The Dark Side of Bank Wholesale Funding

Rocco Huang — *Philadelphia Fed*

Lev Ratnovski — *IMF*

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Abstract

Commercial banks increasingly use short-term wholesale funds to supplement traditional retail deposits. Existing literature mainly points to the "bright side" of wholesale funding: sophisticated financiers through monitoring discipline bad banks and refinance solvent ones. This paper models a "dark side" of wholesale funding. In an environment with a costless but imprecise signal on bank project quality (e.g. market prices, credit ratings), short-term wholesale financiers have lower incentives to conduct costly information acquisition, and instead may withdraw based on negative but noisy public signals, triggering inefficient liquidations. We show that the "dark side" of wholesale funding dominates when bank assets are more arm's length and tradable (leading to more relevant public signals and lower liquidation costs): precisely the attributes of a modern banking system with securitizations and risk transfers. The results shed light on the recent financial turmoil, explaining why some wholesale financiers did not provide market discipline ex-ante and exacerbated liquidity risks ex-post.

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1 Introduction

Commercial banks increasingly use short-term wholesale funds to supplement traditional retail deposits (Feldman and Schmidt, 2001). The retail deposits-based funding model is under strain due to intense competition for household savings from alternative investment institutions (mutual funds, life insurance products, etc.). In response to funding shortage, banks tap into wholesale funding markets to attract liquidity surpluses of other financial institutions, non-financial corporations, state and local authorities, and foreign entities. Such wholesale funds are usually raised on a short-term rollover basis with instruments such as Fed Funds, repurchase agreements (repos), large-denomination certificate of deposit (Jumbo CDs), interbank deposits, commercial paper (CP), etc.

How would this change in funding structure affect banks' performance and risks? The existing literature mainly points to the "bright side" of wholesale funding: more fully exploiting valuable investment opportunities without being constrained by the local deposit supply; the ability of wholesale financiers to provide market discipline (Calomiris, 1999) and to refinance unexpected retail withdrawals (Goodfriend and King, 1998).

However, the credit market turmoil that started in 2007 revealed a "dark side" of wholesale funding. Banks can use wholesale funds to aggressively expand lending and compromise credit quality, particularly when financiers exercise insufficient market discipline. Later, at the refinancing stage, there is a risk of wholesale financiers abruptly withdrawing upon a hint of negative news, triggering inefficient liquidations. When wholesale withdrawals follow a market-wide signal, correlated bank failures exacerbate systemic risk.

This paper attempts to reconcile the traditional view on the virtues of wholesale funding with the recent experience. We suggest that wholesale funding is beneficial when informed, but exacerbates inefficiencies and can create severe liquidity risks when uninformed. We then ask:

- What are the incentives for short-term wholesale financiers to invest in the acquisition of information on bank project quality?

- What are the incentives for wholesale financiers at the refinancing stage to roll-over funding or to force a bank into liquidation, particularly if they are uninformed?
- What are the optimal contractual arrangements for short-term wholesale funds (e.g. their creditor seniority vis-a-vis long-term funds, such as core retail deposits)?
- What are the private incentives for banks to use short-term wholesale funds, and could they diverge from socially optimal ones?

We consider a bank that finances a risky long-term project with two sources of funds: retail deposits and wholesale funds. Retail deposits are sluggish, insensitive to risks (partly because they are insured), and provide a relatively stable source of long-term funding.[1] Wholesale funds are relatively sophisticated and have capacity to acquire information on bank project quality. However they are short-term: provided on a rollover basis and have to be refinanced before final returns realize or the bank will be forced into liquidation.

Our modelling approach is based on Calomiris and Kahn (1991, CK). We take CK as a benchmark of the "bright side" of wholesale funding. CK show that "sophisticated" wholesale financiers add value through their capacity to monitor banks and to impose market discipline (force liquidations) on loss-making ones. Moreover, CK show that monitoring incentives of wholesale financiers are maximized when they are senior at refinancing stage, because it allows them to internalize the benefits of monitoring (payoffs in early liquidations).

[1] The "sluggishness" of retail deposits is a well-established stylized fact (Feldman and Schmidt, 2001; Song and Thakor, 2007). Retail deposits are typically insured by the government. Their withdrawals are motivated mostly by individual depositors' liquidity needs and thus are predictable based on the law of large numbers. Although some accounts are formally demandable, retail deposits are "sluggish" because of the transaction services retail depositors recieved from the banks and the high switching costs (Sharpe, 1997; Kim, Kliger, and Vale, 2003). They therefore provide a relatively stable source of long-term funds. However, the local retail deposit base is considered quasi-fixed in size, as it is prohibitively expensive to expand it in the medium term (Flannery 1982; Billett and Garfinkel, 2004). When the deposit supply is not sufficient to fund all available investment opportunities, banks can choose to attract, in addition, wholesale funds from sophisticated institutional investors.

Note that, in practice, short-term wholesale funds indeed enjoy de facto (effective) seniority thanks to the first-come–first-served sequential service rule and the sluggishness of the insured retail depositors. This was the main reason why in almost all recent bank failures (e.g. Continental Illinois, Northern Rock, IndyMac) short-term wholesale financiers were able to exit well ahead of retail depositors without incurring significant losses for themselves. Interestingly, the well-publicized retail depositor run on Northern Rock took place only after the bank had already nearly exhausted its liquid assets to pay off the exit of short-term wholesale funds.[2]

We then introduce into the benchmark CK model a single novel feature: *a costless but noisy* public signal on bank project quality. This represents public information that wholesale financiers are capable of processing costlessly and that is noisy proxy for bank-specific fundamentals. Examples include secondary market prices or credit ratings for traded assets (e.g. mortgage-backed securities), performance of other similar banks, or various market- or sector-wide indicators (e.g. house or energy prices). Wholesale financiers may use the public signal when costly private monitoring did not produce sufficiently precise information on bank fundamentals (because of either low investment in monitoring or merely bad luck).

We show that such a minor and plausible change to the CK setup can dramatically alter its predictions in a manner consistent with the "dark side" of wholesale funding. The presence of a costless but noisy signal:

- Lowers the incentives of wholesale financiers to monitor;
- Gives wholesale financiers excess incentives to liquidate banks basing on overly noisy public information; and
- Importantly, those distortions become stronger when wholesale financiers are *more*

[2] Marino and Bennett (1999) analyze six major bank failures in the US between 1984 and 1992 and find that uninsured large deposits fell significantly relative to small insured deposits prior to failures. During the New England banking crisis, failing banks experienced a 70 percent decline in their uninsured deposits in their final two years of operation while being able to raise insured deposits to replace the outflow. Billett, Garfinkel, and O'Neal (1998) also find that bank typically raised their use of insured deposits vis-a-vis wholesale deposits after being downgraded by the Moody's.

senior claimants to the liquidated assets – sharply contrasting with CK results.

The mechanism of these effects is that, absent a noisy public signal, uninformed wholesale financiers always roll over funding at the intermediate stage as banks are on average solvent (no news is good news). However, with the availability of a noisy public signal, wholesale financiers uninformed about bank-specific fundamentals can now choose to liquidate a bank based solely on a negative but possibly very noisy public signal.

The key inefficiency is that the incentives of wholesale financiers to liquidate based on noisy information can be too high compared to the socially optimal ones, particularly when they are de facto senior claimants on the liquidation value. Upon liquidation, senior wholesale financiers can obtain a larger share of a reduced bank asset pie, at the expense of providers of long-term funds such as passive core depositors. As a second-order effect, when wholesale financiers anticipate a high likelihood of an early liquidation with a safe exit, they become less interested in acquiring fundamental information on bank project quality in the first place.

Therefore, in the presence of a noisy public signal, higher effective seniority of short-term wholesale funds has two effects. One, in line with CK, is the positive first-order effect that awards monitoring and market discipline efforts. Another, a novel one, is the negative effect that increases the payoff to liquidating banks based on overly noisy information. The socially optimal seniority of short-term wholesale funds must therefore trade-off the two offsetting effects. We find that such welfare-maximizing seniority has an interior optimum. While the monitoring incentives of wholesale financiers increase in seniority for low values of seniority (the CK effect), they decrease for higher values of seniority when higher seniority translates purely into more liquidations. Deviations from that interior optimum to either side result in less monitoring and possibly more inefficient liquidations. This result contrasts sharply with the CK benchmark in which higher seniority for the sophisticated funds is always better.

