DISCUSSION PAPER SERIES

DP11803

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FINANCIAL ECONOMICS

ISSN 0265-8003

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Discussion Paper DP11803
Published 25 January 2017
Submitted 25 January 2017

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JEL Classification: E44, G2, O16, O47

Keywords: opacity, cash-in-the-market pricing, Adverse Selection, underinvestment

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Efficient Lemons

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1 Introduction

Several decades of financial development had given the impression of an irreversible trend where assets, financial institutions, and markets are all becoming more transparent and liquid. This is on the back of several changes in the financial system that should have lowered opacity: rapid advances in information technology, a larger and more diverse number of investors that are competing with each other, and financial innovation that can address informational asymmetries. However, the crisis of 2007-2008 has brought a halt to this illusion. During the crisis, many financial assets became illiquid due to their limited transparency - as highlighted, for instance, in Gorton 2010 - and major markets broke down because of asset opacity. In addition, during the crisis, financial institutions suffered from the opacity of balance sheets, which led to failures in some particular cases.

In this paper we study the implications of opacity from a general equilibrium perspective. We consider a simple model where agents can either undertake productive investments or hold cash. A speculative motive for holding cash emerges because asset originators may be subject to liquidity shocks that cause fire-sales in which assets can be acquired below their fundamental value. While individually desirable, the cash-holdings reduce investment at the aggregate and lower welfare. We consider opacity that arises because outsiders have imperfect information about the quality of an asset.

We show that opacity has a welfare impact that is due to the interaction of adverse selection with cash-in-the market pricing (CITMP). In the absence of CITMP, a standard adverse selection property prevails. Originators with inferior assets that are not hit by the liquidity shock have an incentive to sell their assets in the market. Buyers anticipate the existence of low quality asset sales in the market, which reduces prices accordingly. With competitive markets, opacity could neither affect the gains for asset originators nor for liquidity providers (who both anticipate that they may transact at fire-sale prices in the future) and hence leaves the underinvestment unchanged. This is no longer the case with CITMP. Asset prices then reflect liquidity shortages, and not fundamentals. Thus prices do not adjust when the quality of assets supplied to the market deteriorates. Opportunistic selling by agents with low quality assets lowers the ex-ante gains for liquidity suppliers and increases the gains from investing in assets. This mechanism in turn leads to a larger allocation of resources towards productive investment (asset origination) and improves welfare.

The essence of the mechanism is that even though buyers become fully aware that low quality assets are sold in the market with asset opacity, the asset price in the market does not (fully) adjust to reflect this, hence changing the relative benefits from investing and providing liquidity. In a next step we examine the implications for the choice of asset quality (opaque or transparent) by individual agents. Since asset choice has general equilibrium implications, an individual agent does not necessarily have to have the right incentives to source opaque asssets, creating a potential scope for regulation of financial instruments. We consider a setting where an agent can increase the opacity of an asset at a cost, for example, by creating a complex securitization structure. However, despite the fact that opacity choice affects overall investment levels, we find that an agent's opacity choice coincides with the socially efficient one. The reason is that even though an individual agent's opacity choice causes externalities, the agent internalizes the same proportion of the social costs and benefits and hence his optimization problem is not distorted.

While we demonstrate the main results in the most tractable setup, the analysis is extendable to richer settings. For instance, we evaluate the case where liquidity shortages (leading to CITMP) do not occur at every aggregate state of economy. This attenuates the ex-ante effect to the extent that there are less situations with ex-post fire-sales. However, as cash-in-the-market pricing has to occur in at least some aggregate states of the economy (e.g., as in Allen and Gale (1994 and 2005)), the direction of the ex-ante effects stays the same. Furthermore, we also show that when risk-aversion is introduced (our baseline analysis assumes risk-neutrality) opacity turns out to have additional implications - while the benchmark qualitative result on "welfare improving opacity" remains as long as the degree of risk-aversion is sufficiently small: first, since under opacity prices reflect asset quality to a lesser extent, risk-sharing between agents with high and low quality assets improves. Second, opacity leads to a transfer of rents from early to late consumers, which may work to lower welfare.

It should be noted that the key mechanism that we present in this paper is not specific to how we have modeled the underinvestment problem, which in our context arises from speculative liquidity hoarding. Opacity may have similar beneficial effects when underinvestment arises from agency problems (such as from debt overhang). However, what is important is the presence of liquidity shortages that are priced into assets and that make asset prices less sensitive to fundamentals. Thus, our model suggests that the (ex-ante) benefits from opacity arise from situations with liquidity shortages ex-post. In a situation of a forced liquidation with plenty aggregate liquidity available, opacity may be at best neutral, as suggested by standard models. All in all, our model shows that opacity has non-trivial welfare implications that arise when assets are sold under adverse circumstances and that extend beyond the effects that are immediate only to the buyers and sellers of an asset – as the economy's investment efficiency is affected by the degree of financial asset opacity.

There is a small but growing literature on the implications of asset opacity. A significant part of this literature focuses on the relationship between asset opacity and the liquidity of the asset itself - and not aggregate liquidity holdings, as in the present paper. Farhi and Tirole (2013) show that for an asset to be liquid in the financial market the information concerning its quality needs to be symmetric. This means that asset quality should either be known by all agents, or unknown by all agents. Monnet and Quintin (2013) demonstrate that when secondary markets are shallow, more information can reduce the expected payoff of stakeholders who need to liquidate their positions early. Stenzel and Wagner (2014) show that the relationship between opacity and liquidity can be non-monotonic; for highly opaque assets the private cost of acquiring information to make them transparent is large, resulting in a low amount of asymmetric information.

Another part of this literature has focused on the incentives to create or invest in opaque assets. Kaplan (2006) examines a bank's choice of whether to release information about assets at an interim stage. The paper shows that it can be efficient for the bank to commit to keep information secret as the cost of revealing negative information at an interim stage can outweigh the benefits of positive information. Pagano and Volpin (2012) provide a model where releasing information (about securities) can be undesirable as it creates a winner's curse in primary markets. Dang et al (2014) analyze the incentives of banks to invest in opaque assets. They find that in order to prevent information acquisition by investors, it pays for banks to invest in assets with high information costs, that is, opaque assets. Sato (2014) shows that opaque intermediaries invest in opaque assets in order to inflate investors' beliefs about future returns. Also related to this literature, Bolton et al. (2016) investigate a general equilibrium model of occupation choice and show that opaque financial markets make it more attractive to become a financier, which however distorts the allocation efficiency of human capital in the economy. In our paper, investing in opaque assets provides agents with individual benefits as it allows them to trade assets opportunistically in the market; at the same time, however, this also generates social benefits by reducing speculative liquidity holdings.

There is also a long-standing interest in private liquidity choices, and the implications of such decentralized liquidity decisions for the aggregate welfare. The early literature has emphasized that agents have an incentive to underinvest in liquidity – due to the public good character of liquidity (e.g., Bhattacharya and Gale (1986)). However, other papers have also emphasized that liquidity holdings can be excessive. This may be because of a speculative motive as in our model: the possibility to buy assets at fire-sale prices ex-post causes agents to hoard liquidity ex-ante (Acharya, Shin and Yorulmazer (2011), Gale and Yorulmazer (2013)). Alternatively, excessive liquidity hoardings can also arise from market power. In Acharya, Gromb and Yorulmazer (2012) inefficiencies in interbank lending arise due to monopoly power. Banks with liquidity surplus may rationally not provide liquidity to needy banks in the hope that the latter will fail, enabling them to purchase their assets at fire-sale prices. Diamond and Rajan (2011) show how the fear of future fire sales in the banking sector can induce banks with excess liquidity to hold onto cash. In Malherbe (2104) liquidity holdings can become excessive due to an externality that operates through adverse selection: higher (pre-cautionary) liquidity holdings mean that the likelihood of opportunistic trades increases – causing market breakdowns.[1]

The remainder of the paper is organized as follows. Section 2 presents the benchmark model of asset investment under opacity. Section 3 allows for endogenous asset selection (opaque vs. transparent) at the originator level and compares the opacity choice in a decentralized equilibrium against that of a social planner's. Section 4 discusses several extensions. Section 5 concludes.

