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Opacity of banks and inefficient bank management: an analysis

Abstract

In absence of risk-taking behavior of banks, opacity is defined as the inability of depositors, speculators and central banker to disentangle default risk and asset return from a signal on the asset's expected value. This paper introduces opacity in the bank-run model proposed by Allen and Gale (1998). The authors show the conditions under which opacity leads to a no-run equilibrium of an insolvent bank and to an inefficient central bank's policy response. The model can be useful to explain how opacity hindered the smooth implementation of the Troubled Asset Relief Program in 2008.

Keywords: opacity, bank runs, central bank intervention, cash-in-market pricing.
JEL Classification: E50, E61, G10, G21.

Introduction

The opacity of banks is conventionally perceived as the inability of an agent to assess the effective risk embodied in a banks' assets portfolio. The difficulty in quantifying risk arises from either the bank's engagement in less-transparent and non-traditional activities (Myers and Rajan, 1995; Morgan, 2002; Wagner, 2007; Brunnermeier and Pedersen, 2009; and Pagano and Volpin, 2012) or from limited accounting disclosures (Cordella and Yeyati, 1998; Estrella, 2004; Shaffer, 2011). In the current literature, asymmetric information and/or moral hazard in the banking sector are typically the prerequisites for the existence of opacity, which may provoke interbank liquidity shortages as shown in Acharya and Skeide (2011)[1] and Acharya and Yorulmazer (2008). Opacity is also closely related to the degree of transparency of accounting standards, as it has been observed during the latest financial crisis: discretionary accounting standards used by banks in their assets' valuation have often been blamed to have amplified the uncertainty on banks' actual solvency status. Indeed, before the crisis, fair value standards[2] were only applied to trading books of banks and to brokerage firms' holdings valuation; illiquid assets were, instead, valued at each bank's discretion using internal accounting models. Such internal models made very hard for outsiders to value the effective risk embodied in some of the banks' assets at the credit crisis outburst.

Doubts on the actual solvency of many banks were further intensified by the interplay of opacity with the lack of markets for *toxic* assets during the crisis, which impeded investors to asses those assets' fundamental values. Many commentators have argued that this interplay between opacity and uncertainty about fundamental valuations has obstructed the smooth implementation of some emergency measures taken by the competent authorities, such as the toxic assets' purchase plan implied by the Troubled Asset Relief Program in the US. Central banks have promptly reacted to tackle this lack of transparency and investors' confidence by publicly disclosing the results of stress tests on banks. These tests allowed investors to uncover the risks embodied in the banks' balance sheets and, thus, to reduce the opacity attached to the banks' assets compositions. For instance, Peristani, Morgan and Savino (2010) describe how the stress tests on the 19 largest US banks conducted by federal bank supervisors in 2009 produced important information for decreasing bank opacity.

Existing literature on opacity features diverging conclusions on its desirability and limited evidence on its consequences, mainly assessed by means of empirical studies.

Some existing theoretical models suggest that a certain degree of opacity might be desirable for certain agents. Cordella and Yeyati (1998) argue that portfolio risk disclosure increases the probability of bank failure when the bank manager does not have control over the volatility of the assets return. In Myers and Rajan (1995) investors are better-off in an opaque banking system, as it allows them to restrain managers in their activities of assets trading and substitution. Wagner (2007) shows that it is optimal for banking managers to be less-transparent, especially during periods of increased financial development. Here, the leveraged capital structure imposed by the bank's owners induces managers to substitute assets, whose risk is better observed given the financial development, with more opaque (riskier) assets. It is, indeed, only with the investment in opaque assets that managers are able to extract some rent, since opacity causes owners to impose a less restrictive capital structure. On the other hand, some empirical works suggest that banks are not more opaque than other firms (Flannery et al., 2012; and Flannery, 2012).

On the consequences of opacity, Cohen et al. (2012) demonstrate that a pattern of opacity in a bank fi-

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[1] The authors study interbank liquidity hoarding and, in extremis, interbank freeze.

[2] In order to assess their 'fair' solvency status, banks should have recognized their marked-to-market losses which imply the unveiling of their opaque balance sheet.

nancial statement has little bearing on downside risk during quiet periods, but it has a big impact during a financial crisis. They show that banks demonstrating greater opacity prior to 2007 exhibit substantially higher risk once the financial crisis begins. Similar results are found by Jones, Lee and Yeager (2012) for the same crisis period.

This paper aims to propose a theoretical framework describing the implications of the existence of opacity for bank runs and central banks' interventions. Our work can be considered as a first attempt to explain in a plain framework some observed facets of the current crisis: runs on a bank whose solvency status is not accurately known, the pricing assets whose fundamental value is imperfectly assessed by borrowing banks the central banker. The contribution of the paper is twofold. Firstly, we introduce opacity in a simple bank-run type model. In this way, we are able to investigate the behavior of depositors when an opaque signal on the banks asset portfolio is observed. Alongside, we model a market for the opaque asset and we analyze how opacity affects the pricing of this asset. Also, we investigate the conditions under which the intervention of a central banker that observes the opaque signal is inefficient. Secondly, we adopt a novel characterization of opacity which does not imply moral hazard or asymmetric information, as found in the existing theoretical models. In this regard, we re-define opacity as the inability of depositors, speculators and central banker to disentangle default risk and assets return from the assets expected return. We abstract from asymmetric information since the bank faces the same uncertainty as the other agents when proposing to depositors a standard deposit contract. The signal on the assets expected returns, which is true and accurate, is determined by the nature and announced by the bank in an intermediate period, when all the agents have the same information set. Moreover, we assume that the contract offered to depositors solves the optimal risk-sharing problem (Allen and Gale, 1998) in which the riskiness of the illiquid asset is irrelevant for the optimal portfolio allocation chosen by the bank. In this way, we are able to abstract from a situation in which the bank has incentives to undertake a moral hazard-type of behavior.