The precision of the noisy public signal (i.e., the probability that it is correct) is one of the key parameters of the model. Its one interpretation is the availability of relevant public information on individual bank performance. This may vary across banks depending e.g. on asset type. For example, while the secondary market prices of mortgage-backed securities (MBS) or house price changes can shed some light on the fundamentals of a typical mortgage bank holding mainly arm's length assets, few similarly relevant public signals exist for traditional banks that hold mainly relationship-based small business loans. The signal precision can also be interpreted as the correlation between an individual bank's fundamentals with system-wide outcomes or indicators. With the proliferation of "risk transfer" and "risk dispersion" mechanisms, individual bank performances have become increasingly correlated, so that public signals now provide more relevant information on an individual bank's performance. Note however that, in any case, these costless public signals can only provide imperfect information on an individual bank's true asset quality.[3]

Our results reveal that the incentives for short-term wholesale financiers to liquidate strategically based on a noisy negative signal are *higher*, and therefore the welfare-maximizing seniority of wholesale funds (that compensates for excess liquidation incentives) is *lower*, when:

- *The noisy public signal is more precise*, yet not as precise as to make liquidation decisions based on it socially optimal;
- *The share of passive deposits in bank liabilities is higher*. Interestingly, the seemingly safe buffer of long-term funds provided by passive retail depositors in fact makes early liquidations less costly for wholesale financiers and discourages them from information acquisition efforts;
- *Liquidation value of bank assets is higher*. Liquidation value relates to bank's cash holdings and marketability of its long-term assets. By conventional wisdom, a

[3]For example, while falling energy prices and close business relationship with the failed Penn Square Bank correctly predicted the insolvency of Continental Illinois, the linking of Northern Rock to developments in the U.S. subprime mortgage market did not do justice to the bank which in fact had no material exposures.

higher liquidity buffer should better protect a bank against larger withdrawals. However, in our setup higher liquidation value has detrimental incentive effects: it lowers the cost of early liquidations for wholesale financiers and increases the probability of inefficient "noisy" liquidations.

- *Interest rate offered to wholesale financiers in case of success is lower.* Interest rate offered to competitive wholesale financiers reflects the return on alternative use of money; it is lower e.g. in times of abundant liquidity supply. When the interest rate is lower, wholesale financiers have less to gain if a project succeeds in the long term. This encourages early liquidation.

In a bank cross-section, these predictions suggest that the use of senior short-term funds is beneficial in "traditional" banks that hold mainly opaque and non-tradeable relationship loans, consistenty with the "bright side" predictions of CK. Yet the "dark side" negative effects are likely to dominate in banks with large exposures to arm's length assets with readily available public information, particularly when short-term wholesale financiers are senior claimants.[4] However, importantly, private incentives would in fact drive arm's length banks towards actively using senior short-term wholesale funds: we show that interest rates demanded by wholesale financiers are lower when assets are marketable and public signals are available. Therefore, CK's insights best apply to the traditional relationship banking business with limited public information on asset quality, while our model sheds light on the new banking business characterized by arm's length transactions, high inter-bank correlations, and the availability of relevant public signals such as market prices and credit ratings.

To sum up, we show that higher seniority for wholesale funds is not always socially beneficial. In the presence of a costless but noisy signal on bank quality, higher seniority can in fact reduce monitoring and encourage inefficient liquidations. Social welfare is constrained-maximized for an intermediate level of seniority, depending on the bank's

[4] Note that banks holding securitized assets (e.g. MBS) appear particularly vulnerable to the risk of premature liquidations: trading of assets provides a public signal on quality, and also raises their liquidated value.

funding structure (i.e. share of passive retail deposits on the liability side), the precision of public signals on bank project quality (which often depends on the type of assets held), liquidation value of bank assets, and interest rates offered to wholesale financiers. This is a novel result that usefully contrasts with CK and bears close resemblance to recent developments in the credit market, as well as some earlier instances of bank failures. It reveals the "dark" side of short-term wholesale funding, particularly when its providers are senior claimants.

The rest of the paper is structured as follows. Section 2 sets up the benchmark CK-type model of "bright side" of wholesale bank funding. Section 3 introduces the costless but noisy signal on bank project quality and models the "dark side" of wholesale bank funding. Section 4 provides a discussion of our results. Section 5 concludes.

2 The Bright Side of Wholesale Funding

We start by outlining a version of the Calomiris and Kahn (1991) model. We use it to describe a benchmark "bright side" of bank wholesale funding. (We will use the same model with minor alterations in later sections to describe a "dark side" of wholesale funding.)

We demonstrate a number of key effects. First, the use of wholesale funds allows banks to expand the volume of lending beyond constraints of the fixed local depositor base. Second, wholesale financiers have the capacity to monitor banks and, if informed, exert welfare-enhancing market discipline: roll over funding to good banks but force liquidation of bad ones. Third, the monitoring incentives of wholesale financiers are maximized when they are senior creditors in early liquidations: this allows to internalize the benefits of monitoring. Finally, and importantly, profit-maximizing private choices of banks and wholesale financiers are consistent with constrained-optimal outcomes: banks choose a maximum possible amount of wholesale funds and make them senior, to which wholesale financiers respond by monitoring and providing market discipline.

2.1 Model

Consider an economy with three dates: $0, 1, 2$. The economy consists of a bank (with access to an investment project) and two types of bank financiers: retail and wholesale. Everyone is risk-neutral and there is no discounting.

The project A bank has exclusive access to a profitable but risky long-term project. For each unit invested at date 0, the project returns at date 2: X with probability p or 0 with probability $1 - p$. The project has a positive net present value: $Xp > 1$. The project may also be liquidated at date 1 returning $L < 1$ per unit initially invested. The maximum investment size is 1.

Funding The bank has no initial capital and needs to borrow in order to invest. There are two types of financiers:

1. "*Retail depositors*" are unsophisticated lenders: they never get advance information on date 2 project realization. Retail depositors are passive: they never withdraw before date 2. Therefore, despite being formally demandable, retail deposits provide a source of long-term funds for the bank. The key limitation is that retail deposits are scarce: the bank is endowed with a fixed deposit base of $D < 1$. The interest rate payable on retail deposits (date 0 to date 2) is fixed at R_D: $1 \leq R_D < pX$.

   This model does not distinguish non-depository long-term funds (e.g. long-term debt). Rather, we consider them jointly under the label of retail deposits. We can do so because the key properties of retail deposits and other long-term funds are similar. Firstly, long-term funds are also scarce. Secondly, the interest rate on long-term funds is often fixed before the bank makes any other funding or investment decisions (e.g. the bank attracts long-term funds before date 0 when it is not able to commit to any future course of action). Therefore, from the perspective of date 0 and further, we can take the interest rate payable on all long-term funds as fixed.

2. "*Wholesale financiers*" are sophisticated and can monitor the bank at a cost. The monitoring technology will be specified in detail shortly. The key is that, when monitoring is successful, it produces information on date 2 realization before date 1. That information can therefore be used in making roll over decisions.

   Wholesale financiers are willing to lend to the bank any amount of funds at date 0 against real expected return ρ. Parameter ρ reflects the return on alternative use of wholesale financier's money, and can be interpreted as funding liquidity conditions. The bank's project is more valuable than alternatives, so that initial funding is always available: $1 \leq \rho < pX$.

   The amount of wholesale funding attracted by the bank is denoted W. Wholesale funding is short-term and needs to be refinanced at date 1. If wholesale financiers refuse to roll over, the bank is forced into liquidation. The nominal interest rate on wholesale funding is denoted R. We assume that R is set from date 0 to date 2. This allows to avoid hold up by wholesale financiers at date 1 (cf. von Thadden, 1995). The payoff to wholesale financiers in date 1 liquidations is determined by the liquidation value $L(D+W)$ and their creditor seniority.

3. Since the maximum investment size is 1, $D + W \leq 1$.

Monitoring A wholesale financier can obtain information on the bank's date 2 project realization by monitoring the bank. Monitoring takes place in between dates 0 and 1. The financier chooses the intensity of monitoring m ($0 \leq m < 1$). She incurs cost $C(m)$ ($C(0) = 0$, $C(1) = \infty$, $C'(0) = 0$, $C''(m) > 0$). She then receives a *correct* signal of date 2 realization with probability m. That is, when monitoring succeeds, the financier obtains precise information of bank project quality. The financiers receives no signal at all with probability $1 - m$. In that case the financier knows that monitoring failed, and remains with information on prior probability of success p only.

Seniority The seniority of wholesale financiers relative to retail depositors in date 1 liquidations is described by the share s of liquidation value they receive ($0 \leq s \leq 1$). In early liquidations, wholesale financiers receive $sL(D + W)$ while retail depositors $(1 - s)L(D + W)$. Higher s represents a higher creditor seniority of wholesale financiers relative to retail depositors. Note that s describes the *effective* seniority of wholesale financiers. In practice, effective seniority is determined by a range of contractual choices: formal seniority, collateralization of funding, first-come–first-served rules, as well as official resolution options expected to be applied in case of bank failure.

Continuation For determinacy, we assume that at date 1 all agents marginally prefer bank's continuation to liquidation when otherwise indifferent. Note that, since $L < 1$, bankers receive nothing in date 1 liquidations, and will therefore always prefer continuation. Retail depositors are set up as passive agents who always remain with the bank until date 2. Therefore, in this model, date 1 liquidations can only be triggered by short-term wholesale financiers.