2 The Model

We investigate an economy with three dates $(0, 1,$ and $2)$. There is a continuum of risk-neutral financiers (*agents*) with unit measure. On date 0, each agent is allocated with 1 unit of a physical endowment, called *cash*. Cash can be consumed on any date and stored costlessly (with a one-to-one rate of return) in-between any two dates. Agents are subject to a random liquidity demand for consumption on date 1. The consumption demand is assumed to arrive - without loss of generality - with probability $\frac{1}{2}$ at the beginning of date 1. Those agents who are hit by the *liquidity shock* value consumption on date 1 only. The remaining agents value date-1 and date-2 consumption equally - though we will concentrate on allocations at which they consume on date-2 only. For the rest of the paper, the date-1 consumers will be referred as "early consumers" or "impatient agents" whereas the date-2 consumers will be called "late consumers" or "patient agents". The date-1 demand for liquidity is private information. Neither impatient nor patient agents value consumption on date 0. The expected life-time utility of an agent is thus given by

$$V = \frac{1}{2}[c_1 + c_2], \tag{1}$$

[1] Our paper also relates to the corporate finance literature which has emphasized underinvestment due to agency problems (e.g., Myers (1977) and Hart and Moore (1988)). The analysis suggests that opacity may alleviate the underinvestment problem, by increasing the private benefits of agents from investing in new assets.

where c_1 and c_2 denote the consumption on date 1 and 2, respectively.[2]

At date 0, each agent can invest a fraction of his cash holding into an (agent-specific) asset. For each unit of cash invested on date 0, the asset pays R on date 2 with probability q with $q \in (0, 1)$, and otherwise zero. The return realizations are idiosyncratic across assets. We assume that the expected return from asset investment is larger than one: $qR > 1$. The assets that pay out on date 2 will be called *high quality* assets and the non-paying assets will be called *low quality* assets. Assets cannot be liquidated at date 1, an assumption we relax in the Appendix.

At the beginning of date 1, information about the date-2 return for each asset arrives. We investigate two different information structures:

(i) *Opaque assets*: only the originator of the asset receives the information about asset quality; and,

(ii) *Transparent assets*: the information about asset quality is public to all agents in the economy.

In this section's analysis, we impose the information structure exogenously (first transparency and then opacity) for the entire asset market and compare the aggregate welfare with transparency to the aggregate welfare implied by opacity. In Section 3, we will allow for an endogenous opacity selection at the asset level, derive the degree of asset opaqueness in the market as an equilibrium outcome and study the aggregate efficiency implications of decentralized opacity decisions.

2.1 Efficient Allocation

We start by characterizing the socially efficient allocation. Specifically, we consider a benevolent social planner who manages the aggregate endowment of cash as well as the aggregate stock of assets in the economy and decides on the allocation of consumption between date 1 and date 2. Let us denote with η the (aggregate) share of funds invested in cash ($1 - \eta$ is then asset investment) and with $\tilde{c}_1$ and $\tilde{c}_2$ the aggregate consumption to be made available on date 1 and date 2, respectively.

Since on date 1 only impatient agents have a consumption demand, and on date 2 only patient agents have a demand for consumption, all consumption made available on date 1 will go to impatient consumers, while date-2 consumption will go to patient consumers - as long as date-1 consumption does not exceed date-2 consumption. Recalling that the consumption levels of impatient and patient

[2] In the Appendix of the paper we relax the assumption of risk-neutrality and transferrability across periods.

investors are c_1 and c_2, we thus have:

$$c_1 = 2\widetilde{c}_1 \text{ and } c_2 = 2\widetilde{c}_2.$$

The social planner solves:

$$\max_{\tilde{c}_1, \tilde{c}_2, \eta} \quad \frac{1}{2}[\tilde{c}_1 + \tilde{c}_2], \tag{2}$$

$$s.t. \quad \tilde{c}_1 \leq \eta, \tag{3}$$

$$\tilde{c}_2 \leq (1-\eta)qR, \tag{4}$$

$$c_1 = 2\widetilde{c}_1, c_2 = 2\widetilde{c}_2, c_1 \leq c_2 \tag{5}$$

Given that we have assumed $qR > 1$, the solution to the planer's problem is to hold zero cash ($\eta = 0$) and to set $\widetilde{c}_1 = 0$ and $\widetilde{c}_2 = qR$. This implies

$$c_1 = 0,$$
$$c_2 = 2qR,$$

and total consumption in the economy is qR. Given linear utility, we therefore have that welfare, i.e. the expected life-time utility of any particular agent, is given by

$$V_{soc} = qR. \tag{6}$$

We would like to note that asset opacity, in other words the nature of the arriving information on date 1, does not have any implication for the socially optimal allocation of the aggregate cash available on date-0. This is because the optimal allocation can be achieved by allocating all assets to patient investors; and, the social planer does not need to know an asset's quality for this.

2.2 Equilibrium

We now consider the decentralized equilibrium in the economy, allowing agents to trade assets in an *asset market* on date 1.[3] The asset market opens for transactions after the realization of liquidity shocks and the arrival of asset-specific news about quality. The timing of events in the economy is summarized in Timeline 1. We focus on competitive equilibria in which agents are (individually) indifferent between investing in cash and assets at date 0, and where markets clear at date 1.

<Timeline 1 about here>

[3] Asset trade improves on autarky by allowing impatient agents to sell their assets to patient investors in exchange for cash.

2.2.1 Transparency

Suppose that all assets are of transparent nature, that is, the arrival of information about asset quality on date 1 is public. In this case, only those assets which are known to pay off on date 2 will be exchanged in the market. We denote the market price of a unit asset with p^{tr} and obtain two standard results about cash-in-the-market pricing.

Lemma 1 *In any competitive equilibrium we have:*

(i) expected returns to hold cash and originate assets are equalized, such that both cash and assets are held: $\eta \in (0, 1)$*,*

(ii) the date-1 asset price p^{tr} *satisfies:* $0 < p^{tr} < R$*.*

Proof (i) Suppose first that we have $\eta = 0$, that is no cash is carried forward to date 1. Consider an investor who deviates from this by holding cash only. If impatient, his consumption on date-1 will be one. If patient, he can use his cash to buy all assets of impatient agents. Thus his expected utility is infinite and hence strictly larger than the utility of other investors, contradicting the notion of an equilibrium.

Suppose next that $\eta = 1$, that is, only cash is held in the economy. The utility of the cash-agents is then simply one (they consume one unit either at date 1 or at date 2). Consider now an agent who invests in an asset on date 0. If impatient, his asset is worthless with probability $1 - q$, while with probability q he can sell it at a price of R (there is an excess supply of liquidity in the market, hence $p^{tr} = R$). If patient, his utility is qR, arising from the expected asset return on date 2. Thus his life-time utility is qR, which is strictly larger than the utility from holding cash only.

(ii) Suppose $p^{tr} = 0$. Cash-holders can then make an infinite return on their holdings of cash, which cannot be possible in equilibrium. Suppose $p^{tr} = R$. In this case, asset holders have a life-time utility of qR, while holders of cash obtain 1, which also cannot occur in an equilibrium. □

The result in Lemma 1 follows from Allen and Gale (1994): Since there is only one aggregate state of the economy in the current context (this feature will be relaxed in the Appendix of the paper), cash-in-the-market pricing binds and determines the asset prices in equilibrium. It follows that on date 1 liquidity is inelastically supplied (since $p^{tr} < R$) and the market clearing condition is given by

$$L_1^d = L_1^s,$$

where L_1^d is the aggregate demand for liquidity and L_1^s is the aggregate supply of liquidity.

We next turn to solving the equilibrium recursively.

Date 2. On the last date of the economy, agents do not have to make choices - except for that patient agents consume their asset returns.

Date 1. On date 1, agents trade in a competitive market, taking as given the aggregate measure of cash holdings that got carried over to date 1 from date 0 (η). Specifically, there will be $\frac{\eta}{2}$ units of cash held by patient agents that can be utilized to purchase high-quality assets from impatient agents. The supply of (high-quality) assets is $(1-\eta)q\frac{1}{2}$. Therefore, the market clearing condition on date 1 implies

$$\underbrace{p^{tr}(1-\eta)q\frac{1}{2}}_{L_1^d} = \underbrace{\eta\frac{1}{2}}_{L_1^s},$$

which yields the following equilibrium price for a high-quality asset

$$p^{tr} = \frac{\eta}{(1-\eta)q}.$$

Note the cash-in-the-market pricing feature of the asset price: the price is determined by the ratio of available cash, η, and the quantity of high quality assets, $(1-\eta)q$, and is thus set irrespective of asset fundamentals.