Our task is accomplished through the inclusion of default risk of the risky asset in a modified version to the model of Allen and Gale (1998; 2007). We are able to draw interesting implications of opacity for bank-runs and fire-sale pricing when speculators are risk-averse. We show the conditions under which there is a no-run equilibrium on an insolvent bank. Moreover, we show that opacity leads to uncertainty on the fundamental value of the risky asset when speculators in the asset market are risk-averse. Lastly, we find that the intervention by a central banker might be desirable for depositors since it ensures a fixed level of consumption. However, the intervention will be inefficient with opacity given that the central bank lends either more or less than the bank should be entitled to, given the quality of its assets.

The paper is organized as follows. In section 1 we propose the theoretical framework of the paper in which we define the standard deposit contract offered by the bank to consumers and the asset market in which the risky asset might be traded. Moreover, we specify the information set of the bank, consumers and speculators. Section 2 looks at the risky asset market pricing given the opaque signal sent by the nature in the interim period when speculators are risk-averse. In section 3 we introduce the central banker and analyze the welfare effects for the consumers following an intervention. Section 4 relates the model's findings to the implementation difficulties of the Troubled Asset Relief Program (TARP). The final section concludes the paper.

1. The model

1.1. Framework. The framework comprises a four-periods economy, $t = 0,1,\frac{3}{2},2$, with *one* consumption good (withdrawals). The agents in this framework are: *one* representative risk-neutral bank, a continuum of rational depositors/consumers and speculators. In section 3 we will introduce the central banker.

1.1.1. Depositors. Depositors are uninsured with initial endowment E normalized to 1, i.e. $E = 1$. They will deposit all their endowment in $t = 0$ at the bank, which offers them insurance against idiosyncratic liquidity shock[1]. Indeed, at period 0, depositors do not know when they will be hit by an idiosyncratic liquidity shock: with probability μ a given consumer will be withdrawing C_1 at $t = 1$, thus, being early consumer, and with probability $1-\mu$ he will withdraw C_2 in $t = 2$, being a late consumer. Ex-ante, the size of μ is publicly known, however, each consumer does not know which type (early/late) he will be at $t = 1$. The continuum of depositors is normalized to one such that μ is the proportion of early consumers. The utility arising from the consumption of each type in each period is described by a concave and continuous consumers' utility function $u(C_t)$.

[1] The bank invests on behalf of consumers given its expertise in recognizing valuable risky assets. Deposits allow consumers that are hit in the last date by a liquidity shock to enjoy the return of the investment made by the bank. Depositors that are hit by the liquidity shock in the earlier period are assured a given level of consumption.

1.1.2. The bank. At $t = 0$ the bank issues demand deposit liabilities equal to one unit of consumption, collecting the whole consumers' endowment. The bank operates in a competitive market, maximizing the expected utility of consumers.

At date 0 the bank can invest the deposits in a safe and in a risky asset. The safe asset, y, is in variable supply and can be considered as a storage technology. Its price at $t = 0$ is normalized to one. y can be liquidated at no cost both at $t = 1$ and at $t = 2$ and has a risk-free gross return equal to 1. The amount of investment in risky asset is denoted as x and is such that $x + y = 1$. x is in fixed supply in $t = 0$ and yields a random return R only in $t = 2$. In $t = 2$ R yields R^h with probability p or zero with probability $1 - p$.

1.1.3. Information set of the bank and consumers. At $t = 0$ and $t = 1$ both the bank and the consumers face the same uncertainty regarding the random variable R. More specifically, they do not know both the probability density function of R and the exact value that R might take in the good state, that is, R^h.

Therefore, these agents in $t = 0$ and $t = 1$ know that in $t = 2$ R yields $\tilde{R}^h$ with probability p^i or zero with probability $1 - p^i$, where $i = l, h$. If $p = p^l$ then, the asset carries a high default risk; if $p = p^h$ then, the default risk is low. The probability p allows us to model the default risk of the risky asset, which is equal to $1 - p^i$. $p = p^h$ with probability α, while $p = p^l$ occurs with probability $1 - \alpha$. R^h is also a random variable which is assumed to be distributed according to a normal distribution with mean R^h and finite variance σ_{Rh}. The distribution of R^h is ex-ante common knowledge.

We further assume that $E[R] > 1$; this implies that investment in risky asset dominates in terms of expected value the investment in storage technology.

1.1.4. The deposit contract. The bank offers non-state contingent contracts that allow depositors to withdraw their funds on demand in either $t = 1$ or $t = 2$.

The bank promises a fixed level of consumptions $C_1 = \bar{c}$ to early consumers and $C_2 \geq \bar{c}$ to late consumers. If it is infeasible to give at least $\bar{c}$ to all consumers then there is risky asset liquidation and pro-rata distribution among all depositors. The size of $\bar{c}$ is computed from a state-contingent Optimal Risk-Sharing Problem (ORSP) where no asset liquidation takes place. The equilibrium allocations are fully state-contingent: i.e. the bank does not have to declare bankruptcy whenever the value of its assets falls below a certain threshold. That is, $\bar{c}$ is equivalent to the equilibrium level of state-contingent early consumption $C_1(R)$ that solves the ORSP. $C_2(R)$ is, instead, the state-contingent consumption level of late consumers. Although consumption levels are dependent on R, the portfolio choices by the bank in $t = 0$ solving the ORSP are not a function of R. Indeed, since there is aggregate uncertainty in both the return and of its probability density function of the risky asset, the optimal risk sharing problem will yield an optimal portfolio choice (y^*, x^*) which is independent of R, R^h and of the probabilities attached to it.

