Self-Destroying Prophecies? The Endogeneity Pitfall in Using Market Signals as Triggers for Prompt Corrective Action.

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Abstract

In recent years, authorities from bank supervisors to firm managers or even terrorism fighters have shown increasing interest in the extraction of information from market prices. We argue that the use of market data as guides to action leads to a "double endogeneity problem". Using a private information/action game between an authority and market participants we show that the intended use of market prices for the purpose of prevention may destroy their very information content. We also show under which assumptions market data remain valid risk indicators.

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"[M]arkets ... are extremely efficient, effective and timely aggregators of dispersed and even hidden information." (Defense Advanced Research Projects Agency, US Ministry of Defense, July 2003)

1 Introduction

How should a bank supervisory authority react to seeing the yields on an individual banking institution's debt soar? To begin with, the supervisory authority would probably be concerned. After all, the yield of a debt instrument—as far as it exceeds the yield of a risk-free asset—measures the market perception of the issuer's default risk. A strong increase in the yield would signal that the market has bad news about the solvency of the debtor. Such news may not be otherwise available to the supervisor. Researchers have found that market prices (and quantities) do in fact contain useful information not yet known by supervisors (see below).

Disregarding market signals therefore can hardly be an optimal strategy for a supervisor. This is recognized by an increasing reliance by supervisors on market data—on "indirect market discipline", in the terminology of the "Basel 2" agreement among bank supervisors and central banks.[1] The former Fed chairman Greenspan has admitted the potential value of market information:

"Significant changes in a banking organization's debt spreads, in absolute terms or compared with peer banks, can prompt more intensive monitoring of the institution." (Greenspan, 2001)[2]

As that statement also illustrates, supervisory authorities have been reluctant to pin down their reactions to market movements in advance. Proposals made by Calomiris (1999), Evanoff and Wall (2001) or Herring (2004) suggesting a direct link between a bank's risk premium over the market rate of interest and supervisory intervention have met with skepticism on the side of bank supervisors. "I do not need a spring gun," a Swiss supervisor remarked to one of the authors of the present paper.

Central bankers have known the issue of price-based intervention for long. It arises, for example in the context of exchange rate bands. Over the last few years it has been discussed under the heading: "Should central banks burst bubbles?" Both, advocates, like Roubini (2006), and skeptics, like Posen (2006) seem to agree that asset prices may contain information useful for monetary policy.

More recently, interest in prices as guides for action came from an unlikely corner. In 2003, an agency of the U.S. Ministry of Defense disclosed plans for "political analysis market", a futures exchange where traders could speculate on events like terrorist attacks or political assassination (for details see Wolfers

[1] *Direct* market discipline refers to a risk-sensitive supply of funds by investors. *Indirect* market discipline means that supervisors benefit from the information content of market prices in their assessment of bank risk.

[2] For further references see (Bond, Goldstein and Prescott, 2006).

and Zitzewitz, 2004). This market would have been introduced with the explicit goal of learning from prices. The proponents of the idea argued that markets aggregate dispersed information (see our introductory quotation) and could help to predict and, hopefully, to prevent terrorist attacks.

After becoming public the project was quickly abandoned amid a storm of political and moral opposition.[3] There was not much of an economic debate about whether the plan might have worked at all. Not even those few economists[4] who voiced their views asked whether prices could at the same time *predict* an event and help to *prevent* it.

The present paper tries to close this gap. We use a dynamic rational expectations model to investigate the trading strategy of investors endowed with private information about the probability of failure of a particular bank. In this setting a supervisory authority tries to extract information from the observed market prices. It uses this information to optimize costly action to prevent bank failure. We argue that this use of market signals for policy purposes may fundamentally change their information content or may even lead to a market breakdown. It is easy to see why. Prices, in the ideal case, reflect all information available to the market, including beliefs about any future policy that may affect economic fundamentals. Technically speaking, prices are endogenous to policy. If, in turn, policy reacts to prices, both prices and policies mutually depend on each other. There is a "double endogeneity problem".

In the context of bank supervision this problem has largely been overlooked both by advocates and opponents of price-based action. This seems odd, as it has long been recognized in the context of exchange rate target zones, for example by Krugman (1991) who also shows that an equilibrium may exist despite the mutual endogeneity of prices and actions.

In Section 2 we review the literature on the information content of market prices for bank supervisors. In Section 3 we introduce the double endogeneity effect informally by way of examples. In Section 4 we develop a formal model of asset pricing under price-based intervention. In Section 5 we discuss the results and develop the concept of price-neutral intervention. Section 6 concludes.

2 The informational content of prices for bank debt and equity

It has long been recognized that prices aggregate "the dispersed bits of incomplete and frequently contradictory knowledge which all the separate individuals possess", as von Hayek (1945, p. 519, 525) put it. Grossman (1976) later formalized the idea that market prices are a sufficient statistic for underlying information, at least under simplifying assumptions. Complications arise when markets are incomplete (Brunnermeier, 2001), in the presence of *noise* (Hellwig,

[3]Ironically, a betting market correctly predicted the imminent resignation of the person responsible for the project.

[4] An example is Hal Varian, "A Good Idea With a Bad Press", *The New York Times*, 31 July 2003.

1980) or when information is *endogenous* (Grossman and Stiglitz, 1980; Verrecchia, 1982). An observed price structure thus may not be a perfect mirror of the underlying fundamental conditions, but still a useful source of information.