An impatient asset originator earns p^{tr} on date 1 with probability q. The return to a patient high quality asset originator is R, which also gets realized with probability q. Therefore, the expected life-time value of originating one unit of asset as of date 0 is expressed as

$$E_A = \frac{1}{2}\left[qp^{tr} + qR\right],$$

which after substituting in the asset price becomes

$$E_A = \frac{1}{2}\left[\frac{\eta}{1-\eta} + qR\right]. \tag{7}$$

For an agent who carries over cash to date 1, the unit return on cash equals 1 if the agent turns out to be impatient. A patient agent can buy $\frac{1}{p^{tr}}$ units of the asset on date 1, giving a return of $\frac{R}{p^{tr}}$ on date 2. Hence, the expected life-time return from holding onto one unit of cash until date 1 is expressed as

$$E_C = \frac{1}{2}\left[1 + \frac{R}{p^{tr}}\right].$$

Substituting the market-clearing price p^{tr} this expression gives

$$E_C = \frac{1}{2}\left[1 + \frac{1-\eta}{\eta}qR\right]. \tag{8}$$

Date-0. On date 0, agents decide on their portfolio allocation based on the expected returns from holding onto cash and originating an asset. In the competitive equilibrium, as shown in Lemma 1, the expected returns from holding cash and investing in the asset must be equalized. Solving (7) and (8) together ($E_A = E_C$) yields the equilibrium quantity of cash that gets carried over and the price of transparent assets:

$$\begin{aligned} \eta^{tr} &= \frac{1}{2}, \\ p^{tr} &= \frac{1}{q}. \end{aligned}$$

We obtain for the expected life-time utility:

$$V^{tr}_{market} = E_A = E_C = \frac{1}{2}[qR + 1]. \tag{9}$$

Comparing the expected life-time value of an agent with transparent markets (9) against the expected life-time value under a social planner's regime (6), we can derive the following result.

Proposition 1 $V_{soc} > V^{tr}_{market}$.

Proposition 1 shows that the allocation implied by transparent markets is sub-optimal. The reason is that the opportunity to buy assets at prices below their fundamental value ($p^{tr} < R$) induces investors to hold cash ($\eta^{tr} > 0$). Holding cash however is inefficient due to the assumption of $qR > 1$, hence a lower level of welfare results.

2.2.2 Opacity

We next assume that all assets are of opaque nature. When assets are opaque, the market cannot distinguish between low-quality and high-quality assets on date-1, there is thus a single market for both asset-quality types. The recursive solution is as follows.

Date 1. All impatient investors and patient investors with low quality assets will sell regardless of the market price, whereas patient investors of high quality assets hold onto their assets. As the market prices assets below their expected date-2 return, patient cash holders supply all their liquidity to purchase assets. Likewise, patient sellers of low quality assets will use the liquidity obtained from selling their own assets to acquire new assets in the market.[4]

[4] It is optimal for low-quality patient investors to first sell their own (worthless) to the market and use the proceeds to buy an asset from the market – as the latter has a positive probability of paying out on date 2.

The (gross) supply of liquidity at the date-1 asset market thus comes both from liquidity that has been carried over, and from opportunistic buying of patient agents who sold low quality assets. The total proceeds from selling by the latter group is given by $\frac{1}{2}p^{op}(1-\eta)(1-q)$, thus we obtain for the total liquidity supply:

$$\underbrace{\frac{1}{2}\eta}_{\text{From Date-1}} \quad + \quad \underbrace{\frac{1}{2}p^{op}(1-\eta)(1-q)}_{\text{Re-injected Funds}}.$$

The aggregate supply of assets comes from impatient investors (supplying $\frac{1}{2}(1-\eta)$ in total) and patient investors with low quality assets (supplying $\frac{1}{2}(1-\eta)(1-q)$). Combined this gives a supply of $\frac{1}{2}(1-\eta)(2-q)$. Hence, the market clearing is stated as

$$\underbrace{p^{op}\frac{1}{2}(1-\eta)(2-q)}_{L_1^d} = \underbrace{\frac{1}{2}\eta + \frac{1}{2}p^{op}(1-\eta)(1-q)}_{L_1^s}, \tag{10}$$

which solving for the unit price of an asset yields

$$p^{op} = \frac{\eta}{1-\eta}.$$

Since fractions of high quality assets (supplied by only impatient originators) as well as all low quality assets (supplied by both impatient and patient originators) are sold in the market, the likelihood of purchasing a high quality asset in the market turns out to be $\frac{\frac{1}{2}q}{\frac{1}{2}+\frac{1}{2}(1-q)} = \frac{q}{2-q}$. Therefore, the expected life-time utility generated from investing one unit of cash into an asset on date 0 is

$$\begin{aligned} E_A &= \frac{1}{2}\left[p^{op} + qR + (1-q)p^{op}\frac{q}{2-q}\frac{R}{p^{op}}\right], \\ &= \frac{1}{2}\left[p^{op} + qR\frac{3-2q}{2-q}\right]. \end{aligned}$$

Substituting the price p^{op} this yields:

$$E_A = \frac{1}{2}\left[\frac{\eta}{1-\eta} + qR\frac{3-2q}{2-q}\right]. \tag{11}$$

Remark. For a given aggregate quantity of cash carried over to the date-1 asset market, asset opacity *raises* the expected benefits from originating an asset.

This important property of the model can be appreciated by keeping η fixed and observing that the expected return from originating an asset under transparency ((7)) is larger than the expected return from investment under opacity ((11)). The reason for this property is that opacity gives the originators the chance to replace a low quality asset with a high quality one at date 1. This mechanism has an important general equilibrium welfare implication, as we will see later, because it alleviates the underinvestment inefficiency.

The expected life-time utility from moving forward to date 1 one unit of cash is expressed as

$$E_C = \frac{1}{2}\left[1 + \frac{R\frac{q}{2-q}}{p^{op}}\right],$$

which together with the market clearing implies

$$E_C = \frac{1}{2}\left[1 + qR\frac{1-\eta}{\eta}\frac{1}{2-q}\right]. \tag{12}$$

Date 0. Solving (11) and (12) together, we obtain that the date-0 equilibrium allocation of cash that gets carried over to date 1 fulfils

$$\eta^{op} < \frac{1}{2},$$

and we also observe that the equilibrium price level in the market satisfies

$$p^{op} < \frac{1}{2-q},$$

for the no-arbitrage between E_A and E_C to hold since $qR > 1$.

Therefore, when assets are of opaque nature, the economy carries over less liquidity (cash) from date 0 to date 1 compared to the case of transparent markets. Since asset investment yields higher expected returns than holding liquidity, this means that welfare is higher with opaque assets relative to the case of transparent assets. Of course, since positive quantities of cash get carried over to date 1 (guaranteed by Lemma 1), the aggregate welfare with asset opacity is still lower than the aggregate welfare implied by the planer's allocation.

Proposition 2 $V_{soc} > V^{op}_{market} > V^{tr}_{market}$.

The intuition behind this important result, that establishes the qualitative model feature of *efficient lemons*, can be explained as follows. When assets are opaque, patient investors can opportunistically unload low quality assets at the date-1 asset market. The gains from asset investment thus increase. However, there is no corresponding (offsetting) reduction in the utility of impatient suppliers of high quality, because prices are determined by the available cash in the market and not by the quality of assets supplied. Thus, with asset opacity the returns from investing in assets is higher than the returns to investment with transparency, and hence more investment takes place in an equilibrium with opacity compared to an equilibrium with transparency. The flip-side argument can be made from the perspective of liquidity holders. The return to hold onto cash decreases because on average cash-holders end up buying a higher fraction of worthless assets with the quantity of cash carried over to the date-1 market. Thus the incentive to supply liquidity falls and the aggregate asset investment rises - generating a larger quantity of available consumption for patient agents on date 2.

3 Equilibrium Opacity

We now consider an extension where asset originators individually decide on the "nature of transparency" (opaque vs. transparent) of the originated asset on date 0. This extension allows us to study two questions. First, whether asset opacity can be an equilibrium choice. Second, and more importantly, whether there is any inefficiency associated with decentralized opacity decisions, that is, whether a social planer would choose a different degree of overall market opaqueness compared to individual agents. To this latter end, in principle two sources of inefficiency can arise. First, investing in an opaque asset (as opposed to a transparent one) allows an agent to extract rents from liquidity suppliers who obtain lower quality assets at the date 1 asset market in an equilibrium with high degree of asset opacity. This would suggest that the private benefits from opacity could exceed the social returns. Second, there is a general equilibrium effect, since asset opacity leads to less aggregate liquidity being held, which improves aggregate consumption in the economy - as we discussed above. The two effects thus work in opposite directions. And, an individual agent might not internalize the aggregate consequences of these two effects, suggesting that in equilibrium there could be too little or too much of asset opacity from an aggregate welfare perspective.