The ORSP can be formalized as follows (see Allen and Gale (1998) for details):

$$\underset{x,y}{Max}\ E[\mu U(C_1) + (1-\mu)U(C_2)] \qquad \text{(ORSP)}$$

subject to:

$$y + x \leq 1,$$

$$\mu C_1(R) \leq y,$$

$$\mu C_1(R) + (1-\mu)C_2(R) \leq y + Rx.$$

The solution to the above problem (y^*, x^*) will determine the consumption levels of early and late consumers. In particular, the bank will promise $\bar{c}$ to early consumers such that:

$$C_1 = \bar{c} = \frac{y^*}{\mu}. \qquad (1)$$

Late consumers will receive:

$$C_2 = \frac{Rx^*}{1-\mu}. \qquad (2)$$

In the benchmark, model aggregate uncertainty only concerns the return on the risky asset and is accurately revealed at $t = 1$; there, runs only happen on a truly insolvent banks[1] (i.e. when R is low enough so that $C_2 < \bar{c}$). However, as we will show in section 3, our stochastic structure of p and R^h yields to different implications for the run decisions of consumers, as it causes uncertainty on the size of C_2 (i.e. equation (2) is not accurately observed).

1.1.4. Speculators and asset market. There exists an asset market in which the bank can liquidate the risky asset in the intermediate period $t = 1$ whenever the withdraw of early consumers exceeds y^*. In this market there are some identical speculators that will want to purchase the risky asset whenever speculative profits can be made, i.e. when its price falls below its fundamental value. Speculators hold some of the safe asset, y_s, which will be exchanged for

[1] Throughout the paper, we refer to insolvent bank as a bank which is not able to guarantee at least c to all consumers.

the risky asset at a fire-sale price. This price will be determined by the size of y_s. The market price (cash-in-market pricing) will be:

$$P_x = \frac{y_s}{x^*}. \quad (3)$$

It must be the case that $y_s < y^*$ for liquidation in the asset market to ever take place (see proof 1 in the Appendix).

1.1.5. Information set of speculators. We assume that speculators have the same information set of banks and consumers. However, the size of y_s is speculator's private information in $t = 1$: it is publicly revealed only if cash in market pricing takes place after than a run has occurred. Before any asset market liquidation takes place, the beliefs of the bank and the consumers on the size of y_s are the same and follow a uniform distributions on $[y^s_{\min}, y^*)$ with $y^s_{\min} \neq 0$:

$$y_s \sim U[y^s_{\min}, y^*). \quad (4)$$

1.2. Timing, signal and runs on a solvent bank. *1.2.1. Timing and signal*. In the previous section we have outlined the uncertainty regarding p^i and R^h faced by all agents in the model in both $t = 0$ and $t = 1$. The main implication of the above framework is that *late* consumers before deciding whether to run, can only observe the expected value of their level of consumption in the final period, i.e. C_2. That is, they can work out the expected value of their consumption if no run takes place, which equal to:

$$E[C_2] = \frac{E[R]x^*}{1-\mu} = \frac{\bar{R}^h x^*}{1-\mu}(\alpha p^h + (1-\alpha)p^l). \quad (5)$$

However, we assume that in $t = 1$ the nature reveals a true and accurate signal on the expected value of the risky asset. That is,

$$\varphi = E[R] = pR^h. \quad (6)$$

The main implication of the above opaque signal is that depositors cannot assess with certainty how much of the observed ϕ is due to default risk or asset return.

Definition: An accurate signal on the assets expected return is opaque because it does not enable agents to disentangle default risk and assets return.

The uncertainty regarding p^i and R^h is solved in $t = \frac{3}{2}$ while the uncertainty regarding whether R is R^h or *zero* is solved in the last period, $t = 2$. Therefore, the expected no-run consumption of late consumers in $t = 0$ and $t = 1$ becomes:

$$E[C_2] = \frac{\varphi x^*}{1-\mu}. \quad (7)$$

Late consumers, imposing $\mu = 1 - \mu$, will run only if the following condition holds:

$$E[C_2] < \bar{c} \quad (8)$$

that is, if:

$$\varphi < \frac{y^*}{x^*}. \quad (9)$$

Since $\phi > 1$ then it must also be that a run can only occur when $y^* > x^*$. Clearly, sufficiently low values of ϕ can imply very opposite outcomes: very high returns associated with very high default risk or very low returns and low default risk.

If condition (8) holds, then, the run will cause costly liquidation on the asset market. As stated in the previous section, when consumers decide to run they do not know the exact size of y_s and so what the market price will be in case of liquidation. While formal asset pricing is derived in the following section, we summarize the timing of the framework in Figure 1.

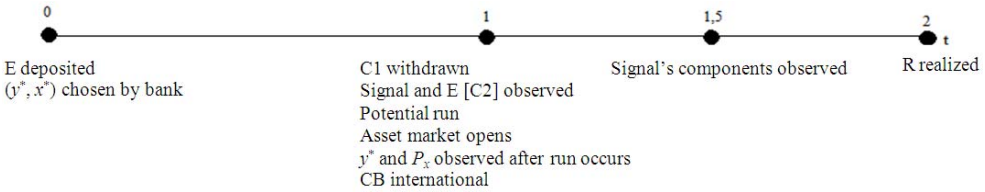

Fig. 1. Timing of the model

1.2.2. Inefficient runs. In this section we illustrate the main implications following an opaque signal in a simple framework which disregards how much depositors would obtain in the event of fire-sale (the market for asset liquidation is formally modeled in section 2).

The problem of runs dictated by the expected values of future consumptions is mainly that there can be equilibriums in which a run has occurred on what turns out to be a solvent bank and equilibriums in which a run did not happen on what turns out to be an insolvent bank. In particular, for a given portfolio

choice of the bank, (y^*, x^*), inefficient runs will depend on the sizes of $\widetilde{R}^h$. For each observed signal ϕ (i.e. ex-post), $\widetilde{R}^h$ can be either R^{hl} or R^{hh}, such that $\phi = p^h R^{hl}$ with probability α and $\phi = p^l R^{hh}$ with probability $1-\alpha$.

