See DeMarzo and Duffie (1999), for instance.

$$U_H(p<1,y)=\begin{cases}2\ln\left(\frac{1+y(R_H-1)}{2}\right) & ;\ y\le\frac{1}{1+R_H}\\ \ln(1-y)+\ln(yR_H) & ;\ \frac{1}{1+R_H}\le y\le\frac{1}{1+p}\\ \ln\left(\frac{1+y(p-1)}{2}\right)+\ln\left(\frac{1+y(p-1)}{2}\left(\frac{R_H}{p}\right)\right) & ;\ \frac{1}{1+p}\le y\,.\end{cases}\quad\text{(A1)}$$

Letting $U_i^{'}\equiv[\frac{\partial U_0}{\partial y}|i]$ be the marginal utility of y conditional on being in state i, I have $U_L^{'}<0,\forall y$, and $U_H^{'}\gtreqless 0$ if $y\lesseqgtr\frac{1}{2}$. Therefore $(1-\pi)U_L^{'}+\pi U_L^{'}$ is always strictly negative for all $y\ge\frac{1}{2}$. Hence, it can only be null for a $y\in[0,\frac{1}{2}[$, and it must be the case that $y(p)\mid_{p<1}<\frac{1}{2}$. Q.E.D.

Proof of Proposition 4: I seek to establish that $\frac{\partial t(p,y)}{\partial y}>0$, $\forall y\in[\frac{1}{1+p},1]$ and $p\in[R_L,p_{liq}]$, where $p_{liq}\equiv R_L+\frac{\pi}{2-\pi}(R_H-R_L)$ is the price at the high-liquidity equilibrium.

When $y\ge\frac{1}{1+p}$, from equation (5) I have

$$\frac{\partial t(p,y)}{\partial y}=\pi(R_H-p)\left(\frac{p+1}{2p}\right)+(1-\pi)(R_L-p).$$

First, note that $\frac{\partial t(p,y)}{\partial y}$ is decreasing in p. I can therefore focus on $p=p_{liq}$ since it is the most unfavorable case. Since buyers break even on expectation at equilibrium, I have $t(p_{liq},1)=0$. But, when $y=\frac{1}{1+p_{liq}}$, I have $x_H(p_{liq},\frac{1}{1+p_{liq}})=0$. This implies that $t(p_{liq},\frac{1}{1+p_{liq}})=\frac{(1-\pi)(R_L-p_{liq})}{1+p_{liq}}<0$. Since $\frac{1}{1+p_{liq}}<1$, and $\frac{\partial t(p,y)}{\partial y}$ does not depend on y, it must therefore be the case that $\frac{\partial t(p,y)}{\partial y}>0$, $\forall y\in[\frac{1}{1+p_{liq}},1]$, which establishes the result. Q.E.D.

Proof of Proposition 5: First, define $p^{'}(p,\rho)\equiv R_L+q(p,y(p,\rho))[R_H-R_L]$, the implied price correspondence for a given ρ.

Let $p^{''}(\rho)$ denote the largest fixed point that solves $p^{'}(p,\rho)=p$. The first step of the proof is to show that, if this fixed point $p^{''}(\rho)$ exists, it is strictly decreasing in ρ, for $p>1$.

A direct adaptation of Proposition 1 (optimal investment) shows that constraint (9) is binding when $p>1$. Hence, at the optimal investment level, $x_H(p,y)=x_H(p,1-\rho)=\max\{0;\frac{1-\rho}{2}-\frac{\rho}{2p}\}$. Since it is decreasing in ρ, the resulting average quality $q(p,1-\rho)$ is decreasing in ρ too, and it is easy to check that it is increasing in p. Therefore, considering $\rho_{low}<\rho_{high}$, the price corresponding to the largest fixed point under ρ_{low} (denoted $p^{''}(\rho_{low})$) is larger than the price it would imply under ρ_{high}, that is, $p^{'}(p^{''}(\rho_{low}),\rho_{high})<p^{''}(\rho_{low})$. Hence, $p^{''}(\rho_{low})$ cannot be a fixed point under ρ_{high}. Since $q(p,1-\rho)$ is decreasing in ρ for any p, and, by definition, $p^{''}(\rho_{low})$ is the largest fixed point under ρ_{low}, there cannot exist a fixed point $p^{''}(\rho_{high})$ such that $p^{''}(\rho_{high})\ge p^{''}(\rho_{low})$.