The extended setup which incorporates the endogenous asset-opacity choice is as follows. On date 0, at first an agent still chooses whether to hold cash or to originate an asset. Different from the analysis of Section 2, asset originators now also decide whether to make the originated asset opaque (for example, through a complex securitization structure) or leave it as transparent. Creating an opaque asset requires a non-monetary utility cost equivalent of c units of consumption and opacity creation is subject to a stochastic process. Specifically, when the opacity cost is incurred on date 0, the originated asset turns out to be opaque on date 1 with probability α ($\alpha \in (0,1)$). With probability $1-\alpha$, as of date 1 it will be identical to a transparent asset. Therefore, not all of the "ex-ante" opaque assets turn out to become opaque "ex-post". This randomness in opacity creation allows for the coexistence of opaque and transparent assets on date 1 - despite the linear structure of the model. The realization of a particular asset's opaqueness on date 1 is public information. The adjusted timing of events is presented in timeline 2.

<Timeline 2 about here>

We will solve for the equilibrium first and then contrast the private returns to originate opaque assets against the social returns to opacity in order to discuss the efficiency properties of equilibrium opacity. We note that since transparent and opaque assets can now coexist, there are separate markets for (high quality) transparent assets and for opaque assets.

Since we are primarily interested in addressing the question of whether the private opacity decisions of individual agents are socially efficient, we concentrate on parameters for which agents are individually indifferent between opacity and transparency. We then consider a constrained-efficient social planner who can set the degree of opaqueness for all assets in the economy (while leaving all other decisions decentralized) and study whether it can improve the aggregate welfare upon the welfare implied by decentralized opacity decisions.

The recursive solution for the competitive equilibrium is presented as follows.

Date 1. On date 1, a proportion $1-\alpha$ of the ex-ante opaque assets turns out to be transparent. When such assets are of low quality, they are not traded in any market. Hence, the probability of an (ex-post) transparent asset traded in the transparent asset market being of high quality is 1. For an (ex-post) opaque asset the probability of being high quality in the opaque asset market – as before – is $\frac{q}{2-q}$. Absence of arbitrage opportunities between the two markets requires that the relative price of the assets fulfills

$$\frac{p^{tr}}{p^{op}} = \frac{2-q}{q}. \tag{13}$$

Otherwise, opaque assets (the case of $\frac{p^{tr}}{p^{op}} < \frac{2-q}{q}$) or transparent assets (the case of $\frac{p^{tr}}{p^{op}} > \frac{2-q}{q}$) cannot be traded at date 1 markets, neither of which can constitute an equilibrium.

As in our benchmark analysis in Section 2, patient opaque asset originators that have a low quality asset (there is a mass of $(1-\eta)\frac{(1-q)\alpha}{2}$ of such originators) sell their own assets and buy assets sold by other asset originators. This yields the following market clearing on date 1

$$p^{tr}(1-\eta)\frac{q(1-\alpha)}{2} + p^{op}(1-\eta)\frac{(2-q)\alpha}{2} = \eta\frac{1}{2} + p^{op}(1-\eta)\frac{(1-q)\alpha}{2}. \tag{14}$$

Utilizing (13) in (14) solves for p^{op} as

$$p^{op} = \frac{\eta}{(1-\eta)[(2-q)(1-\alpha)+\alpha]}. \tag{15}$$

Date 0. The expected return from an opaque asset can be expressed as the sum of a term that captures the expected return from originating a transparent asset and another term that captures the net benefit from opacity:

$$E_A^{op} = \frac{1}{2}\left[qp^{tr} + qR\right] + \left[\frac{\alpha(1-q)}{2}(\frac{qR}{2-q} - p^{op}) - c\right]. \tag{16}$$

The benefit from opacity, represented by the term $\frac{\alpha(1-q)}{2}(\frac{qR}{2-q} - p^{op})$ in (16), arises because opacity may enable the asset originator to opportunistically sell low quality assets at the date 1 opaque assets market – but this has to be weighed against the date 0 cost of opacity c. The return to holding onto cash is expressed as in Section 2:

$$E_C = \frac{1}{2}\left[1 + \frac{R}{p^{op}}\frac{q}{2-q}\right] = \frac{1}{2}\left[1 + \frac{R}{p^{tr}}\right].$$

We next derive the condition at which - as of date 0 - asset originators are individually indifferent between opacity and transparency. Given that we have a continuum of agents, an individual agent cannot affect the aggregate outcomes. Hence, unilateral deviations of a single agent from the rest of the originators' behavior will not alter the market clearing condition stated at (14). We can therefore express the return from sourcing transparent assets as before:

$$E_A^{tr} = \frac{1}{2}\left[qp^{tr} + qR\right]. \tag{17}$$

Imposing the condition $E_A^{tr} = E_A^{op}$, an asset originator is indifferent between staying transparent and originating an opaque asset if:

$$\frac{\alpha(1-q)}{2}\left(\frac{qR}{2-q} - p^{op}\right) = c. \tag{18}$$

Combining (18) with the equilibrium no-arbitrage condition that keeps agents indifferent between holding cash and originating assets ($E_A^{tr} = E_A^{op} = E_C$) we obtain

$$p^{tr} = \frac{1}{q}, \tag{19}$$

$$p^{op} = \frac{1}{2-q}. \tag{20}$$

Plugging (20) in (18), we derive the configuration of the model's primitives that generates an equilibrium where asset originators are indifferent towards asset types:

$$\frac{\alpha(1-q)}{2(2-q)}(qR-1) = c. \tag{21}$$

From this condition the following result is derived.

Proposition 3 *Agents invest in opacity on date 0 if and only if* $\frac{\alpha(1-q)}{2(2-q)}(qR-1) > c.$

This means if agents are allowed to choose the degree of their asset opacity freely in an environment with relatively low cost opacity creation, a high degree of market opaqueness could prevail. Our model thus can rationalize phenomena such as the creation of complex securitization products prior to the crisis of 2007-2008.

Building upon this insight, we utilize the equilibrium price level of opaque assets that we derived at (20) in (15) and solve for the equilibrium quantity of cash carried forward:

$$\eta^{tr=op} = \frac{(2-q)-\alpha(1-q)}{2(2-q)-\alpha(1-q)}. \tag{22}$$

Given condition (21), the expected utility net of opacity costs when all agents invest in opacity can be derived as:

$$V_{market}^{tr=op} = E_A(p^{op}, p^{tr}) = \frac{1}{2}[1+qR]. \tag{23}$$

Next we investigate whether the equilibrium-opaqueness produced by markets is constrained efficient. Specifically, we compare the (net) expected utility obtained at (23) to the (net) expected utility achieved when a social planner dictates investment in asset opacity on date-0, but leaves agents free to choose the date-0 allocations in terms of holding cash and investing in assets. Specifically, a *social planner* in this current context can be thought as a policy maker, who lets markets clear on date-1 (at equilibrium prices $\{p^{op}, p^{tr}\}$) and by taking equilibrium price adjustments and the cost of investing in opacity as given, decides on whether on date-0 individual agents should be allowed to invest in opacity or not. We know that when there is no investment in opacity, which is equivalent to the case of $\alpha = 0$ in the current context, the equilibrium quantity of cash carried forward from date 0 would be $\eta(\alpha = 0) = \frac{1}{2}$. We also note that with opacity investment on date 0 - we obtain

$$\eta(\alpha > 0) = \frac{(2-q)-\alpha(1-q)}{2(2-q)-\alpha(1-q)} < \eta(\alpha = 0) = \frac{1}{2}$$

for all parameter values, i.e. incurring the cost of opacity when $p^{op} = \frac{1}{2-q}$ and generating opaque assets with probability α raises the aggregate quantity of assets originated on date-0. In order to evaluate the aggregate net benefits (relative to aggregate costs) from letting private agents invest in opacity on date-0, we first derive

$$\begin{aligned} Aggregate\ Benefit\ Opacity &= (\eta(\alpha=0)-\eta(\alpha>0))(qR-1) \\ &= \left(\frac{1}{2} - \frac{(2-q)-\alpha(1-q)}{2(2-q)-\alpha(1-q)}\right)(qR-1) \\ &= \frac{\alpha(1-q)}{2[2(2-q)-\alpha(1-q)]}(qR-1), \end{aligned} \tag{24}$$

where the first multiplicative term on the right-hand-side of (24) is the expansion in the base of the asset origination on date-0 provided by opacity (relative to the case of full transparency) and the second multiplicative term is the net consumption gain from originating an asset. We also derive

$$\begin{aligned} \textit{Aggregate Cost Opacity} &= (1 - \eta(\alpha > 0))\, c \\ &= \frac{2-q}{2(2-q) - \alpha(1-q)} c, \end{aligned} \tag{25}$$

where the first multiplicative term on the right-hand-side of (25) is the total quantity of assets originated and the second multiplicative term is the unit cost of date-0 investment in opacity.