Let's firstly assume that $\phi < \frac{y^*}{x^*}$ so that a run occurs and the bank liquidates the risky asset. When default risk is low ($\alpha = 1$)[1] and the good state of the world unveils in $t = 2$ ($p^i = p^h = 1$) the bank is solvent if:

$$R^{hl} > \frac{y^*}{x^*} \tag{10}$$

or, if:

$$\varphi < \frac{y^*}{x^*} < R^{hl}. \tag{11}$$

Therefore, when the ratio $\frac{y^*}{x^*}$ satisfies (11), then the ϕ observed will induce late consumers to run on the bank, which would have been solvent in $t = 2$ if no costly liquidation would have taken place in the interim period and if the good state of the world materialized with low default risk.

Now we consider the no-run case in which the observed ϕ satisfies $\phi > \frac{y^*}{x^*}$. In this case, there can be in equilibrium the event that a run does not happen on a bank that turns out to be insolvent in the good state of the world (i.e. $E[C_2] < \bar{c}$). In particular, this happens whenever ϕ is low enough, such that $\phi \to 1$, but it is still greater than R^{hl}. Indeed, given that the bank is insolvent whenever $R^{hl} < \frac{y^*}{x^*}$ and the no-run condition implies $\phi > \frac{y^*}{x^*}$, then, whenever the following condition applies:

$$R^{hl} < \frac{y^*}{x^*} < \phi \tag{12}$$

there can be a no-run equilibrium for an insolvent bank. Therefore, the following proposition can be formalized.

Proposition 1: In the presence of an opaque signal such that $\phi \to 1$ and $\phi < \frac{y^*}{x^*}$, there might be in equilibrium a run on a bank which turns out to be solvent if the good state of the world materializes and low default risk unveils. This will occur whenever $R^{hl} > \frac{y^*}{x^*}$. In this state of the world, however, there might be a no-run equilibrium (i.e. for $\phi > \frac{y^*}{x^*}$) on a bank which is insolvent. This would happen whenever ϕ is low enough and $R^{hl} < \phi$.

[1] We are implicitly assuming that $R^{hh} x^* > y^*$.

2. Risky asset market pricing

2.1. Risk-neutral speculators. In this section we consider the pricing of the risky asset in the market when identical speculators are risk-neutral. If at date 1 the bank receives a higher level of withdraws than its available liquidity promised to early consumers, then, it is obliged by its contract terms to liquidate x and distribute all its assets on a pro-rate basis to all consumers.

The speculators in this market will observe the signal ϕ before carrying out any purchase of the risky asset. In particular, the signal $\phi = E[R]$ will perfectly reflect the fundamental value of the asset, given the risk neutrality of speculators. Indeed, the risk-neutrality of these agents implies that their spending decisions are not affected by the default risk or the relative return implied in the signal. Speculators, then, once observed ϕ will purchase the risky asset if its market price, P_x, is below its fundamental value, i.e. ϕ.

The pricing in the market happens through a cash-in-market mechanism (Allen and Gale, 1998). That is, since speculators will want to exchange all their safe asset for the risky ones, given $\phi > 1$, then the price of the risky asset will simply be the ratio of the safe asset of the speculators, y_s, to the risky asset of the bank, x^*. In other words, it is the amount of safe asset, readily exchangeable to cash, to determine the market price of the risky asset. However, speculators will only buy if speculative profits can be made, that is, if y_s in their hands is such that prices are below fundamentals, that is:

$$P_x = \frac{y_s}{x^*} \leq E(R) = \varphi. \tag{13}$$

Given that (8) must hold, in order to a run to ever occur, then it must be that speculators will purchase the risky asset whenever the observed signal satisfies the following condition:

$$\frac{y_s}{x^*} \leq \varphi \leq \frac{y^*}{x^*}. \tag{14}$$

The associated consumption levels will be:

$$C_1 = C_2 = \frac{y^* + y_s}{2}. \tag{15}$$

Figures 2 and 3 (in Appendix) depict the asset market pricing of the risky asset and the (expected and actual) late consumption levels for all signal levels respectively.

In Figure 2 it can be seen that for $\phi < \frac{y_s}{x^*}$ there does not exist a market for the risky asset as speculators are not willing to buy the risky asset. In this case, as shown in Figure 3, early and late consumers share equally the available safe asset in the bank's portfolio, i.e. y^*. It is clearly seen from the pictures that when (14) is satisfied, then the late (realized) consumption level is specified in (15). For high enough signals, i.e. $\phi > \frac{y^*}{x^*}$, then no run occurs and expected late consumption, as perceived in $t = 1$, is equal to $E[C_2] = \phi x^*$.

2.2. Risk-averse speculators. In this section we relax the assumption of risk-neutrality of speculators, by assuming that they are risk-averse. The main implication of this modified setting is that the observed signal ϕ does not reveal anymore the fundamental value of the risky asset, which is perceived as the discounted expected return of the asset. Therefore, speculators now face uncertainty regarding the intrinsic value of the asset. Indeed, now the fundamental value has to reflect the default premia that speculators require to take on more risk. At date 1, if the risky asset has a higher default risk, i.e. $p^i = p^l$, then its fundamental value will be lower than the fundamental value of the asset with the lower default risk, i.e. $p^i = p^l$. The fundamental values of the asset in each state of the world can be written as:

$$F_v^h = \frac{E(R)}{1+\pi^l}, \tag{16}$$

$$F_v^l = \frac{E(R)}{1+\pi^h}, \tag{17}$$

where π^l and π^h are the discounts which reflect the default premium of the asset in each state with $\pi^h > \pi^l$. Given $F_v^h > F_v^l$, F_v^h is the fundamental value of the asset for which $\phi = p^h R^{hl}$ is true; while F_v^l is the fundamental value of the asset for which $\phi = p^l R^{hh}$ is true.