Finally, we focus on the case when the amount of wholesale funding attracted by the bank is not too small compared to the liquidation value:

$$pW > L \tag{1}$$

This single assumption, while mildly restrictive, allows to keep results easily tractable. It is a sufficient condition for

$$pWR > L(D + W)$$

and rules out outcomes when uninformed senior wholesale financiers *always* prefer to liquidate the bank at date 1 to receive $L(D + W)$ rather than wait until date 2 when they obtain expected pWR. It captures the stylized fact that, on average, all banks are solvent and stable, "no news is good news", and bank runs are generally uncommon.

We analyze the model in three steps. First, we consider the basic case of a bank funded by retail deposits only. Second, we introduce wholesale funds and show their positive effect on social welfare in a constrained optimum. Finally, we model the equilibrium resulting from private choices of banks and wholesale financiers, and show that its outcome is consistent with the maximization of social welfare. This demonstrates the "bright side" of wholesale funding.

2.2 Retail deposits only

Consider first a bank funded by retail deposits only. Then, the volume of initial investment D is lower than maximum possible 1. Maintaining spare investment capacity is inefficient, because the bank's project has a positive net present value.

Furthermore, the bank always continues until date 2. This is because bankers are at least indifferent between continuation and liquidation at date 1, while retail depositors are uninformed and passive. This means that bad projects are not terminated at date 1 (which would preserve liquidation value L), but continue until date 2 returning 0. This is the second source of inefficiency.

Overall, the net present value of the bank's investment when financed with retail deposits only is:

$$\Pi^{+} = D(pX - 1) \tag{2}$$

2.3 Wholesale funds: Welfare maximization

Now consider a bank that also attracts wholesale funds in the amount W. In this section, we derive the benchmarks for what would be the socially optimal monitoring and continuation decisions of wholesale financiers and the amount of wholesale funds attracted by a bank.

Consider first the continuation decision. At date 1, if monitoring was successful, a bad bank (which yields 0 at date 2) needs to be liquidated to preserve L. A good bank (which yields X at date 2) needs to be refinanced. When monitoring was unsuccessful, so that the bank's project quality is unknown, a bank also needs to be refinanced since $Xp > L$.

Consider now the optimal intensity of monitoring, m^*, and the optimal amount of wholesale funds, W^*. The monetary value of social welfare:

$$\Pi = (D + W)\left(pX + m(1-p)L - 1\right) - C(m) \tag{3}$$

is maximized for

$$W^* = 1 - D$$

so that a bank uses the maximum possible amount of wholesale funds and the complete initial investment opportunity of 1 is used, and for m^* given by

$$C'(m^*) = (1-p)L \tag{4}$$

Comparing (3) with (2) highlights the beneficial effects of the use of wholesale funds: higher investment volume $D + W$ instead of D, and preserving the liquidation value of some bad banks $m^*(1-p)L$ at the cost of monitoring $C(m^*)$.

2.4 Wholesale funds: Private equilibrium

We now derive equilibrium private choices of banks and wholesale financiers, and compare it with the socially optimal outcome.

Wholesale financiers Consider first the choices of wholesale financiers. They take decisions on the intensity of monitoring and on continuation (whether to roll over funds or liquidate the bank). Note immediately that their continuation decision is in line with the socially optimal. If monitoring was successful, wholesale financiers have incentives to liquidate bad banks to receive $sL(D + W)$, and to roll over funding to good banks to receive WR. When monitoring was unsuccessful, uninformed wholesale financiers choose to roll over funding since, by (1), $pWR > sL(D + W)$.

Consider now the monitoring decision of wholesale financiers. In choosing the intensity of monitoring m, they maximize:

$$\Pi^W = pWR + m(1-p)sL(D+W) - C(m)$$

which obtains their private choice of monitoring intensity m^W given by:

$$C'(m^W) = (1-p)sL(D+W) \tag{5}$$

Observe from (4) and (5) that $m^W = m^*$ for $s = 1$ and $D+W = 1$. This means that wholesale financiers choose the optimal intensity of monitoring when they are senior creditors at the refinancing stage and the amount of wholesale funding is the maximum possible. The intuition for this outcome is that being senior allows wholesale financiers to fully internalize the benefits of monitoring: preserved liquidation value $L(D+W)$

which is higher for a higher use of wholesale funds. Optimal high seniority of wholesale financiers is an important result as it describes the nature of optimal contracting arrangements between the bank and short-term wholesale financiers.

Banks The bank takes decisions on the amount of wholesale funds W to attract and on the creditor seniority s to offer them. The bank's surplus is:

$$\Pi^B = p\left[D(X - R_D) + W(X - R)\right] \tag{6}$$

The interest rate R demanded by competitive wholesale financiers, obtained from their zero-profit condition, is:

$$R = \frac{W\rho + C(m^W) - m^W(1-p)sL(D+W)}{Wp}$$

Lemma 1 Π^B *increases in* s *and* W*.*

Proof. See Appendix. ∎

The intuition for Lemma 1 is as follows. Π^B increases in s because R decreases in s: as wholesale financiers receive a larger share in early liquidations, the amount needed to compensate them in successful outcomes falls. Π^B increases in W because the bank is able to invest more funds, while at the same time the cost of monitoring per unit of wholesale funds used falls.

It follows directly from Lemma 1 that a bank acting in its own private interests choose the maximum possible $W = 1 - D = W^*$ and $s = 1 = s^*$, consistent with the socially optimal outcome.

We can now formulate the main result of this section. It describes the benchmark "bright side" effects of bank wholesale funding.

Proposition 1 *In the benchmark "bright side" case, the wholesale financiers' monitoring and continuation decision, and the banks' decisions on the amount of wholesale funds* *to use and their creditor seniority, are all in line with the constrained social optimum. In equilibrium, the amount of wholesale funds used by a bank is maximum possible:* $W^* = 1 - D$*, wholesale funds are senior:* $s^* = 1$ *so that all benefits of monitoring are internalized, and the investment of wholesale financiers in monitoring* m^* *is given by* $C'(m^*) = L(1 - p)$*.*

Observe that these predictions are fairly strong. Not only is the use of wholesale funding in banks unambiguously welfare improving, but also the private choices of banks and wholesale financiers fully coincide with welfare-maximizing outcomes.

3 The Dark Side of Wholesale Funding

In this section, we turn to the analysis of the "dark side" of bank wholesale funding. Specifically, we show how a plausible and minor change to the "bright side" CK-style setup of Section 2 can significantly alter the benchmark results.

To model the "dark side" of wholesale funding, we introduce an additional source of information available to "sophisticated" wholesale financiers. We assume that even when monitoring was unsuccessful (did not produce information about date 2 realization, either because of low investment in monitoring or merely by bad luck), wholesale financiers still obtain a free but *noisy* signal of date 2 realization in advance of date 1. That signal is best interpreted as a piece of publicly available information, and can represent for example market-wide or sector-wide news. Depositors have no capacity to process the free signal as they are unsophisticated.

We show that such a seemingly minor twist can generate results that are almost opposite to those of CK. The presence of a costless but noisy signal lowers the incentives of wholesale financiers to monitor, and gives them excess incentives to liquidate banks based on overly noisy public information. These distortions become stronger when wholesale financiers are made senior claimants to the liquidated assets. The reason is that senior sophisticated investors benefit disproportionately in date 1 liquidations. When liquidating they can obtain a larger share of a smaller bank assets pie, at the expense of passive depositors. We show that, as a result, the incentives of opportunistic wholesale financiers are most aligned with the social optimum when they are assigned intermediate (rather than high) creditor seniority at the refinancing stage – sharply contrasting with CK results.

We further address the incentives of banks. We show that, when banks do not fully internalize the externalities of their contracting with short-term wholesale financiers on the providers of long-term funds (e.g. retail depositors) they may choose to assign too high seniority to short-term wholesale funds. This would lead to excess noisy liquidation in equilibrium, and bear close resemblance to effects observed during the recent turmoil.

Moreover, in a cross-section, we find that both the risk of noisy liquidation by wholesale financiers and the incentives of banks to opportunistically assign them too high seniority – the "dark side" of wholesale funding – dominate in "modern" banks characterized by arm's length and tradable assets and an active combination of retail and wholesale funds in the liability structure.

3.1 Additional feature: A noisy public signal

To model the "dark side" of wholesale funding, we add to the setup of Section 2 a free but noisy signal on bank quality. The free signal is received by wholesale financiers after monitoring but before date 1. This sequence reflects the fact that the choice of intensity of monitoring is a strategic (anterior) decision and that monitoring needs to be performed continuously in the course of lending. Also observe that while monitoring is assumed to be precise if successful, the free signal is noisy: information produced through dedicated private investigation is of higher quality.