Finally, comparing (24) against (25), we can show that in the aggregate the economy's social planner would be indifferent between letting private agents invest in opacity on date 0 and having the private agents to keep their assets fully transparent - i.e. aggregate benefit of opacity equals to its aggregate cost - if and only if

$$\frac{\alpha(1-q)}{2(2-q)}(qR - 1) = c. \tag{26}$$

We can note that (21) and (26) are identical to each other. Hence, there is no wedge between private returns and social returns to opacity - allowing us to establish the following result.

Proposition 4 *The private and social returns to opacity coincide with each other.*

This an important finding, because it shows that as long as the cost of opacity is not too large, market equilibria would endogenously exhibit opaqueness and such equilibrium opacity is socially efficient. That is, opacity is not only efficient for the aggregate allocations when it is exogenously imposed (as in Section 2), but also when agents are allowed to set asset opaqueness themselves at the individual level, it replicates the constrained efficient outcome of the economy.

As we expressed earlier, there are two different effects of individual agents' opacity decisions that could influence the aggregate welfare, which in principle work in opposite directions: (i) investing in an opaque asset (as opposed to a transparent one) allows an agent to extract rents from liquidity suppliers; and, (ii) there is a general equilibrium effect, since asset opacity leads to less aggregate liquidity being held. Proposition 4 shows that the two effects cancel out in such a way that the markets provide the right amount of opacity. The intuition for this property is related to the no-arbitrage between asset origination and holding onto cash ($E_A = E_C$) dictated by cash-in-the-market pricing determining the asset prices in equilibrium: with cash-in-the-market pricing, the asset prices are pinned down by the no-arbitrage condition and the quantity of cash carried to the date-1 market at such prices gets passively determined. Specifically, the no-arbitrage between holding liquidity and originating assets determining the equilibrium asset prices ensures that any motive of asset originators to source opacity in order to scrutinize liquidity holders would result in a 1-to-1 reduction in asset prices. Since the implication of this mechanism is a general equilibrium contraction in liquidity carried over to date 1, cash-in-the-market pricing aligns the incentives of individual market participants and the social planner when choosing the optimal degree of opacity. Therefore, endogenizing the asset opacity as a choice variable for agents does not alter the aggregate efficiency implications of opacity.

4 Further Extensions

The benchmark analysis has used some simplifying assumptions. First, we have assumed risk-neutral preferences and also that the value of consumption to impatient investors (at date 1) is the same as to patient investors (at date 2). Dispensing with these two features affects the impact of opacity in two ways. First, opacity reduces the variance of prices at which assets can be sold - as the buyer does not know the asset quality, the asset prices will not depend on the assets' idiosyncratic states of nature. This will make opacity more beneficial when agents are risk-averse. Second, when the preference for early consumption is sufficiently large, there is no longer an underinvestment problem. Appendix A analyzes a case of departure from perfectly transferable linear utility and shows that the key results we obtained in Section 2 continue to hold qualitatively.

Second, we have assumed that assets cannot be discontinued on date 1, i.e. the asset scrap value is zero. Introducing scraping creates a benefit to transparency, as transparency allows assets to be discontinued on date 1 when expected asset returns are low. As we show in Appendix B, opacity is welfare optimal as long as the scrap value of assets are sufficiently low.

Third, we have considered a special economy where on date 1 cash-in-the market pricing always occurs. If, for instance, there is some randomness to agents' endowments on date 1, there may also be aggregate states of the economy where cash-in-the market pricing does not occur. The presence of such states will in turn affect the desirability of sourcing opaque assets. Appendix C analyzes this situation, and shows that under a generalized cash-in-the-market pricing framework it is still optimal to have an economy with opaque financial assets as opposed to an economy with transparent assets. The reason is that in states with cash-in-the-market pricing, the utility from asset origination is higher for opaque assets (compared to transparent assets), while in other states, the returns to opacity and transparency are identical. Hence, as long as cash-in-the-market pricing occurs in some aggregate states of the economy, incentives to originate assets are higher under opacity and the key baseline results continue to hold.

Fourth, in Section 3 we have assumed that sourcing opaque assets incurs a cost to the asset originator. Alternatively, there could also be a productivity differential between opaque and transparent assets. This case is considered in Appendix D, where we assume that opaque assets yield lower returns than transparent assets. In this case, opacity can also have costs for the eventual buyers of opaque assets (as they obtain lower return assets). However, as Appendix D shows, the private and the social returns to opacity are still equalized, and hence the same qualitative result as in section 3 is obtained.

5 Conclusion

We have developed a simple framework in order to study the general equilibrium implications of asset opacity. The key result from our analysis shows that asset opacity improves aggregate consumption by spurring investment and diminishing the incentives to hold liquidity for speculative motives. The mechanism rests on the fact that when there are liquidity shortages, asset prices become less sensitive to fundamentals. In particular, in the standard cash-in-the-market pricing model, the price of an asset is determined by an inelastic supply of, and an inelastic demand for, liquidity, and asset fundamentals do not matter. Opacity then allows holders of low quality assets to sell in the market, replenish their asset holdings, and transfers rents away from providers of liquidity. This in turn has ex-ante implications: asset origination becomes more attractive - improving the aggregate welfare of the economy.

The fact that opacity has general equilibrium implications raises the question of whether an agent's choice of asset opacity would be efficient from the perspective of the society. In order to address this question, we have also studied a key extension to the model where – against a cost – agents can turn an investment opaque. We have shown that because of the presence of cash-in-the-market pricing agents internalize the societal costs and benefits of opacity to proportional extents and hence the decentralized opacity choice is efficient. There is thus potentially no rationale for discouraging asset opaqueness.

Taken together, our study has shown that opacity has non-trivial implications that go beyond the immediate impact on buyers and sellers in financial markets, such that asset opacity can affect an economy's overall level of investment and thereby its aggregate welfare. In addition, our analysis demonstrates that in markets which exhibit cash-in-the-market pricing opacity can benefit asset sellers – even when buyers are fully aware of potential adverse selection consequences of asset opacity.

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Appendix

A Non-transferrable Preferences

We investigate the equilibrium consequences of an alternative utility function, which relaxes the perfectly transferable linear utility specification we studied in sections 2 and 3. Following Dang et al. (2014), let us index an early consumer with E and suppose that an early consumer's utility is given by

$$u_E = c_1 + \beta \min\{z, c_1\}, \quad z \in (0,1). \tag{27}$$

For a late consumer (L), we continue to assume

$$u_L = c_2.$$

This alteration has two implications. First, the utility of early consumers exhibits risk aversion. Second, consumption cannot be perfectly transferred to the late consumers without incurring a welfare loss.

Assumption 1. $\beta > qR - 1$.

Assumption 1 implies that the social planner keeps $\eta = \frac{z}{2} < \frac{1}{2}$ units of liquidity until date 1 to compensate early consumers' consumption needs and invests $1 - \eta = 1 - \frac{z}{2}$ units of cash into asset origination. Doing so generates a welfare of

$$V_{soc} = \frac{1}{2}(2 - z)qR + \frac{1}{2}z(1 + \beta),$$

where V_{soc} is the expected utility implied by the social planner's allocation with the alternative preference structure. We start by showing that the equilibrium allocation remains inefficient under transparency. With transparent assets and standard risk neutral preferences, in Section 2 we showed that in equilibrium the aggregate units of cash carried over to date 1 equaled to $\eta^{tr} = \frac{1}{2}$. We first examine whether $\eta^{tr} = \frac{1}{2}$ still constitutes an equilibrium. Plugging in $\eta^{tr} = \frac{1}{2}$ into the expected return functions from originating assets and holding onto cash, we get

$$\begin{aligned} E_A &= \frac{1}{2}\left[q(1+\beta)z + 1 - qz + Rq\right], \\ E_C &= \frac{1}{2}\left[(1+\beta)z + 1 - z + Rq\right], \end{aligned}$$

which yields that $E_C > E_A$. It follows then that in the new equilibrium with alternative preferences, the allocation of cash (η_*^{tr}) should satisfy $\eta_*^{tr} > \frac{1}{2}$, which is larger than the welfare-optimal amount.

The equilibrium with transparent assets thus remains inefficient. The resulting expression for the welfare (expected utility) becomes:

$$V^{tr}_{market} = \underbrace{qR(1-\eta^{tr}_*)}_{c_2 \text{ from asset returns}} \underbrace{+z(1+\beta)\left[\frac{\eta^{tr}_*}{2} + q\left(\frac{1-\eta^{tr}_*}{2}\right)\right]}_{\text{from cash for } c_1 < z} + \underbrace{\left[\eta^{tr}_* - \frac{z}{2}(\eta^{tr}_* + q(1-\eta^{tr}_*))\right]}_{\text{from cash for } c_1 \geq z}.$$

Next we investigate the efficiency of the equilibrium under opacity. Recalling that the equilibrium cash allocation implied by markets in Section 2.2.2 was denoted with η^{op}, two cases arise:

i. $\frac{\eta^{op}}{1-\eta^{op}} > z$,

ii. $\frac{\eta^{op}}{1-\eta^{op}} < z$.