Speculators, will buy the risky asset only if (8) occurs and if the two conditions below are satisfied:

$$E(F_v) = \alpha F_v^h + (1-\alpha) F_v^l > 1, \tag{18}$$

$$P_x = \frac{y_s}{x} < E(F_v). \tag{19}$$

Condition (18) implies that the expected fundamental value corresponding to the observed ϕ has a gross return higher than that of the safe asset. Equation (19), instead, states that the liquidity (safe asset, y_s) in the hands of speculators has to be such that the market price of the risky asset is less than the expected fundamental value. Indeed, buying only if $\frac{y_s}{x} < F_v^l$, would prevent speculators to make potential speculative profits if $F_v^l < \frac{y_s}{x} < E(F_v)$. Solving (19) with respect to ϕ, we find that:

$$\theta \frac{y_s}{x} < \varphi, \tag{20}$$

where:

$$\theta = \frac{1}{\psi} = \frac{1}{\frac{\alpha}{1+\pi^l} + \frac{(1-\alpha)}{1+\pi^h}} > 1. \tag{21}$$

Combining equations (8) with (20), we find that the buy-condition for risk-averse speculators is:

$$\theta \frac{y_s}{x^*} < \phi \le \frac{y^*}{x^*} \tag{22}$$

or

$$\frac{y_s'}{x^*} < \phi \le \frac{y^*}{x^*} \tag{23}$$

with $\theta y_s = y_s'$.

The market price of the risky asset, if speculators but, is always $\frac{y_s}{x}$. However, now, contrarily to what seen in the previous section, there is the chance that speculators might not make speculative profits. Figures 4 and 5 (in Appendix) show how this might occur in $t = \frac{3}{2}$. Figure 4 shows what happens when speculators hold a larger amount of y_s. If speculators purchase the risky asset (as condition (23) holds for an observed ϕ), then, at a market price $P_x = \frac{y_s}{x}$ speculative profits will be made only if uncertainty unveils in $t = \frac{3}{2}$ that $\phi = p^h R^{hl}$ (i.e. so that $F_v = F_v^h$). If in $t = \frac{3}{2}$, however, turns out that $\phi = p^l R^{hh}$, then, the asset has been overpriced by the cash-in-market mechanism, i.e. speculators have paid too much for the risky asset. If, instead, y_s held by speculator is lower, as depicted in Figure 5, then speculative profits can be made even if uncertainty unveils in $t = \frac{3}{2}$ that $\phi = p^l R^{hh}$ (i.e. $F_v = F_v^l$) given that the signal is at least s. If, instead, the signal is such that $\frac{y_s'}{x^*} < \phi \le s$, then, again speculators have paid too much for the risky asset. It is worth noting that a buying strategy for speculators which implies buying if $s < \phi \le \frac{y^*}{x^*}$ is not desirable since it would preclude speculators to make considerable profits if $F_v = F_v^h$.

The last case should also be considered; that is, the possibility that the safe asset in the hands of specu-

lators could be so low that they would make speculative profits whatever the signal. In this case, the market prices would be smaller than the so-far considered cases and speculators will price the risky asset at a price lower than F_v^l for all signal in the interval $\frac{y_s'}{x^*} < \phi \leq \frac{y^*}{x^*}$. If there is no central banker's intervention, late consumers will be better-off the higher y_s in the speculators' portfolio, given that it is proportional to market price paid for the asset.

Given that, as stated in section 1.1.5, the beliefs of consumers on the size of y_s follow a uniform distribution on $[y_{\min}^s, y^*)$ with $y_{\min}^s \neq 0$, the expected late consumption in case of liquidation depends on y_s and in $t = 1$ is equal to:

$$E[C_2] = \int_{y_{\min}^s}^{y^*} \frac{y_s}{y^* - y_{\min}^s} dy^s = \frac{y^* + y_{\min}^s}{2}. \quad (24)$$

Proposition 2 below formalizes the above findings.

Proposition 2: With risk-averse speculators, an opaque signal causes uncertainty on the fundamental value of the risky asset in $t = 1$. When speculators hold enough safe asset they may overprice the risky asset if the nature unveils a state of the world with high default risk in $t = \frac{3}{2}$. In this instance, late consumers are better-off than if the safe asset in the hands of speculators was lower. Therefore, consumers benefit at the speculators' expenses from speculators' higher amounts of safe asset holdings with higher default risk.

3. Central banker's intervention

In this section we consider the welfare effects of an intervention by the central banker. In particular, the intervention considered here recalls the several policies to support asset-markets, as often observed during crisis times: most notably, the TARP during the Subprime crisis for the US and the European Central Bank's sovereign bond purchase during the European Sovereign Debt Crisis.

We assume that the central bank has an exogenous initial endowment of cash equal to E_b, which might be lent to the bank if a net gain can be made. The central banker in this model has the same information set of consumers. That is, he observes the signal ϕ at t = 1. Depending on the market price of the risky asset, whenever, a bank run occurs, the central banker might decide to intervene in order to sustain asset prices. If intervenes, he enters a repurchase agreement with the bank in which he purchase the risky asset. The price paid for the risky asset in the repo agreement is equal to its fundamental if investors are risk-neutral. If, instead, investors are risk-averse then the central bank faces uncertainty on the fundamental value of the risky asset and might over/under price the asset. The terms of the repurchase agreement oblige the bank to re-pay the central banker in t = 2 whatever it gets from the risky asset. The central banker will enter the repo agreement only if its expected net gain is greater than zero:

$$E[NG^{cb}] = \varphi x^* - M[\alpha(1 - p^h) + (1 - \alpha)(1 - p^l)] > 0, \quad (25)$$

where $M = P^s x^*$ is the price paid by the central banker to the bank for the purchase of the risky asset at the support price P^s. The social optimality of the central banker's intervention, whenever (25) holds, depends on the risk-attitude of speculators and on the liquidity they hold, as we show in the following sections.