Next, note that there exists a $\rho<1$ such that $x_H(p^{''}(0),1-\rho)=0$. Since $p^{''}(\rho)$ is strictly decreasing for $p>1$ and $x_H(p,y)$ decreases with p, there exists a $\rho<1$ for which $x_H(p,1-\rho)=0$, for any $p\le p^{''}(0)$, which is inconsistent with the existence of a high-liquidity equilibrium. Then, since $p^{''}(\rho)$ is strictly decreasing for $p > 1$, there exists a $\hat{\rho}$ such that $p^{''}(\rho) = R_L$, $\forall \rho > \hat{\rho}$.

Finally, if the high-liquidity equilibrium still exists under the liquidity requirement, that both types of agents are strictly worse off with a liquidity requirement is a direct consequence of the externality. Since p is lower with the requirement, agents L, who sell everything, are strictly worse off. Agents H are strictly worse off too because holding cash wastes resources, which strictly shrinks their budget set, and because the price of date-1 consumption becomes higher (since p is lower). Q.E.D.

Appendix B: Lack of Global Strategic Complementarities

In this appendix, I show that increasing cash holdings when they are already high presents strategic *substitutabilities*, which I argue precludes the use of standard equilibrium selection techniques.

A. Strategic Substitutabilities

I show that, when $1 - y \geq \frac{p}{1+p}$, increasing cash holdings further increases the expected transfer and hence the market price. Since an increase in price decreases incentives to increase cash holdings, this establishes the strategic substitutabilities.

Since $1 - y \geq \frac{p}{1+p}$ corresponds to $y < \frac{1}{1+p}$, this implies that $x_H(p, y) = 0$. In that case,

$$\frac{\partial t(p, y)}{\partial y} = (1 - \pi)(R_L - p) \leq 0\ .$$

There are two relevant cases to consider: either $p = R_L$ (which is the case at the low-liquidity equilibrium) or $p > R_L$ (which is the case at the high-liquidity equilibrium but can also happen out of equilibrium).

The interesting case is the latter, because $\frac{\partial t(p,y)}{\partial y} < 0$ implies that an increase in cash holdings (a decrease in y) imposes a positive pecuniary externality. An agent who increases cash holdings decreases the quantity of long-term assets that he invests in. If these turn out to be good, he does not sell them (because $y < \frac{1}{1+p}$); if they turn out to be lemons, he sells them. But the quantity of lemons he sells has decreased. Thus, the expected transfer increases (it is negative but decreases in absolute value). This establishes the strategic substitutabilities. When $p = R_L$, there are only lemons in the market, and an increase in cash holdings does not affect the price.

B. Implications for Equilibrium Selection

In games of strategic complementarities, while multiple equilibria are typical, they are generally not robust to a slight departure from the assumption that agents share a common knowledge of the economic environment. For instance, under global strategic complementarities one can generally use equilibrium selection techniques based on the iterative deletion of dominated strategies, such as global games (Carlsson and van Damme (1993), Frankel, Morris, and Pauzner (2003), Morris and Shin (2004), Vives (2005)). When they concern actions that are outside the relevant range of possible actions, the presence of strategic substitutabilities does not preclude equilibrium uniqueness under incomplete information (Goldstein and Pauzner (2005), Mason and Valentinyi (2010), Bueno de Mesquita (2011)). However, the strategic substitutabilities present in my model concern the relevant range of action. Technically, it can be shown that they imply that best responses to monotonic strategies are not always monotonic, which rules out the single-crossing conditions for uniqueness exploited in Goldstein and Pauzner (2005), Mason and Valentinyi (2010), and Bueno de Mesquita (2011).

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