We specify the signal to have the same distribution as that of the underlying project, but providing only noisy information on the final outcome. Formally, the signal takes two values: "positive" or "negative", and is characterized by a precision parameter θ ($0 \leq \theta \leq 1$; $\theta = 0$ for uninformative; $\theta = 1$ for precise). The probability of receiving a positive signal is p (same as for X at date 2); conditional on that the probability of getting X at date 2 is $[p + \theta(1 - p)]$, and that of getting 0 is $[(1 - p) - \theta(1 - p)]$. The probability of a negative signal is $1 - p$ (same as for 0 at date 2); conditional on that the probability of getting X at date 2 is $[p - \theta p]$, and that of getting 0 is $[(1 - p) + \theta p]$.

The principal impact of the noisy signal on the mechanics of the model is as follows. Recall that without such signal, fundamentally uninformed wholesale financiers (who did not receive precise information from monitoring) always rolled over funding at date 1. This was consistent with both welfare maximization ($pX > L$) and their private incentives ($pWR > sL(D + W)$). Now however, fundamentally unformed wholesale financiers may choose not to roll over funding after receiving a negative but noisy signal. This paves way early liquidations of banks based on free but noisy information only ("noisy liquidations"). In this section we demonstrate how the possibility of early liquidations distorts incentives of both wholesale financiers and banks in such a way that their private choices may no longer lead to socially optimal outcomes.

We analyze the model in four steps. First, we derive the benchmark for the socially optimal use of the noisy costless signal. Second, we analyze the incentives of wholesale financiers. We show that they may have incentives for excess liquidations of banks based on overly noisy public information, particularly when they are senior. Third, we analyze socially optimal contracting with wholesale financiers. We show that, with the risk of excess noisy liquidations, it is optimal that wholesale financiers have intermediate (rather than high) creditor seniority. Finally, we study incentives of banks, and show why they can deviate from the socially optimal ones. Bank can opportunistically offer too high seniority to wholesale financiers to reduce the interest rates they have to pay on short-term wholesale funding. This is the source of inefficient noisy liquidations in equilibrium.

Throughout the section, we focus on cross-sectional predictions on the risk of early liquidations and inefficient bank funding choices. In the end of the section, we consider options for regulatory response.

3.2 Welfare maximization

We start by outlining the benchmark socially optimal decisions on continuation, monitoring, and the use of wholesale funds in the presence of a free but noisy signal on bank project quality.

Noisy liquidations Consider the optimal use of a noisy public signal. When monitoring was successful, bank quality is known precisely. The noisy signal cannot add to the fundamental information produced through monitoring. As before, good banks need to be refinanced while bad banks need to be liquidated.

When monitoring was unsuccessful, without the noisy signal, date 1 continuation was always optimal. The noisy signal can refine probabilities associated with success or failure at date 2. For a positive noisy signal, the posterior of success at date 2 increases to $p + \theta(1-p)$. It remains optimal that the bank is refinanced. However for a negative noisy signal, the posterior of success at date 2 falls to $[p - \theta p]$. There are two possible outcomes. If the precision θ of the noisy signal is low so that $[p - \theta p]\, pX \geq L$, it is still optimal to refinance the bank. In this case, the noisy signal is optimally disregarded: it has no impact on the continuation and by implication any other decisions. However if the precision of the noisy signal θ is high enough so that $[p - \theta p]\, pX < L$, it is optimal to liquidate the bank based solely on a noisy signal. The threshold value of θ is

$$\theta^* = 1 - \frac{L}{pX} \tag{7}$$

Note that, unless $\theta = 1$, some good banks will suffer noisy liquidations as well.

Monitoring and use of wholesale funds Now consider how the availability of a costless noisy signal affects the optimal intensity of monitoring and the optimal amount of wholesale funds to use. The impact depends on the precision of a noisy signal. Recall that, when its precision is low, $\theta \leq \theta^*$, it is optimal to disregard the noisy signal. As a consequence, the maximization problem is the same as in the benchmark case (3). The optimal amount of wholesale funds to use is the maximum possible $W^* = 1 - D$ and the optimal amount of monitoring is m^* as defined by (4).

When the precision of the noisy signal is high, $\theta > \theta^*$, it is socially optimal to use the noisy signal, and liquidate the bank when the it is negative. The monetary value of social welfare in this case is:

$$\Pi_{Liq} = (D + W)\,(m\,[pX + (1-p)L] + (1-m)\,[p\,[p + \theta(1-p)]\,X + (1-p)L] - 1) - C(m) \tag{8}$$

The term $m\,[pX + (1-p)L]$ is the payoff to successful monitoring, similar to (3). The term $(1-m)\,[p\,[p + \theta(1-p)]\,X + (1-p)L]$ is novel: it is the payoff from using the noisy signal when monitoring was unsuccessful (and liquidating the bank upon a negative signal). The probability of a positive signal is p; conditional on it the bank is refinanced and yields X with probability $[p + \theta(1-p)]$. The probability of a negative signal is $(1-p)$; the bank is liquidated to preserve L.

As before, the social welfare (8) is increasing W, so that it is optimal to use as much wholesale funding as possible: $W^*_{Liq} = 1 - D = W^*$. The optimal intensity of monitoring m^*_{Liq} is given by:

$$C'(m^*_{Liq}) = p\,(1-p)\,(1-\theta)\,X \tag{9}$$

Observe that $m^*_{Liq} < m^*$. This is easy to verify this by applying the condition for using the noisy signal $[p - \theta p]\,pX < L$ to (4) and (9). The intuition is that the availability of a noisy but free signal makes the information obtained through costly monitoring less valuable.

3.3 Wholesale financiers: Incentives and optimal seniority

Now consider private choices of wholesale financiers.

Noisy liquidations When monitoring was successful, as before, wholesale financiers have incentives to follow its outcome: refinance known good banks and force liquidation of bad ones. When monitoring was unsuccessful, uninformed wholesale financiers can use the noisy public signal. Upon a negative noisy signal, their expected continuation payoff is $[p - \theta p]\,WR$. Their liquidation payoff is $sL(D+W)$. For wholesale financiers, it is privately optimal to follow a noisy signal and liquidate the bank for

$$sL(D+W) > [1-\theta]\,pWR \tag{10}$$

Expression (10) can be interpreted either as sufficiently high precision of the noisy signal:

$$\theta > \theta^W = 1 - \frac{sL(D+W)}{pWR} \tag{11}$$

or as sufficiently high seniority of wholesale financiers:

$$s > s^W = \frac{(1-\theta)\, pWR}{L(D+W)} \tag{12}$$

Note that the private threshold θ^W can be either above or below the socially optimal threshold θ^* depending on the value of s. When s is low and $\theta^W > \theta^*$, wholesale financiers have insufficient private incentives to liquidate banks. When s is high and $\theta^W < \theta^*$, wholesale financiers have excess private incentives to liquidate banks based solely on noisy information. However observe that wholesale financiers always have excess incentives to liquidate banks based on noisy information when they are senior: $\theta^W_{s=1} < \theta^*$.

From this point on, we will focus on the case with the richest interpretations. We consider the case when private and public incentives to liquidate banks based on noisy information diverge. Specifically, we consider θ in the interval $\theta^W_{s=1} < \theta < \theta^*$. This describes the environment where the noisy public signal is not very informative, so that from the social welfare perspective it is optimal to disregard it. But it is still informative enough to be used by senior wholesale financiers and to trigger "noisy" bank liquidations.

Monitoring Consider now the monitoring choices of wholesale financiers. Recall that when wholesale financiers are sufficiently junior, $s \leq s^W$, they disregard the noisy signal. Therefore, their private choice of monitoring intensity is the same as the benchmark m^W (5).

However when wholesale financiers are sufficiently senior, $s > s^W$, they have incentives to use the noisy public signal and liquidate the bank when it is negative. Then, in choosing monitoring intensity, they maximize

$$\Pi^W = m\left[pWR + (1-p)sL(D+W)\right] + (1-m)\left[p\left[p + \theta(1-p)\right]WR + (1-p)sL(D+W)\right] - C(m) \tag{13}$$

which obtains:

$$C'(m_{Liq}^W) = p\,(1-p)\,(1-\theta)\,W R_{Liq} \tag{14}$$

Observe that, unlike in expression (5) for m^W, s does not enter directly into the specification of m_{Liq}^W (14). Rather, it affects m_{Liq}^W indirectly through R_{Liq}. To see that in detail, consider the interest rate charged by competitive financiers:

$$R_{Liq} = \frac{W\rho + C(m_{Liq}^W) - (1-p)sL(D+W)}{m_{Liq}^W Wp + (1-m_{Liq}^W)\,[p+\theta(1-p)]\,Wp}$$

As s increases, and wholesale financiers may receive more in date 1 liquidations, they need to be paid less (in interests) in date 2 success: in equilibrium, R_{Liq} decreases in s. Therefore, since m_{Liq}^W increases in R_{Liq}, it decreases in s. This contrasts with the benchmark case without the noisy signal where m^W (5) increased in s. The intuition behind this result is that senior wholesale financiers become less interested in the bank's long-term value. They can easily liquidate the bank on mild negative news before the long-term value is realized, at only very low private cost.