If the fundamental value of the risky asset is uncertain, then, it becomes more problematic for the central bank to pursue an intervention aimed to support fundamental prices. Reasonably, the central banker's intervention when there is opacity in fundamental values will be such that (1) consumers get more than they would do from the cash-in-market pricing and (2) the expected net gain of the central banker are maximized. The risky asset price that the central bank will support is, thus, dependent on these two conditions. However, it will on a first place depend on the cash-in-market price in the asset's market which is determined by y_s. Indeed, a *one-fits-all* policy that sustains prices at the expected fundamental level (i.e. $P^s = E(F_v)$ for $\forall\ \phi < \frac{y^*}{x^*}$) could decrease the expected net gains of the central bank. Let's see this in more details.

Let's assume, for simplicity, that the central bank has three possible intervention strategies. That is, it can lend to the bank either M_1, M_2 or M_3:

$$M_1 = E(F_v)x^*, \quad (26)$$

$$M_2 = F_v^h x^*, \quad (27)$$

$$M_3 = F_v^l x^*. \quad (28)$$

The corresponding expected net gains are:

$$E[NG_1^{cb}] = x^*(\varphi - E(F_v))[\alpha(1-p^h) + (1-\alpha)(1-p^l)]\}, \quad (29)$$

$$E[NG_2^{cb}] = x^*(\varphi - F_v^h)[\alpha(1-p^h) + (1-\alpha)(1-p^l)]\}, \quad (30)$$

$$E[NG_3^{cb}] = x^*(\varphi - F_v^l)[\alpha(1-p^h) + (1-\alpha)(1-p^l)]\}. \quad (31)$$

Given that $\phi > E(F_v)$, $\phi > F_v^i$ and that $0 \leq \alpha(1-p^h) + (1-\alpha)(1-p^l) \leq 1$ then it must be that:

$$E[NG_3^{cb}] < E[NG_1^{cb}] < E[NG_2^{cb}]. \quad (32)$$

Also note that equations (29), (30) and (31) are all greater than zero $\forall\varphi$, therefore, the central banker always wishes to intervene and lend to the bank.

3.1. Intervention and liquidity. If the risk-averse speculators hold abundant levels of y_s in their portfolio, as described in Figure 4, as we have already seen, they will make speculative profits only if he fundamental value turns out to be high (low default risk) when $\frac{y_s'}{x^*} < \phi \leq \frac{y^*}{x^*}$. Sustaining asset price to low fundamental values, i.e. $P^s = F_v^l$ and $M_3 = F_v^l x^*$, although maximizes the expected net gain of the central banker, would not be a sustainable intervention. This is because early and late consumers would get less than if speculators were purchasing the asset, that is:

$$\frac{y^* + y_s}{2} > \frac{y^* + F_v^l x^*}{2}. \tag{33}$$

Therefore, when $\frac{y_s'}{x^*} < \phi \leq \frac{y^*}{x^*}$ the central bank will support prices to its expected fundamental values since $E[NG_3^{cb}] < E[NG_1^{cb}]$. The actual consumption level is, thus:

$$C_1 = C_2 = \frac{y^* + E[F_v]x^*}{2}. \tag{34}$$

However, when the signal is low enough so that no market for the risky asset exists, that is, when $\phi < \frac{y_s'}{x^*}$, then the central banker can support prices to low fundamental values, that is $P^s = F_v^l$. In this case, early and late consumers will get more than if they were sharing equally the available y^*:

$$C_1 = C_2 = \frac{y^* + F_v^l x^*}{2} > \frac{y^*}{2}. \tag{35}$$

The pricing of the risky asset with central bank's intervention and high levels of y_s is depicted in Figure 6 (in Appendix).

A central banker's intervention of this kind (i.e. with opacity) can cause inefficient asset pricing, that is, asset pricing different from fundamentals. Indeed, when the signal is very low such as $\phi < \frac{y_s'}{x^*}$ the central bank might underprice the asset, lending to the bank less than it should have received if in $t = \frac{3}{2}$ it occurs that $\phi = p^h R^{hl}$ (so that $F_v = F_v^h$). For higher levels of the signals such that $\frac{y_s'}{x^*} < \phi \leq \frac{y^*}{x^*}$ the central bank is surely either overpricing or under-pricing the asset. In other words, the central bank is lending either more or less than the bank should be entitled to, given the quality of its assets.

If speculators hold relatively low levels of safe asset as in Figure 5, we have already shown that there exists a boundary signal s which determines two different outcomes for speculators. If the signal is such that $s < \phi \leq \frac{y^*}{x^*}$, then, speculative profits can be made whatever the fundamental value unveils (although clearly F_v^h is associated with higher profits). If, instead, the signal is such that $\frac{y_s'}{x^*} < \phi \leq s$ then again speculators make profits only if the default risk attached to the asset is low, that is, if $F_v = F_v^h$.

The central banker, thus, will adopt three different intervention strategies, depending on the observed signal. If there is no market for the risky asset as $\phi < \frac{y_s'}{x^*}$, as before, the central banker will support prices to F_v^l, lending to the bank M_3 and achieving the consumption levels as in equation (39). If the signal is such that $\frac{y_s'}{x^*} < \phi \leq s$ then, for the same reasoning as in the previous section, the central banker lends M_1 to the bank. If, instead, $s < \phi \leq \frac{y^*}{x^*}$ then the central bank will maximize its expected net gain by lending M_3 to the bank, which implies $P^s = F_v^l$ with the following consumption levels:

$$C_1 = C_2 = \frac{y^* + F_v^l x^*}{2} > \frac{y^* + y_s}{2}. \tag{36}$$

The pricing of the risky asset with central bank's intervention and low levels of y_s is depicted in Figure 7 (in Appendix).

The safe asset in the hands of speculators, however, could be so low that they would make speculative profits whatever the signal (in this case the signal s would not exist). In this case, clearly the central bank would support the prices of the asset at its low fundamental value.