Case i. With $\frac{\eta^{op}}{1-\eta^{op}} > z$, the respective life-time returns from investing in an asset and holding onto cash are expressed as

$$\begin{aligned} E_A &= \frac{1}{2}\left[(1+\beta)z + \frac{\eta^{op}}{1-\eta^{op}} - z + qR\left(\frac{3-2q}{2-q}\right)\right], \\ E_C &= \frac{1}{2}\left[(1+\beta)z + 1 - z + qR\left(\frac{1-\eta^{op}}{\eta^{op}}\right)\left(\frac{1}{2-q}\right)\right], \end{aligned}$$

implying that $E_A = E_C$ and hence the equilibrium allocation of cash with opaque assets continues to equal to η^{op} (which is smaller than $\frac{1}{2}$) under the alternative utility specification. Under case i, the aggregate welfare of the society is then given by

$$V^{op}_{market} = \underbrace{qR(1-\eta^{op})}_{c_2 \text{ from asset returns}} + \underbrace{\frac{z}{2}(1+\beta)}_{\text{from cash for } c_1 < z} + \underbrace{\left(\eta^{op} - \frac{z}{2}\right)}_{\text{from cash for } c_1 \geq z}$$

Case ii. With $\frac{\eta^{op}}{1-\eta^{op}} < z$, the life-time return from investing in an asset and holding onto cash until date 1 are expressed as

$$\begin{aligned} E_A &= \frac{1}{2}\left[(1+\beta)\left(\frac{\eta^{op}}{1-\eta^{op}}\right) + qR\left(\frac{3-2q}{2-q}\right)\right], \\ E_C &= \frac{1}{2}\left[(1+\beta)z + 1 - z + qR\left(\frac{1-\eta^{op}}{\eta^{op}}\right)\left(\frac{1}{2-q}\right)\right], \end{aligned}$$

yielding that $E_A < E_C$. Therefore, if z is sufficiently large, then under the alternative utility specification the cash allocation induced by markets with opaque assets is pinned down by an η^{op}_*, where $\eta^{op} < \eta^{op}_* < \frac{1}{2}$. Under case ii, aggregate welfare is either given by

$$V^{op}_{market} = \underbrace{qR(1-\eta^{op}_*)}_{c_2 \text{ from asset returns}} + \underbrace{\frac{z}{2}(1+\beta)}_{\text{from cash for } c_1 < z} + \underbrace{\left(\eta^{op}_* - \frac{z}{2}\right)}_{\text{from cash for } c_1 \geq z}, \tag{28}$$

or by

$$V^{op}_{market} = \underbrace{qR(1-\eta^{op}_*)}_{c_2 \text{ from asset returns}} + \underbrace{\eta^{op}_*(1+\beta)}_{c_1 \text{ from cash}}, \tag{29}$$

depending on whether in equilibrium $\frac{\eta^{op}_*}{1-\eta^{op}_*} > z$ (the case of equation (28)) or $\frac{\eta^{op}_*}{1-\eta^{op}_*} < z$ (the case of equation (29)).

Proposition 5 *The relative welfare between opacity and transparency have the following properties:*

i. If $\frac{\eta^{op}}{1-\eta^{op}} > z$, $V^{op}_{market} > V^{tr}_{market}$.

ii. If $\frac{\eta^{op}}{1-\eta^{op}} < z$ *and* $\frac{\eta^{op}_*}{1-\eta^{op}_*} > z$, $V^{op}_{market} > V^{tr}_{market}$.

iii. If $\frac{\eta^{op}}{1-\eta^{op}} < z$ *and* $\frac{\eta^{op}_*}{1-\eta^{op}_*} < z$, $V^{op}_{market} > V^{tr}_{market}$ *as long as* $z \leq \hat{z}$, *where* $\hat{z} \in (0, 1)$.

Proof *i and ii. The result follows from the argument that the quantity of cash carried over with transparent assets is inefficiently high and that only a fraction* q *of asset originators who turned out to be impatient could consume. Formally,* $\eta^{tr}_* > \eta^{op} > z$ *and* $q < 1$ *(at i) and* $\eta^{tr}_* > \eta^{op}_* > z$ *(at ii).*

iii. First note that the quantity of cash carried over with transparent assets (η^{tr}_**) is larger than the cash carried over with opaque assets (*η^{op}_**).* $V^{op}_{market} > V^{tr}_{market}$ *if*

$$qR(\eta^{tr}_* - \eta^{op}_*) + \eta^{op}_*(1+\beta) - \eta^{tr}_* > z\beta\left[\frac{\eta^{tr}_*}{2} + q\left(\frac{1-\eta^{tr}_*}{2}\right)\right],$$

where since for $z = 0$ $V^{op}_{market} > V^{tr}_{market}$ *it follows that there exists a* $\hat{z} \in (0, 1)$ *such that for all* $z \leq \hat{z}$ $V^{op}_{market} > V^{tr}_{market}$. *For* $z \in [\hat{z}, 1)$, *whether* $V^{op}_{market} > V^{tr}_{market}$ *or* $V^{op}_{market} < V^{tr}_{market}$ *depends on the parameter constellations.* □

This result shows that the (qualitative results) we obtained in Section 2 regarding the welfare-dominance of opaque assets hold as long as the welfare consequences of foregoing "liquidity demand" of the early consumers are not very high. Intuitively this is because when the preference for early consumption becomes very high, there is no longer an underinvestment problem (investment that pays off at date 2 becomes socially less desirable).

B Asset Reversibility

We now allow for assets to be discontinued on date 1. In particular, we assume that the scrap value of an asset on date 1 is x with $x \in (0, 1)$ in case it is high quality, and zero otherwise.

We consider first the case of transparency. The social planner can now decide (next to the amount of investment on date 0) also whether assets should be scrapped on date 1. On date 1, the continuation value of a high quality asset is R, while its scrapping value is only x. The social planner will hence never scrap - regardless of the nature of arriving information on date 1. The social planner thus allocates exactly the same way as in the benchmark model: it will invest all cash in assets and welfare continues to be expressed as

$$V_{soc} = qR. \tag{30}$$

We now turn to the analysis of the equilibrium. The timing of the various decisions for agents is presented in timeline 3

<Timeline 3 about here>

We show that the decentralized equilibrium in the benchmark model with transparent assets remains an equilibrium with scrapping. The asset price in the baseline model was $p^{tr} = \frac{1}{q}$, which is strictly larger than x. Hence it is never optimal to scrap assets (agents will always prefer to sell instead of scrapping), and we obtain the same outcome as in the baseline model: we have $\eta^{tr} = \frac{1}{2}$ and welfare is given by

$$V_{tr} = \frac{1}{2}[qR + 1].$$

We have $V_{tr} < V_{soc}$ and hence the economy with transparent assets continues to produce a socially inefficient aggregate allocation.

Next we turn to the decentralized equilibrium with opaque assets. There are now two cases to consider, depending on the date-1 price p^{op} in an equilibrium without scrapping: (i) $p^{op} < x$ and (ii) $p^{op} > x$. Consider first $p^{op} < x$. In this case, impatient agents who hold high quality assets would prefer scrapping assets instead of selling them. This implies that only low quality assets would remain on a date 1 market. Trade in the asset market hence breaks down. Since asset transparency generates gains from trade compared to the autarkic state, for x large enough asset transparency turns out to be socially desirable. Consider next $p^{op} > x$. The asset price is now higher than the scrapping value, hence scrapping will not be undertaken by high quality asset holders. The equilibrium in this case will thus remain as in the benchmark analysis without scrapping. We can therefore conclude with the following result.

Proposition 6 *Asset opacity raises welfare as long as the scrap value of assets, x, is sufficiently low.*

C Generalized Cash-in-the-Market Pricing

To relax the special-case cash-in-the-market pricing feature of the baseline model, we consider the following alteration. On date 1 patient agents receive $\tilde{\theta}$ units of cash, which they can utilize to make asset purchases. We assume that $\tilde{\theta}$ is a random variable drawn from a well-behaved distribution function with support $[\bar{\theta}, \underline{\theta}]$ on density $f(\theta)$. The introduction of aggregate uncertainty on date 1 allows for the cases where cash-in-the-market pricing does not apply and where assets are priced according to fundamentals. We assume that $\underline{\theta}$ is sufficiently close to zero, such that in some aggregate states of the economy cash-in-the-market pricing prevails in equilibrium. The adjusted timing of events is presented in Timeline 4.