This makes $s = s^W$ a threshold point not only for the liquidation decision, but also for the choice of intensity of monitoring of wholesale financiers. Its properties are summarized in the following lemma:

Lemma 2 *Consider s^W given by (10).*

1. For $s \leq s^W$ wholesale financiers never liquidate a bank based on noisy information and the intensity of their monitoring increases in seniority: $\partial m^W/\partial s > 0$, consistent with the benchmark "bright side" of bank wholesale funding.

2. For $s > s^W$ uninformed wholesale financiers choose to liquidate a bank following a negative noisy signal and the intensity of their monitoring decreases in seniority: $\partial m_{Liq}^W/\partial s < 0$, contrasting with the "bright side" benchmark.

3. The intensity of monitoring chosen by wholesale financiers is maximized for $s = s^W$, that is for an intermediate value of their seniority.

Proof. See Appendix. ■

The contrasting effects of seniority on the behavior of wholesale financiers with and without the noisy public signal are illustrated in Figure 1. The left panel shows monitoring choices of wholesale financiers depending on their creditor seniority in the benchmark case without the noisy signal. The right panel shows the same with the noisy signal. There, for low values of seniority, wholesale financiers disregard the noisy signal so their actions is identical to those in the benchmark case. However when seniority exceeds the threshold value $s = s^W$ wholesale financiers start (a) to liquidate based on a negative noisy signal, and (b) to reduce the intensity of monitoring in response to higher seniority.

<< Figure 1 here >>

Optimal use and seniority of wholesale funds We now take the incentives of wholesale financiers identified in Lemma 2 as given, and ask what would be the resulting *socially optimal* use W and seniority s of wholesale funds. Of course in practice the decisions of how much wholesale funds to use and which creditor seniority to offer them are taken by a bank with the objective of maximizing its private surplus. We will analyze those immediately afterwards. However understanding the socially optimal use of wholesale funds would allow us to analyze whether the private choices of banks are consistent with social welfare maximization, and if not, identify scope for regulatory intervention.

The key result on the optimal use of wholesale funds by banks is as follows:

Proposition 2 *Consider the case with possible welfare-reducing noisy liquidations where* $\theta^W_{s=1} < \theta \leq \theta^*$. *Then the socially optimal creditor seniority of wholesale financiers is* $s = s^W$ *(12). This is the intermediate level of seniority, lower then the "bright side" benchmark* $s = 1$. *Setting* $s = s^W$ *fully aligns the continuation decision of wholesale financiers with the socially optimal: there are no noisy liquidations. At the same time,* $s = s^W$ *maximizes the intensity of monitoring privately chosen by wholesale financiers,* *albeit at the level below the socially optimal:* $m^W(s^W) < m^*$*. The optimal amount of wholesale funds remains the highest possible* $W = 1 - D = W^*$*.*

Point s^W can be thought of as the highest seniority of short-term wholesale funds that does not give rise to early liquidations. For $s < s^W$ increasing seniority increases the intensity of monitoring chosen by wholesale financiers. After that, for $s > s^W$, fundamentally uninformed wholesale financiers will start liquidating banks based on a negative noisy signal. That is not socially optimal. Moreover, for $s > s^W$, the monitoring effort of wholesale financiers starts to decrease in higher seniority. In effect, for $s > s^W$, higher seniority of wholesale financiers translates not into higher intensity of monitoring (as was in the "bright side" case) but purely into excess liquidations – and less monitoring.

The fact that intermediate rather than high seniority of wholesale funds is optimal in order to prevent excess liquidations of banks based on overly noisy public information is a key departure from the CK-type result describing the "bright side" of wholesale bank funding.

Comparative statics Lemma 2 and Proposition 2 offer important cross-sectional predictions on (a) the risk of excess noisy liquidations in different types of banks, and (b) the optimal seniority of short-term wholesale funds in different types of banks. The two are closely inter-related: banks with a higher risk of excess noisy liquidations should optimally assign lower seniority to wholesale funds. That would increase the losses that wholesale financiers incur in early liquidations, and by this reduce their incentives to liquidate based on overly noisy information.

Consider inequalities (10) and (12). It is more likely that they are satisfied, so that the risk of noisy liquidations by short-term wholesale financiers is higher and their optimal seniority is lower, when:

- The precision of a noisy signal on bank project quality θ is higher;
- The bank's liquidation value L is higher;

- The amount of depositor funding D is higher, while the amount of wholesale funds used W is lower;
- The cost of wholesale funds ρ (which determines the interest rate paid on them R) is lower.

Also, from (10), the risk of noisy liquidations is higher when the seniority of short-term wholesale funds s is higher.

These predictions indicate an interesting distinction between the optimal use of wholesale funds in (1) "traditional" banks making relatively relationship-based small business loans (which are associated with low θ and L) and in (2) "modern" banks holding mostly tradable arm's-length assets (which are associated with relatively higher liquidation value L, and relatively precise public information on quality – high θ – because of the availability of secondary market prices and credit ratings). The characteristics of "traditional" banks are largely consistent with the CK-type "bright side" view of wholesale funding and it is socialy optimal for these banks to assign high seniority to wholesale funds to maximize their incentives to monitor. "Modern" banks, in constrast, run a higher risk of liquidations based on noisy public information; it is socially optimal for them to assign relatively lower seniority to wholesale funds to mitigate that risk.

The predictions also suggest, interestingly, that the long-term funds D, while being a seemingly safe liability by themselves, also serve as a buffer for short-term wholesale financiers that make liquidations less costly for them, increasing the risk of overly noisy liquidations and reducing the wholesale financier's monitoring incentives. This result has potential implication for thinking about liquidity regulation: it identifies potential incentives costs of higher liquidity buffers.

Finally, the predictions from comparative statics suggest that the problem of socially nonoptimal use of wholesale funds is most acute during the periods of abundant liquidity as characterized by low cost of wholesale funds ρ.

3.4 Banks' Incentives to Use Wholesale Funds

The previous section has established optimal contracting with opportunistic wholesale financiers: how their choices can be brought closer to the social optimum by assigning them an intermediate level of creditor seniority s^W. However in practice the decisions of how much wholesale funds to use and which creditor seniority to offer them are taken by a bank with the objective of maximizing its private surplus. In this section, we will study the incentives of banks, and ask whether unconstrained bank choices can deviate from the social optimum.

They key mechanism behind the results of this section is that banks do not internalize the externalities of their contracting with short-term wholesale financiers on passive depositors (and other providers of long-term funds). The reason is that the interest rate on deposits and long-term funds is fixed in advance: a higher risk of non-repayment does not translate into a correspondingly higher interest rate punishment for a bank. To sum up, the reason for the externality is that deposits and other long-term funds are generally not fully efficiently priced.

Bank's choice of seniority for wholesale financiers Consider the impact of offering wholesale financiers a higher creditor seniority than is socially optimal: $s > s^W$. Recall that the social cost of this action is (a) inefficient noisy liquidations and (b) lower intensity of monitoring by wholesale financiers. Let us now consider private costs and benefits for the bank. The bank's private cost is similar to the social one: a bank loses when good projects are liquidated prematurely in early liquidation. However the bank also has a private benefit. Offering higher seniority to wholesale financiers reduces the interest rate R charged by them. As long as the interest rate charged by providers of long-term funds (e.g. passive depositors) R_D is fixed, this leads to an increase in bank's surplus. When the net effect of higher seniority on bank's surplus is positive (the lower interest rate effect dominates the higher risk of liquidation effect), the bank has private incentives to offer too high seniority to short-term wholesale financiers.

To see this formally, compare the bank's surplus from selecting $s = s^W$ versus some $s > s^W$.

For $s = s^W$ we have:

$$\Pi^B_{s=s^W} = p\left[D(X - R_D) + W(X - R)\right] \tag{15}$$

where

$$\begin{aligned} R &= \frac{W\rho + C(m^W) - m^W(1-p)sL(D+W)}{Wp} \\ s &= s^W \end{aligned}$$

For $s > s^W$ we have:

$$\Pi^B_{Liq} = \left[p - (1 - m^W_{Liq})p(1-\theta)(1-p)\right]\left[D(X - R_D) + W(X - R_{Liq})\right] \tag{16}$$

where

$$R_{Liq} = \frac{W\rho + C(m^W_{Liq}) - (1-p)sL(D+W)}{W\left(p - (1 - m^W_{Liq})p(1-\theta)(1-p)\right)}$$

(Note that $m^W(s^W) = m^W_{Liq}(s^W)$ and $R(s^W) = R_{Liq}(s^W)$. This is easy to show formally by substituting expressions for m^W (5), s^W (12), and m^W_{Liq} (14). The intuition is that, although at s^W there is a discrete change in the liquidation strategy of wholesale financiers (from not using to using the noisy signal), at s^W they are indifferent between the two. Therefore marginal changes in s lead to marginal changes in m and R.)