4. Model predictions and public interventions during the subprime crisis

Our model can be used to explain why some government or central bank's interventions to sustain asset prices during the subprime crisis did not attain the expected results. For instance, the uncertainty about the fair price of risky assets in the US has hindered the full implementation of the TARP (Troubled Asset Relief Program) in 2008. The Treasury's inability to price toxic assets to be bought from banks had led to the introduction of a more successful plan aimed to let private investors discover the fair price of these complex assets (namely the Public-Private Investment Program, PPIP). In particular, the TARP introduced by US authorities in 2008 involved among other things the purchase of toxic assets from banks and the resale of these same securities to sustain their market prices. The main difficulty encountered by the Treasury in the implementation of this plan, was, however, related on

how to set the purchasing price of the toxic asset. Indeed, a price too low would have not helped the banks to recover from their financial fragility but a price too high would have deterred any investor to purchase these assets in the market resale and would have been too much of a burden for taxpayers. Even the proposal of a reverse auction process for price determination was not satisfactory as sale prices set by the market would have been too low for the policy to effectively save banks out from insolvency. Therefore, in the first year of the TARP, the first tranche of TARP funds ($350 billion) was mainly employed to rescue banks via capital injections, rather than through toxic asset repurchase. In March 2009 was then introduced the Public-Private Investment Program (PIPP), a plan directly aimed to restore liquidity and prices in the market of toxic assets through the investments of private investors. In order to stimulate private investors to purchase these assets the government has granted funding to investors who could have bought as much as $500 billion of toxic assets. The main idea behind this plan is that leaving private investors trading these complexes assets can lead to a fairer price discovery and thus avoid mispricing by the government. This plan has proved to be more viable than its antecedent: after 3 years since its beginning the total market value of both non-agency residential and commercial MBS held by the funds reached 72% and 28% of the portfolio holdings in the two types of assets respectively.

Conclusions

In this paper we study opacity in a simple model in which a representative bank, solving an optimal risk-sharing problem, is subject to runs by depositors. Opacity is modeled through the inclusion of unobservable default risk on the bank's portfolio, as well as unobservable return on the risky asset. The inability of the agents to distinguish between the two, given a signal sent by the nature on their product, has many interesting implications. Firstly, we show that run decisions based on expected consumption levels can cause a run on a solvent bank or no-runs on an insolvent bank. Secondly, we model the asset market pricing that occurs through a cash-in-market mechanism. In this regard, we stress that opacity leads to uncertainty on the fundamental value of the risky asset when speculators in the asset market are risk-averse. Lastly, we analyze the welfare implications of a central banker's intervention which is unable to prevent the run but ensures a fixed level of consumption higher than if speculators were purchasing the asset during a run. The central banker, with the aim to minimize its loss function, will be very likely to enter a repo agreement with the bank by offering a price for the risky asset equal to the lowest fundamental level that it can take. Therefore, opacity can cause inefficient policy responses: this is because the central bank lends either more or less than the bank should be entitled to, given the quality of its assets. During the recent crisis, this lack of transparency on assets provoked the impaired implementation of the asset repurchase plan within the Troubled Asset Relief Program in the US. As recommendations, we invoke for various types of public interventions such as mandatory standards, provision of liquidity to distress banks or secondary market support, as suggested in Pagano and Volpin (2012).

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Appendix

Proof 1. Given the optimal allocations of the ORSP: $C_1 = \overline{c} = \frac{y^*}{\mu}$ and $C_2 = \frac{Rx^*}{1-\mu}$, for simplicity we assume that $\mu = 1-\mu$ so that $C_1 = \overline{c} = y^*$ and $C_2 = Rx^*$. A run will occur whenever $y^* > Rx^*$, that is, when $\frac{y^*}{x^*} > R$ where *R* is the asset's fundamental value. Let's now assume that $y_s > y^*$, which implies that in the case of asset liquidation the market price would be: $P_x = \frac{y_s}{x^*} > \frac{y^*}{x^*} = R$. However, for a market price higher than the fundamental value no purchase of the risky asset by speculators will take place.

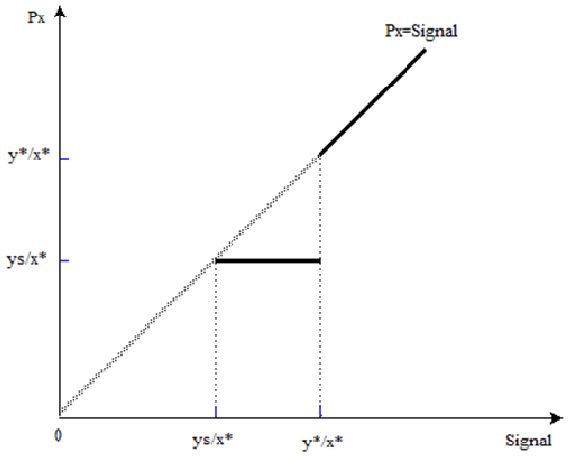


Fig. 2. Risky asset pricing and observed signal with risk-neutral speculators (without central banker's intervention)

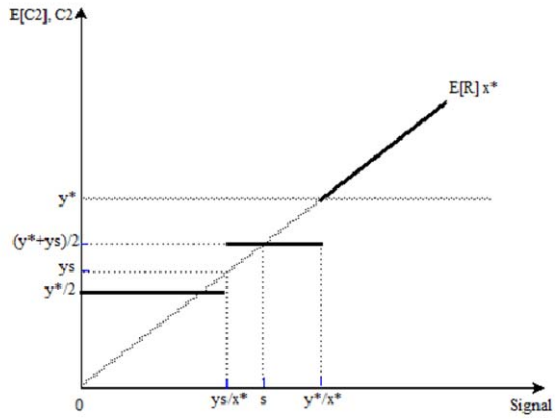
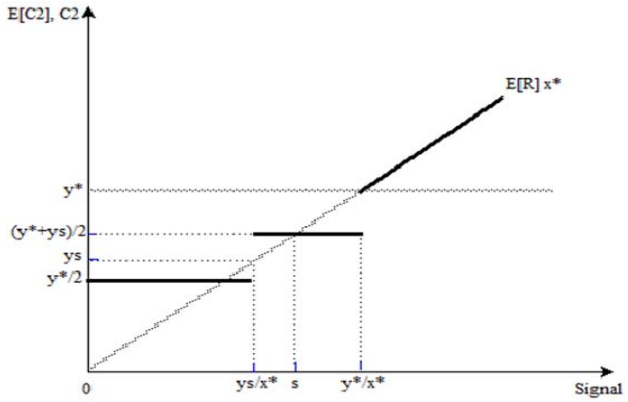