<Timeline 4 about here.>

The modification in the setup does not alter the social planner's solution (it is still optimal to not carry any liquidity over to date 1: $\eta = 0$). In what follows, we concentrate on comparing the efficiency of the equilibria under transparency and under opacity.

First, we consider transparency. Due to the aggregate uncertainty associated with θ, there is now a distribution of prices at the date-1 asset market - determined as a function of θ, $p(\theta)$. Note that for $\bar{\theta}$ large enough, there could be realizations of θ such that $p(\theta) = R$. This is because for sufficiently large amounts of date-1 cash, there will no longer be cash-in-the market pricing and prices will equal fundamentals. The life-time expected returns from originating assets and carrying over cash can be expressed as follows

$$E_A^{tr} = \frac{1}{2}\left[q\int_{\underline{\theta}}^{\bar{\theta}} p^{tr}(\theta)f(\theta)d\theta + qR + R\int_{\underline{\theta}}^{\bar{\theta}} \frac{\theta f(\theta)}{p^{tr}(\theta)}d\theta\right], \tag{31}$$

$$E_C^{tr} = \frac{1}{2}\left[1 + R\int_{\underline{\theta}}^{\bar{\theta}} \frac{(1+\theta)f(\theta)}{p^{tr}(\theta)}d\theta\right]. \tag{32}$$

Next we turn to the case of opaque assets. The respective expected returns can now be expressed as follows

$$\begin{aligned}
E_A^{op} &= \frac{1}{2}\left[\int_{\underline{\theta}}^{\bar{\theta}} p^{op}(\theta)f(\theta)d\theta + qR + \int_{\underline{\theta}}^{\bar{\theta}} (1-q)p^{op}(\theta)\frac{q}{2-q}\frac{R}{p^{op}(\theta)}f(\theta)d\theta + R\left(\frac{q}{2-q}\right)\int_{\underline{\theta}}^{\bar{\theta}} \frac{\theta f(\theta)}{p^{op}(\theta)}d\theta\right], \\
&= \frac{1}{2}\left[\int_{\underline{\theta}}^{\bar{\theta}} p^{op}(\theta)f(\theta)d\theta + qR\left(\frac{3-2q}{2-q}\right) + R\left(\frac{q}{2-q}\right)\int_{\underline{\theta}}^{\bar{\theta}} \frac{\theta f(\theta)}{p^{op}(\theta)}d\theta\right], \qquad (33)
\end{aligned}$$

$$E_C^{op} = \frac{1}{2}\left[1 + R\left(\frac{q}{2-q}\right)\int_{\underline{\theta}}^{\bar{\theta}} \frac{(1+\theta)f(\theta)}{p^{op}(\theta)}d\theta\right]. \tag{34}$$

Proposition 7 *Under a generalized cash-in-the-market pricing framework, a market-equilibrium with asset opacity has higher aggregate efficiency compared to a market-equilibrium with asset transparency, i.e.* $V^{op}_{market} > V^{tr}_{market}$.

Proof In equilibrium $E^{op}_A = E^{op}_C$ and $E^{tr}_A = E^{tr}_C$ must hold as in the benchmark analysis of Section 2. In order to prove the claim in the proposition C.1 we need to show that $E^{op}_C > E^{tr}_C$ (or $E^{op}_A > E^{tr}_A$). Suppose that $V^{op}_{market} = V^{tr}_{market}$, which implies that

$$E^{op}_C = E^{tr}_C. \tag{35}$$

Using (32) and (34), we can note that the equality (35) would hold if and only if:

$$\int_{\underline{\theta}}^{\overline{\theta}} \frac{1}{p^{op}(\theta)} f(\theta)d\theta + \int_{\underline{\theta}}^{\overline{\theta}} \frac{\theta}{p^{op}(\theta)} f(\theta)d\theta = \frac{2-q}{q}\left[\int_{\underline{\theta}}^{\overline{\theta}} \frac{1}{p^{tr}(\theta)} f(\theta)d\theta + \int_{\underline{\theta}}^{\overline{\theta}} \frac{\theta}{p^{tr}(\theta)} f(\theta)d\theta\right] \tag{36}$$

Next we need to check, when the asset price condition (36) holds, whether the condition $E^{op}_A = E^{tr}_A$ could be satisfied. Using (31) and (33), at asset prices given by (36), the condition $E^{op}_A = E^{tr}_A$ could hold only if

$$\begin{aligned} qR\left(\frac{3-2q}{2-q}\right) - qR &= q\int_{\underline{\theta}}^{\overline{\theta}} p^{tr}(\theta)f(\theta)d\theta - \underbrace{\frac{q}{2-q}\int_{\underline{\theta}}^{\overline{\theta}} p^{tr}(\theta)f(\theta)d\theta}_{=\int_{\underline{\theta}}^{\overline{\theta}} p^{op}(\theta)f(\theta)d\theta}, \\ \Rightarrow qR\left(\frac{1-q}{2-q}\right) &= q\left(\frac{1-q}{2-q}\right)\int_{\underline{\theta}}^{\overline{\theta}} p^{tr}(\theta)f(\theta)d\theta. \end{aligned} \tag{37}$$

As long as $\underline{\theta}$ is not too high (such that cash-in-the-market pricing binds in some states), $E[p^{tr}] = \int_{\underline{\theta}}^{\overline{\theta}} p^{tr}(\theta)f(\theta)d\theta < R$, implying that (37) can never be satisfied. This means that $E^{op}_A > E^{tr}_A$ given the price condition (36) and also that $E^{op}_A > E^{op}_C$. Therefore, in a market-equilibrium with asset opacity

$$\int_{\underline{\theta}}^{\overline{\theta}} \frac{1}{p^{op}(\theta)} f(\theta)d\theta + \int_{\underline{\theta}}^{\overline{\theta}} \frac{\theta}{p^{op}(\theta)} f(\theta)d\theta > \frac{2-q}{q}\left[\int_{\underline{\theta}}^{\overline{\theta}} \frac{1}{p^{tr}(\theta)} f(\theta)d\theta + \int_{\underline{\theta}}^{\overline{\theta}} \frac{\theta}{p^{tr}(\theta)} f(\theta)d\theta\right] \tag{38}$$

should hold in order to ensure the no-arbitrage between originating assets and holding cash ($E^{op}_A = E^{op}_C$). Then, the inequality (38) yields that $E^{op}_C > E^{tr}_C$ (and also $E^{op}_A > E^{tr}_A$) and $V^{op}_{market} > V^{tr}_{market}$. □

The result at Proposition 7 shows that relaxing the degree of cash-in-the-market pricing in the economy does not alter the key qualitative result that the economy with opaque assets is more efficient in its date-0 portfolio allocation compared to an economy with transparent assets.

D Productivity-reducing Opacity

It could be the case that opaque financial assets are also inherently of lesser quality. Such quality differentiation would imply a cost of holding opaque assets, not only for originators but also for purchasers. In order to dig deeper into the implications of this alternative cost structure, let us assume that opacity investment on date 0 results in a "productivity loss" for the originated asset. Specifically, on date 0 an asset originator decides whether as of date 1 he wants to have a fully transparent asset with certainty or an opaque asset with probability α. Different from the analysis in Section 3, there is no cost of originating an opaque asset on date 0 (i.e. $c = 0$); however, if an asset becomes opaque on date 1, it looses its date 2 (high state) return: we assume that the date 2 high-state return of a transparent asset is R^H whereas that of an opaque asset is R^L with $\frac{R^H}{R^L} \equiv \theta > 1$ and $qR^L > 1$. Different from the case of costly origination with an extensive margin lump-sum cost, this alternative structure taxes high-paying assets at the intensive margin. Hence, the current cost structure has the potential of being distortionary. The rest of the model structure remains. The recursive solution is as follows.