Compare $\Pi^B_{s=s^W}$ and Π^B_{Liq}. Observe that Π^B_{Liq} has a lower probability of bank's success: it is reduced by the probability of inefficient liquidations $(1-m^W)p(1-\theta)(1-p)$. As a result there is a discrete fall in Π^B as soon as s exceeds s^W as a bank becomes subject to inefficient early liquidations. The value of that fall is

$$\Delta = (1 - m^W)p(1-\theta)(1-p)\left[D(X - R_D) + W(X - R)\right] \tag{17}$$

However after that $\Pi^B_{s>s^W}$ can increase in s. The reason is that higher s gives wholesale financiers more in date 1 liquidations (at no expense to the bank), and allows the bank to repay them less in case of success at date 2. To see this formally, consider

$$\frac{d\Pi^B_{Liq}}{ds} = -\frac{dR_{Liq}}{ds}\left[p-(1-m^W_{Liq})p(1-\theta)(1-p)\right]W+\frac{dm^W_{Liq}}{ds}p(1-\theta)(1-p)\left[D(X-R_D)+W(X-R_{Liq})\right] \tag{18}$$

The first term on the right-hand side is overall positive: it reflects the reduction in interest rate the bank has to pay on short-term wholesale funds: $dR_{Liq}/ds < 0$. The second term on the right-hand side is overall negative: $dm_{Liq}/ds < 0$ as wholesale financiers lose their incentives to monitor the bank, leading to more ineffective liquidations.

Either effect can dominate depending on parameter values. For example, one can verify that for a very low L the term dR_{Liq}/ds is so low that the second term dominates and $d\Pi^B_{Liq}/ds$ is negative. Then the bank would never have incentives to choose $s > s^W$. Yet, as another example, when the impact of s on m^W_{Liq} is very small, the second term is so low that the first term dominates and $d\Pi^B_{Liq}/ds$ is positive. In this case, should the initial fall in bank's surplus Δ be outweighed by a subsequent increase of Π^B_{Liq} as s becomes high enough, the bank would have incentives to assign wholesale financiers a higher seniority $\hat{s} > s^W$ than is socially optimal.

This latter case would correspond to the dark side of wholesale bank funding. There, banks opportunistically assign very high seniority to wholesale financiers in order to benefit from savings on interest rate payments that they have to make in case of success. Senior wholesale financiers, in their turn, opportunistically liquidate banks based on very noisy public information although that is not socially optimal. We now focus on this case in more detail.

"Dark side" of wholesale funding in equilibrium We first prove the existence of the "dark side" case when banks have incentives to assign short-term wholesale financiers a higher seniority than is socially optimal.

Proposition 3 *There exist parameter values of θ, L, D, W and ρ such that for some*

$\hat{s} > s^W$: $\Pi^B_{Liq}(\hat{s}) > \Pi^B_{s=s^W}$ so that a bank has incentives to assign higher creditor seniority to wholesale financiers than is socially optimal.

Proof. See Appendix. ■

Proposition 2 is one of the key results of the paper. It proves the existence of the "dark side" of wholesale funding. It demonstrates the existence of outcomes where banks opportunistically assign too high seniority to wholesale financiers, while wholesale financiers opportunistically liquidate banks based on too noisy public information can exist in equilibrium.

We now turn to comparative statics. In order to be able to produce tractable results, we need an additional simplification. We have to require that m_{Liq} is relatively unaffected by changes in exogenous parameters that we are going to let vary. This is the case, for example, when $C(m)$ is relatively flat. Otherwise minor changes in exogenous parameters can lead to significant changes in m_{Liq} (e.g. it may suddenly turn into zero) which would significantly complicate the analysis.

Under this condition, interest rate saving effects in $d\Pi^B_{Liq}/ds$ are likely to dominate possible increases in Δ, and therefore on the net increase bank's incentives to choose some $s > s^W$ over s^W when:

- The precision of a noisy signal on bank project quality θ is higher. The intuition is that a higher θ makes the noisy liquidations more precise and therefore less costly: it is easy to see in (17) that a higher θ reduces Δ. One can also observe in (18) that a higher θ increases a multiplier of dR_{Liq}/ds, leading to a higher $d\Pi^B_{Liq}/ds$.
- The bank's liquidation value L is higher. To verify this note first that L does not affect Δ. The reason is that although L enters expressions for R and m^W it does so always proportionally to s^W. Yet s^W itself is inversely proportional to L (as seen in (12)). Therefore $d\Delta/dL = 0$. At the same time a higher L increases the value of dR_{Liq}/ds leading to a higher $d\Pi^B_{Liq}/ds$.

Observe that these predictions are reinforcing the comparative statics observed in the incentives of providers of wholesale funds. Precisely the same bank characteristics found predominantly in "modern" rather than "traditional" banks – more relevant public signal on project quality and a higher liquidation value – make the providers of wholesale fund more likely to liquidate the bank based solely on noisy public information *and* make the bank more likely to assign the providers of wholesale funds inefficiently high seniority.

We will not formulate results for the impact of funding structure (D and W) on banks' incentives. The reason is that those are ambiguous. Higher D and W increase losses due to noisy liquidations Δ as well as the interest rate savings dR_{Liq}/ds. Depending on parameter values, either effect can dominate.

To close the solution, we verify that the bank always chooses to use the maximum amount of wholesale funds $W = 1 - D = W^*$. Lemma 1 proved that Π^B increases in W for $s \leq s^W$. It is straightforward to obtain through similar derivations that Π^B_{Liq} also increases in W (there is an additional effect that as m^W_{Liq} falls in W the probability of noisy liquidations falls increasing Π^B_{Liq}). The intuition, as before, is that using a higher amount of wholesale funds allows banks to utilize more of the valuable investment opportunity and to reduce the per-unit cost of monitoring.

3.5 Policy response

This paper has articulated two main results on potential inefficiencies in the banks' use of wholesale funds:

- Wholesale financiers can liquidate banks based on overly noisy public signal;
- Banks can assign too high seniority to wholesale financiers, exposing themselves to the risk of early liquidations

The two inefficiencies are mutually reinforcing as they are likely to be present in banks with similar cross-sectional characteristics. Here we analyze actions that the regulators can take to bring the choices of banks and wholesale financiers closer to the social optimum.

While regulators have little leverage over the actions of wholesale financiers, they can try and influence banks' choices. Their objective is to make sure that the banks do not assign wholesale financiers seniority higher than $s = s^W$ as defined by (12). Below we describe some options at their disposal.

Impose lower seniority for short-term wholesale financiers If regulators could direclty influence the creditor seniority assigned to short-term wholesale financiers, they could simply impose $s = s^W$. But there are many reasons why this may be difficult or impossible. Firstly, s^W varies across banks and over time as bank charateristics change. Secondly, as s is defined as *effective* seniority and not just formal seniority, it is very difficult to influence s through official requirement, unless a bank has been taken over by the authorities and payments to wholesale funds can be suspended; historically, however, most wholesale funds had managed to exit before the banks fell under control of the authorities.

Assess taxes or deposit insurance premia on banks to correct for distorted incentives Recall that the private incentives of banks are not in line with the socially optimal because banks do not internalize the losses of depositors and other providers of long-term funds. The interest rate R_D was set before short-term funds were attracted, and at that stage the bank was unable to commit to any future course of action. For retail deposits, which are the dominant source of long-term funds, R_D is insensitve due to the protection by deposit insurance. As a result, by offering a higher s to wholesale financiers, the bank was able to save on its total interest rate payments.

Authorities can attempt to correct bank's incentives ex-post by charging the bank (through taxes or deposit insurance premia) for whatever private benefits it obtains through offering a too high s to wholesale financiers. The problem, again, is how to define a "too high" s. recall that the threshold s^W for "too high" is different for different banks.

We first analyze a possible taxation structure that does not rely on knowing the precise s^W for each bank, identify its shortcomings, and then propose a taxation structure that requires knowing s^W but more difficult to implement.

Consider Π^B_{Liq}: the bank's profit function at $s > s^W$ (16). Again assume for simplicity that monitoring effects are secondary: m is fixed. Interest rate savings from a given s are $(1-p)sL(D+W)$. To remove them from the profit function the bank can be taxed (or charged a deposit insurance premium) $T = (1-p)sL(D+W)$. It is easy to observe that $d\left(\Pi^B_{Liq} - T\right)/ds < 0$. The intuition is that the interest rate savings effect is now compensated by tax T on the opposite direction. Under such a tax, a bank has no incentives to choose $s > s^W$.