Fig. 3. Expected late consumption and observed signal with risk-neutral speculators (without central banker's intervention)

A bank run associated with speculators purchase of the risky asset occurs if the observed signal at date 1 is such that $\frac{y_s}{x^*} \le \phi \le \frac{y^*}{x^*}$. Realized late consumption in this case is equal to $C_2 = \frac{y^*+y_s}{2}$. It is easily seen that at this consumption level, late consumers receive more than they would have got if they did not run if $\frac{y_s}{x^*} \le \phi \le s = \frac{y^*+y_s}{2x^*}$. Otherwise (i.e. if $s \le \phi \le \frac{y^*}{x^*}$) late consumers would have received more if they did not run and cash-in-market pricing did not take place, even

if $E[C_2] < y^*$. Indeed, recall that when a run takes place, consumers are unaware of the size of y_s. When the signal is so low that speculators are not willing to buy, i.e. $\phi \leq \frac{y_s}{x^*}$, the bank will share equally among early and late consumers the available y^*. Also in this case, late consumers might have received more if they did not run, in particular as $\phi \to \frac{y_s}{x^*}$.



Note: $\frac{y's}{x^*} = \theta \frac{y_s}{x^*}$.

Fig. 4. Buying decision and observed signal with risk-averse speculators – high levels of y_s

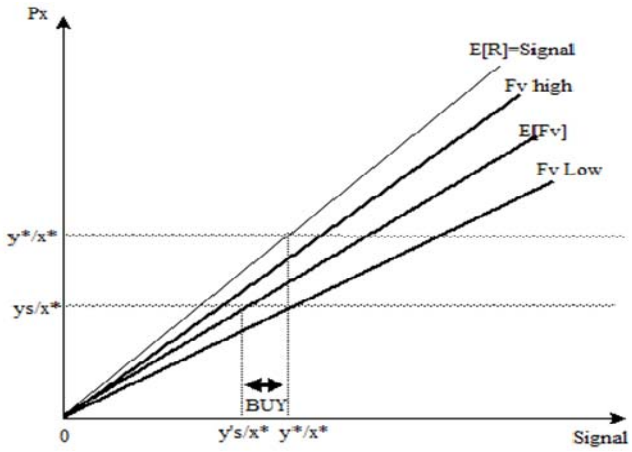


Fig. 5. Buying decision and observed signal with risk-averse speculators – low levels of y_s

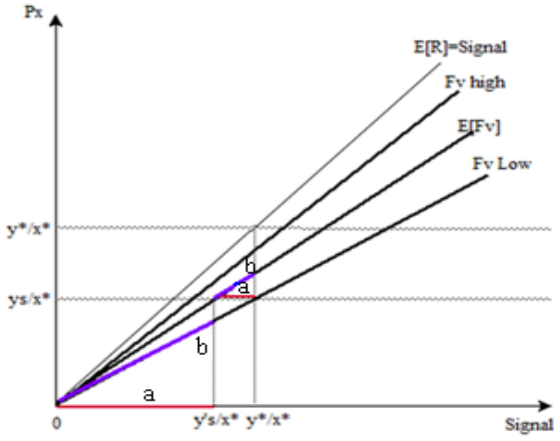


Fig. 6. Risky asset pricing and observed signal with risk-averse speculators (with central banker's intervention) – high levels of y_s

a-lines refer to asset market pricing without intervention. That is, when $\phi < \frac{y_s'}{x^*}$ there is no market for the risky asset; when $\frac{y_s'}{x^*} < \phi \leq \frac{y^*}{x^*}$ there is cash-in-market asset pricing. In the former case, the central bank will support prices to low fundamentals (*b*-line). In the latter case, it will support prices to expected fundamental values (*b*-line).

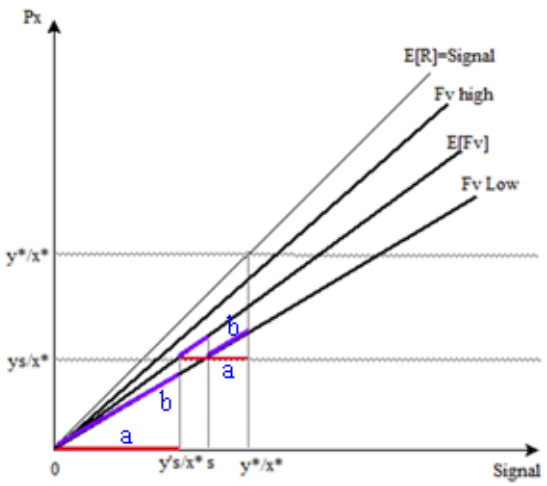


Fig. 7. Risky asset pricing and observed signal with risk-averse speculators (with central banker's intervention) – low levels of y_s

a-lines refer to asset market pricing without intervention. That is, when $\phi < \frac{y_s'}{x^*}$ there is no market for the risky asset; when $\frac{y_s'}{x^*} < \phi \leq \frac{y^*}{x^*}$ there is cash-in-market asset pricing. In the former case, the central bank will support prices to low fundamentals (*b*-line). When $\frac{y_s'}{x^*} < \phi \leq s$ the central banker supports prices at expected fundamental values (*b*-line). When $s < \phi \leq \frac{y^*}{x^*}$ the central bank supports prices to low fundamentals (*b*-line).