Date-1. In this case, the equilibrium no-arbitrage between p^{op} and p^{tr} on date 1 is given by the following:

$$\frac{p^{op}}{p^{tr}} = \frac{q}{2-q}\frac{R^L}{R^H} = \frac{q}{2-q}\frac{1}{\theta}. \tag{39}$$

We utilize the date 1 no-arbitrage condition (39) and express the market clearing on date 1 as

$$p^{op}(1-\eta)\frac{(2-q)\theta(1-\alpha)}{2} + p^{op}(1-\eta)\frac{(2-q)\alpha}{2} = \eta\frac{1}{2} + p^{op}(1-\eta)\frac{(1-q)\alpha}{2}, \tag{40}$$

which solves for p^{op}

$$p^{op} = \frac{\eta}{(1-\eta)[(2-q)\theta(1-\alpha)+\alpha]}. \tag{41}$$

Date-0. Moving on to the individual agents' decision to invest in opaqueness by the time the portfolio choices are made, we can express the value function of originating an asset (with an embedded opacity choice) as

$$E_A = \frac{\alpha}{2}\max\left\{0, \left[qR^L\left[\frac{3-2q}{2-q} - \theta\right] - p^{op}(\theta(2-q)-1)\right]\right\} + \frac{1}{2}\left[qp^{tr} + qR^H\right], \tag{42}$$

where the value of carrying cash forward is

$$E_C = \frac{1}{2}\left[1 + \frac{R^L}{p^{op}}\frac{q}{2-q}\right] = \frac{1}{2}\left[1 + \frac{R^H}{p^{tr}}\right]. \tag{43}$$

We again look for the parameter configurations of the model that would keep the individual asset originator indifferent between investing in opacity and keeping assets fully transparent and then evaluate the aggregate benefits of letting agents to invest in opacity against its aggregate costs for such configurations of the parameter space. An individual agent is indifferent towards opacity as of date 0 if

$$qR^L\left[\frac{3-2q}{2-q}-\theta\right]=p^{op}(\theta(2-q)-1). \tag{44}$$

Since the right hand side is always positive, the condition (44) requires that $\theta \leq \frac{3-2q}{2-q}$ - an assumption that we will keep for the rest of the analysis. We again assume that when an asset originator is indifferent, on date 0 he prefers to invest in opacity. Then, using (44) in the date 0 no-arbitrage condition ($E_A = E_C$) we derive the equilibrium price of opaque assets

$$p^{op}=\frac{1}{2-q}\frac{1}{\theta}, \tag{45}$$

and also the equilibrium price of transparent assets

$$p^{tr}=\frac{1}{q}. \tag{46}$$

We use (46) in (44) to get

$$qR^L=\frac{\theta(2-q)-1}{\theta[(3-2q)-\theta(2-q)]}, \tag{47}$$

which is the full parameter characterization of an individual agent's opacity indifference condition that we sought to express. This yields the following Proposition:

Proposition 8 *Agents invest in opacity on date 0 if and only if* $qR^L > \frac{\theta(2-q)-1}{\theta[(3-2q)-\theta(2-q)]}$.

Finally, (47) in (41) gives

$$\eta(\alpha>0)=\frac{(2-q)\theta-\alpha[(2-q)\theta-1]}{2\theta(2-q)-\alpha[(2-q)\theta-1]}. \tag{48}$$

Similar to the equilibrium opacity analysis from Section 3, we know that when there is no investment in opacity (implying $\alpha = 0$), then the equilibrium quantity of cash carried forward from date-0 would be $\eta(\alpha = 0) = \frac{1}{2}$. We can note that

$$\eta(\alpha>0)=\frac{(2-q)\theta-\alpha[(2-q)\theta-1]}{2\theta(2-q)-\alpha[(2-q)\theta-1]}<\eta(\alpha=0)=\frac{1}{2}$$

for all parameter values, i.e. incurring the expected productivity cost associated with investing in opacity on date 0 and generating opaque assets with probability α raises the aggregate quantity of assets originated on date 0. Given condition (47), the welfare in the economy (expected utility) when all agents invest in opacity is derived as:

$$V^{op}_{market}=E^{op}_A(p^{op},p^{tr})=\frac{1}{2}[1+qR]. \tag{49}$$

We can note that given equilibrium prices derived at (45) and (46), the unilateral deviation of an asset originator to full transparency gives him

$$E_A^{tr} = \frac{1}{2}[qp^{tr} + qR] = \frac{1}{2}[1 + qR], \tag{50}$$

confirming the state of indifference towards opacity.

In order to evaluate the social planner's willingness to allow for opacity (while letting the date 1 asset markets clear), we first observe that the aggregate benefits from opacity result from the expansion of the asset origination on date-0, which gives us:

$$\begin{aligned} Aggregate\ Benefit\ Opacity &= (\eta(\alpha = 0) - \eta(\alpha > 0))\left[\alpha(qR^L - 1) + (1 - \alpha)(qR^H - 1)\right] \\ &= \left(\frac{1}{2} - \frac{(2-q)\theta - \alpha[(2-q)\theta - 1]}{2\theta(2-q) - \alpha[(2-q)\theta - 1]}\right)\left[\alpha(qR^L - 1) + (1-\alpha)(qR^H - 1)\right] \\ &= \frac{\alpha[(2-q)\theta - 1]}{2[2\theta(2-q) - \alpha[(2-q)\theta - 1]]}[qR^L[\alpha + (1-\alpha)\theta] - 1]. \end{aligned} \tag{51}$$

The first multiplicative term on the right-hand-side measures the expansion in the asset base whereas the second multiplicative term is the net consumption benefit for the society for having originated a unit of asset - which takes into account that α fraction of the additional assets will be of "low" quality and $1 - \alpha$ fraction will be of "high" quality.

The aggregate costs on the other hand are associated with the contraction in asset productivity, which we can express as

$$\begin{aligned} Aggregate\ Cost\ Opacity &= (1 - \eta(\alpha = 0))\,\alpha q R^L(\theta - 1) \\ &= \frac{\alpha}{2} q R^L(\theta - 1), \end{aligned} \tag{52}$$

where the first multiplicative term ($\alpha/2$) on the right-hand-side is the total quantity of assets that suffer a productivity loss with opaque asset investment - compared to the case of full transparency - whereas the remaining multiplicative term is productivity loss at the asset level.

Finally, comparing (51) against (52), from an aggregate point of view a social planner would be indifferent towards opacity if the following condition holds:

$$\frac{\alpha[(2-q)\theta - 1]}{2[2\theta(2-q) - \alpha[(2-q)\theta - 1]]}[qR^L[\alpha + (1-\alpha)\theta] - 1] \overbrace{=}^{?} qR^L(\theta - 1). \tag{53}$$

To understand the net social returns to opacity (relative to its private returns), we will investigate whether condition (53) would hold with equality given the level of qR^L that keeps an individual agent indifferent towards opacity (derived at (47)). Therefore, plugging the expression for qR^L from

(47) to both sides of (53), we can evaluate the net aggregate benefits of opacity given parameter configurations of the model that would keep an individual asset originator indifferent towards opacity. Specifically, using (47) in (53), (53) reduces to the following:

$$\frac{[\alpha+(1-\alpha)\theta][(2-q)\theta-1]-\theta[(3-2q)-\theta(2-q)]}{2\theta(2-q)-\alpha[(2-q)\theta-1]} \overbrace{=}^{?} \theta-1. \tag{54}$$

Simplifying the left-hand-side (LHS) of (54) further shows that the LHS expression in fact equals to $\theta - 1$. Hence, aggregate benefits of opacity equal to the aggregate costs of opacity given the parameter conditions (47) that would keep an individual agent indifferent towards opacity.

Proposition 9 *The private and social returns to opacity coincide with each other.*

This result implies that incorporating a productivity loss associated with originating (and holding onto) an opaque asset does not alter the key equilibrium efficiency implication of decentralized opacity decisions of financial market participants.

Date-0	Decision to hold cash versus invest in asset
Date-1	Random liquidity need of agents get realized
	Asset quality becomes known (privately or public)
	Asset markets open
	Impatient agents consume
Date-2	High quality projects pay off
	Patient agents consume

Timeline 1: Benchmark

Date-0	Decision to hold cash versus invest in asset
	Decision to incur opacity cost
Date-1	Random liquidity need of agents get realized
	Assets opacity is realized
	Asset quality becomes known (privately or public)
	Asset markets open
	Impatient agents consume
Date-2	High quality projects pay off
	Patient agents consume

Timeline 2: Opacity Choice

Date-0	Decision to hold cash versus invest in asset
Date-1	Random liquidity need of agents get realized
	Asset quality becomes known (privately or public)
	Decision whether to scrap high quality assets
	Asset markets open
	Impatient agents consume
Date-2	High quality projects pay off
	Patient agents consume

Timeline 3: Asset Scrapping

Date-0	Decision to hold cash versus invest in asset
Date-1	**Cash-flow of patient agents (θ) gets realized**
	Random liquidity need of agents get realized
	Asset quality becomes known (privately or public)
	Asset markets open
	Impatient agents consume
Date-2	High quality projects pay off
	Patiet agents consume

Timeline 4: Aggregate Uncertainty