However, under tax T that does not rely on knowing s^W the bank has no incentives to choose s^W either. Indeed, consider Π^B: the bank's profit for $s < s^W$ (6). There, interest rate savings from a given s are $m(1-p)sL(D+W)$, and one can verify that $d\left(\Pi^B - T\right)/ds < 0$. Under a tax T a bank simply has no incentives to choose any $s > 0$ because the tax penalizes the use of senior wholesale funds in general, even when the seniority assigned to wholesale fundsis lower s^W.[5]

To address this problem, authorities could try to relate taxes or insurance premia to s^W. Their ability to implement such taxes depends on the verifiability of individual s^W, which varies across banks dependent on bank characteristics. The revised insurance premia formula $\hat{T} = (1-p)\max\{(s-s^W);0\}L(D+W)$ would counterbalance banks' incentives to choose $s > s^W$ but would not affect banks' choices on $s \leq s^W$, therefore leading to a socially optimal outcome $s = s^W$.

The formula suggests that banks assigning higher *effective* seniority s to wholesale funds should pay a higher premium. In practice, however, it is hard to quantify s precisely, although it is fair to say that funds with shorter remaining maturity enjoy

[5] Interestingly however the tax T although blunt can be welfare improving under some conditions. To see that, consider the case when the level of monitoring is almost fixed. Then the key to achieving high social welfare is to avoid ineffective liquidations. The tax T does just that. More generally, observe that the tax T reduces monitoring incentives compared to the socially optimal level but improves liquidation incentives. When it is more important to avoid inefficient liquidations rather than to incentivize monitoring tax T improves social welfare.

relatively higher effective seniority than those with longer remaining maturity, and funds that by contracts are strictly subordinated to other creditors, such as subordinated debts, are more junior.

Further, it is even more difficult to quantify s^W than s. s^W varies across banks dependent on many parameters reflecting bank characteristics. We can compute the optimal seniority s^W easily in our theoretic model because the model is very stylized. In practice, the authorities also need to make some simplification to find proxies for s^W . For example, our model predicts that banks holding arm's length assets are associated with a lower s^W than banks holding mainly relationship loans, because the former are typically associated with higher L and θ. Therefore, the authorities may choose not to raise insurance premium for a bank with high percentage of small business loans until the wholesale funds seniority exceeds a much higher threshold s^W. Admitedly such ad-hoc proxies are approximate and they can never completely account for all circumstances that influence s^W, but each of them can bring the banks' actions one step closer to that socially optimal.

Note also that this optimal deposit insurance premium formula suggests that the premium be assessed in proportion to the bank's total liabilities $D + W$ rather than only insured retail D. The reason is that the externalities imposed by the use of short-term wholesale funds – which risk-based deposit insurance attempts to correct – are proportional to the total value of liabilities. Interstingly, this corresponds to the current FDIC policy that assess deposit insurance premia based on bank's "total deposits" (i.e. not only insured deposits but also uninsured ones that behave like wholesale funds). The stated reason for such FDIC policy is that it is technically difficult to separate insured and uninsured deposit accounts. Our model offers a deeper economic explanation: such a policy reduces banks' incentive to attract risky short-term wholesale funds such as jumbo CD's. Our model further suggest that FDIC can do even better by including in the assessment base all other short-term liabilities such as commercial paper and interbank borrowings

Interestingly, the formula also suggests charging higher premia for banks with more liquid balance sheets (i.e. higher L). At first sight, this looks counterintuitive because a more liquid balance sheet should reduce the authorities costs of seizing assets. However, the reality is that wholesale funds usually manage to run down the liquid assets and exit before the bank is taken over by the authorities, and therefore, the benefits of a liquid balance sheet accrue mainly to the short-term wholesale financiers and not to the retail depositors or the deposit insurance agency. Indeed, as reflected in our model, short-term financiers charge lower interest rate for funding banks with a more liquid balance sheet, and banks overuse such funds because of the lower interest costs. By charging a higher deposit insurance premium accordingly, the authorities can correct for the distortion of incentives and restore the bank's action to the socially optimal. We are not the first to uncover such a "paradox of liquidity:" Myers and Rajan (1998) show that greater asset liquidity reduces the management's ability to commit crediably to an investment strategy that protects investors. In our case, greater asset liquidity, by allowing the wholesale financiers to exit without much loss, reduces their incentive to adopt liquidation strategies that protect retail depositors.

Outright ban on the use of short-term wholesale funds Another option is to restrict the use of wholesale funds in certain banks.

Lemma 3 *There exist parameter values of θ, L, D, W and ρ such that social welfare under $W = 0$ is higher than $W = 1 - D$.*

Proof. See Appendix. ■

Lemma 3 shows that there exist parameter values such that the outright ban on the banks' use of wholesale funds is better than exposing the system to the risk of noisy liquidations. The intuition is that the cost of not using wholesale funds are unused investment opportunities and no monitoring. Yet when unused investment opportunities are not too high and when wholesale financiers provide little monitoring (which is plausible when they are too senior and hence by Lemma 2 have lower incentives to monitor), outright ban on the use of wholesale funding is banks can improve social welfare.

Note that unused investment opportunities are not too high when D is high. As we showed in comparative statics in section 3.3 these are precisely the values where wholesale financiers' are likely not to monitor banks. So for such *depository* banks it will most likely be socially optimal to restrict their use of wholesale funds.

4 Discussion

4.1 Arm's length banking, Wholesale funding, and Financial fragility

The results of our model help explain two stylized facts highlighted by the behaviors of banks in recent years leading up to the recent financial turmoil:

- Why, in practice, do we observe that traditional banks funding mainly relationship loans are less likely to supplement retail deposits with short-term wholesale funds, while banks holding relatively arm's length assets are more likely to do so (Berlin and Mester, 1999; Kashyap et al. 2002; Berger et al. 2005; Song and Thakor, 2007)? Why is the proliferation of securitizations (and thus more arm's length assets on banks balance sheets) closely related to more active use of short-term wholesale funds?
- In the years leading up to the current credit market turmoil, why didn't the wholesale financiers, who had the capacity to monitor, exert sufficient market discipline on banks, and why did they exacerbate liquidity risks once the crisis was on the way?

The analyses of our model provide some new explanations. In our model, the wholesale financier's incentives to incur private monitoring efforts depend on (1) the availability and relevance of the costless public signal and (2) the private costs of liquidating the bank (note also that short-term wholesale funds in practice enjoy high claimant seniority to the liquidated assets). Arm's length assets and relationship loans differ critically in both of these two parameters:

- Arm's length assets typically have some costless public signals available in the form of secondary market prices or credit ratings, and they also have lower liquidation costs. According to our model, wholesale financiers will demand lower interest rates for funding banks holding arm's length assets because the lower need to incur private monitoring costs and the lower losses associated with premature liquidations.

- Relationship-based loans in contrast have few relevant public signals available and such assets typically have higher liquidation costs. Banks financing relationship loans thus need to pay a higher interest rate to attract short-term wholesale funds to compensate for their private monitoring costs.

- Therefore, banks holding relationship loans typically find it more expensive to use wholesale funding, which answers our first question: why banks holding relatively arm's length transaction loans or securities are more likely to use short-term wholesale funds.

In the years leading up to the 2007 credit market crisis, financial innovations and global liquidity conditions induced banks to acquire more arm's length assets that are more abundant (Dooley, Folkerts-Landau, Garberand, 2008). Banks in turn financed these assets heavily with short-term wholesale funds, because such an asset-liability match reduces funding costs (which is consistent with the predictions of our model). However, our model also shows that such a bank asset-liability match pattern observed in practice, although consistent with the banker's private incentive, is not necessarily consistent with the maximization of social welfare.

Our model explained how the availability of costless but noisy public signals on bank quality reduces the incentives of wholesale financiers to monitor, and creates the incentives for them to exit based on a negative noisy signal is further increased by their effective seniority over other longer-term sources of funding such as retail deposits. The analysis of our model is consistent with the behaviors of short-term wholesale funds in many bank failure events such as Continental Illinois, Northern Rock, IndyMac, and reveal the "dark side" of bank wholesale funding:

- The short-term wholesale funds seemed to have acted based on noisy public signals more than private information on individual banks' fundamentals. In the case of Continental Illinois's failure, the collapse of the energy sector and the Penn Square Bank (to which the market suspected Continental Illinois had large exposures) triggered the event. In the case of Northern Rock failure, the US subprime mortgage crisis caused the freezing of wholesale funding markets across the board although Northern Rock had no material exposure to the US subprime sector[6];

- When the short-term wholesale funds exit, they typically managed to withdraw ahead of the retail depositors and the authorities, and suffered few losses.[7]

To maximize social welfare, our model suggests that banks relying on wholesale funding should either make their loans more relationship-based or reduce the effective seniority of the wholesale funds [8], in order to dampen their incentives to prematurely liquidate banks based on noisy public signals. Such changes in asset-liability arrangement can encourage market discipline and reduce liquidity risks (the benefits of which are not fully internalized by the banks), but will also raise the interest rate demanded by the wholesale financiers, reducing the profits of the banks. Therefore, the self-interest of bankers would not lead them to adopt the socially optimal solution described above, and would instead drive them to adopt the more fragile asset-liability structures that we observe in practice, i.e., banks funding relatively arm's length assets such as mortgage-backed securities are more enthusiastic in complementing their retail deposits with short-term

[6]In a letter to The Economist, the chairman of Northern Rock, Matt Ridley, wrote: "We were repeatedly advised that liquidity in wholesale markets depended on lending quality: good loan books would continue to attract funding when bad loans began to default. Instead, from August 9, liquidity had dried up across all wholesale markets, making no distinction between loans of different quality, for much longer than even the most extreme forecast."

[7]Interestingly, the well-publicized retail depositor run on Northern Rock took place only after the bank had already nearly exhausted its liquid assets to pay off the exit of short-term wholesale funds. Marino and Bennett (1999) analyze six major bank failures in the US between 1984 and 1992 and find that uninsured large deposits fell significantly relative to small insured deposits prior to failures. During the New England banking crisis, failing banks experienced a 70 percent decline in their uninsured deposits in their final two years of operation while being able to raise insured deposits to replace the outflow. Billett, Garfinkel, and O'Neal (1998) also find that bank typically raised their use of insured deposits vis-a-vis wholesale deposits after being downgraded by the Moody's.

[8]Note that the effective seniority of wholesale funds reflects a combination many factors: official resolution policies (such as deposit insurance coverage in bank failures, and the treatment of wholesale creditors in central bank bailouts), private contractual arrangements (such as the collateralization of funding and inclusion of withdrawal suspension clauses), and behavioral factors (such as the sluggishness of the retail depositors). Observe that, by default, short-term wholesale financiers do enjoy effective seniority because of the first come–first served rule; any deviations from that would require additional contractual arrangements.

wholesale funds. As discussed in last section, taxation or deposit insurance that is fairly assessed on banks can help restore the distorted incentives.

Note that the model applies also to financial institutions that operate without retail depositors and use wholesale funds only. Conflicts of interest that we describe exist whenever liquidation payoffs are (for contractual or behavioral reasons) skewed across groups of creditor claimants e.g. short-term vs. long-term wholesale funds, or collateralized vs. unsecured wholesale funds. For example, Bear Stearns was financed by both long-term and short-term wholesale funds, with most of the short-term funds collateralized by marketable assets. Our model explains why secured short-term lenders, being effectively more senior, had insufficient incentives to acquire information on the bank's fundamentals, and were tempted to walk out upon noisy negative news. Had short-term wholesale funds been unsecured or with longer contractual maturity (implying lower effective seniority), their providers would have had higher incentives to monitor and would have been less likely to abruptly stop funding Bear Stearns.

4.2 Robustness: Multiple financiers

4.3 Systemic effects

4.4 Relationship to corporate finance literature

5 Conclusion

Our paper demonstrates the possibility of opportunistic behaviors by short-term wholesale financiers (that they do not monitor banks and instead withdraw based on noisy public signals) and by banks (using such risky wholesale funds).

We show how short-term wholesale financiers can "run" on banks based solely on costless but possibly very noisy public signals regarding bank asset quality. Their incentives to run may offset or even dominate the incentives to monitor (as is highlighted by Calomiris and Kahn, 1991). In principle, the risk of wholesale runs can be reduced by assigning lower creditor seniority to them. However banks may have contrasting private incentives: we show that the use of senior wholesale funds generates interest rate savings for banks. Moreover, making short-term wholesale funds sufficiently junior may be outright impossible due to the sequential service constraint.

In a bank cross-section, our model predicts that the use of short-term wholesale financiers would have more beneficial effects in "traditional" banks holding mainly opaque and non-tradeable relationship loans. In contrast, the use of wholesale funds is likely to create additional risks for "modern" banks with large exposures to arm's length assets with readily available public information, such as secondary market prices and credit ratings on bank assets. These predictions are consistent with evidence from the credit markets turmoil of 2007–.

The paper discusses a number of policy options, including a risk-based deposit insurance (or taxation) formula that takes into account the influence of short-term wholesale funds, and outright ban on the use of short-term wholesale funds in banks most exposed to the risk of wholesale runs. The paper analyzes these options advantages and limitations.

A Proofs

Lemma 1

1. To see that $d\Pi^B/ds > 0$ consider:

$$\frac{d\Pi^B}{ds} = m^W(1-p)sL(D+W) - \frac{d(C(m^W) - m^W(1-p)sL(D+W))}{ds}$$

Use (5) to re-arrange:

$$\begin{aligned}\frac{d\Pi^B}{ds} &= m^W(1-p)sL(D+W) - \frac{d(C(m^W) - m^W C'(m^W))}{dm^W}\frac{dm^W}{ds} \\ &= m^W(1-p)sL(D+W) + m^W C''(m^W)\frac{dm^W}{ds}\end{aligned}$$

Observe that $m^W(1-p)sL(D+W) > 0$. Recall that $C''(m^W) > 0$ and $dm_W/ds > 0$. Therefore both terms are positive and $d\Pi^B/ds > 0$. QED.

2. To see that $d\Pi^B/ds > 0$ consider:

$$\begin{aligned}\frac{d\Pi^B}{dW} &= pX - \frac{d(pWR)}{dW} \\ &= pX - \rho - \frac{d(C(m^W) - m^W(1-p)sL(D+W))}{dW}\end{aligned}$$

Use (5) to re-arrange:

$$\begin{aligned}\frac{d\Pi^B}{dW} &= pX - \rho - \frac{d(C(m^W) - m^W C'(m^W))}{dm^W}\frac{dm^W}{dW} \\ &= pX - \rho + m^W C''(m^W)\frac{dm^W}{dW}\end{aligned}$$

Recall that $pX > \rho$. Also recall that $C''(m^W) > 0$ and $dm_W/dW > 0$. Therefore $d\Pi^B/ds > 0$. QED.

Lemma 2 Points 1 and 2 were explained in text. Point 3 requires that m^W and m^W_{Liq} are continuous at s^W. This is easy to verify by applying $[p - \theta p]\, pWR = s^W L(D+W)$ from (12) to m^W (5) and m^W_{Liq}(14). QED.

Proposition 2 We construct an example of parameters under which a bank chooses to assign short-term wholesale financiers creditor seniority $s = 1$ instead of $s = s^W$. This is sufficient to prove existence.

1. Consider a function $C(m)$ which is almost horizontal until the close environ of certain $\bar{m}$, is increasing in that small environ, and is almost vertical after that. This makes the wholesale financiers' choice of monitoring always very close to $\bar{m}$. Such a function allows to make the effects on seniority on m secondary to the effects of seniority on liquidation decisions and interest rates.

2. We further take:

   - $\bar{m}$ and $C(\bar{m})$ to be both close to 0
   - liquidation value L to be the highest possible: $L = pW$
   - precision of signal θ to be the highest possible: $\theta = \theta^* = 1 - \frac{L}{pX} = 1 - \frac{W}{X}$

3. Under these conditions:

$$\begin{aligned} R(s^W) &= \frac{W\rho + C(m^W) - m^W(1-p)sL(D+W)}{Wp} = \frac{\rho}{p} \\ s^W &= \frac{(1-\theta)pW}{L} = \frac{W}{X}\frac{\rho}{p} \end{aligned}$$

4. We can substitute everything into the inequality in question:

$$\begin{aligned} (1-p)L(D+W)(1-s^W) &> \Delta \\ (1-p)pW(D+W)\left(1 - \frac{W}{X}\frac{\rho}{p}\right) &> p\frac{W}{X}(1-p)\left[D(X-1) + W\left(X - \frac{\rho}{p}\right)\right] \end{aligned}$$

5. Arranging terms gives:

$$\begin{aligned} X(D+W) &> D(X-1) + WX \\ D &> 0 \end{aligned}$$

   which always holds. QED.

6. 6. As a side-line, note that the inequality $(1-p)L(D+W)(1-s^W) > \Delta$ does not necessarily hold under milder condition. For example, it does not hold for L close to 0, for θ close to to θ^W (which would make $s^W = 1$).

Lemma 3

1. Consider similar parameter values as those in the proof of Proposition 2. Then an unregulated bank chooses $W = 1 - D$ and $s = 1$. Then the social welfare is

$$\Pi_{Liq} = [p\,[p + \theta(1-p)]\,X + (1-p)L] - 1$$

2. The social welfare under W equal to 0 is

$$\Pi^{+} = D(pX - 1)$$

3. Now take D is close to 1, so that W (and hence L) are both close to 0 in the non-zero case. Then $\Pi^{+} > \Pi_{Liq}$ reduces to

$$pX > p\,[p + \theta(1-p)]\,X$$

QED

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Figure 1.

Liquidation and monitoring decisions of wholesale financiers.

Left panel: **Without a noisy signal** *Right panel:* **With a noisy signal**