Markets add the fire of self interest to the fuel of statistics: "market participants have an incentive to look through reported accounting figures to the real financial condition of a bank and to price a bank's securities based on their best estimates of the distribution of the security's future cash-flows" (Flannery, 2001). Although supervisors can collect confidential data, market information may be just as reliable.

Several empirical studies have examined the information content of market data on bank risk for the US (Flannery, 1998; Berger, Davies and Flannery, 2000; Evanoff and Wall, 2002; Krainer and Lopez, 2004; DeYoung, Flannery et al., 2001; Swidler and Wilcox, 2002; Curry, Elmer and Fissel, 2003; Fan, Haubrich et al., 2003; Krishnan, Ritchken and Thomson, 2006), for European countries (Gropp et al., 2002; Persson, 2002; Sironi, 2003; Cannata and Quagliariello, 2005), for Japan (Brewer et al., 2003), and for emerging countries (Bongini et al., 2002; Sy, 2002).

The different studies show that in industrial countries markets, particularly those for equity and for subordinated debt (BCBS (Basel Committee on Banking Suvervision), 2003), are sufficiently developed to provide meaningful information for supervisors. Several researchers argue that market data contain information which is *not yet* part of confidential supervisors information. Conversely, market data do not reflect *all* information available to supervisors. In other words, the empirical evidence suggests that supervisory information and market information are *complementary* sources of bank supervisory intelligence.

One might conclude that supervisors should not neglect the information contained in market prices. However, the evidence cited stems from a period in which supervisors did probably not react much to changes in market data. It may not carry forward to an environment where markets expect supervisors to *react* to market data.

3 The double endogeneity problem

3.1 A potential paradox

Let us start from an example: Assume that banking supervisory authority, following a suggestion by Calomiris (1999), declares to intervene whenever the risk premium a bank pays on subordinated debt (the difference in yield to a comparable treasury bond) hits some threshold. Let this threshold be a 5 per cent p.a.. Assume further that an intervention (a mandatory recapitalization, say) is always successful in the sense that it prevents the bank from defaulting.

What would be the consequence? Rational investors would anticipate that whenever a bank's subordinated yield spread hits the 5 per cent ceiling, recapitalization would follow. After recapitalization, the bank would be quite safe again. No investor would thus sell subordinated debt at a discount corresponding to a yield spread of 5 per cent. Thus, the spread would never hit the threshold, and the authority would never intervene—but then the bank may indeed fail, and the spread should reflect that failure.

This paradox is explained by the informational efficiency of the market: In an informationally efficient market all available information is reflected in the price. This includes information or beliefs about supervisory reactions to observed prices. The price—here: the implied risk premium—therefore does not reflect the bank's risk pre-intervention, but post-intervention. Prices, in other words, are *endogenous* to expected policy reactions. An authority who misreads market prices as signals of pre-intervention probabilities would therefore be misguided.

The example is reminiscent of the well-known case of an exchange rate target. In the context of exchange rate intervention, the endogeneity effect has long been known. Krugman (1991) for example pointed out that exchange rate target zones had an impact on exchange rates long before these hit any of the intervention points. In fact, if the target band is perfectly credible, the central bank never has to intervene.

3.2 Fragile equilibrium

The exchange rate example also illustrates that even in the face of endogenous action, there may be an equilibrium. Market participants try to anticipate the authority's action, while the authority tries to anticipate market participants' reasoning. In equilibrium, both parties are right and hold consistent beliefs. In the context of bank supervision the logic behind an equilibrium can be shown with the following arbitrary example.

The supervisory authority again observes the risk premium banks pay on subordinated debt. It is common knowledge that the authority acts according to the following scheme: (i) from the observed risk premium the authority infers the probability with which the bank would fail in the absence of supervisory intervention; (ii) the authority intervenes in a way to reduce the perceived probability of failure (without intervention) by half.

The authority may observe a risk premium for a bank of 3 per cent. With risk-neutral investors this would roughly correspond to a 3 per cent probability of failure. This would suggest that the market believes the bank has a 6 per cent probability of failure. The authority would take corrective action to reduce this probability by half, leaving the bank with a 3 per cent post-intervention chance of failure. This is exactly what market participants expected when they traded the bank's debt. No party regrets their decision in the light of other parties' decisions; the market thus is in *equilibrium*.

The equilibrium price fully reveals the bank's failure probabilities, both with and without supervisory intervention. However, while it directly reflects the post-intervention probability (of 3 per cent), it only indirectly reveals the pre-intervention probability (of 6 per cent).

Note that in the example the authority did not reduce the bank's risk of failure to zero. A "zero tolerance" policy would kill the message (the information content of the market price). So would any policy to achieve a fixed target probability of failure. The post-intervention probability of failure must be an increasing function of its pre-intervention probability if an equilibrium should exist.

3.3 Previous literature

We have already mentioned that the mutual endogeneity of prices and price-based action was recognized in the context of exchange rates by Krugman (1991). In the debate about whether central banks should react to asset price developments (to bubbles, in particular), Cecchetti, Genberg and Wadhwani (2002, p. 5) for example note that the mere expectation of a central bank's intent to react to asset prices would already change their dynamics: "if it were known that monetary policy would act to 'lean against the wind' in this way' it might reduce the probability of bubbles arising at all".

In the context of bank supervision the double endogeneity effect was long overlooked. DeYoung, Flannery et al. (2001) were led to the effect by some puzzling empirical evidence: They found that after an unexpectedly poor outcome of an on-site examination bond spreads of financially troubled banks *decreased*, rather than increased. They conclude that a poor result of a supervisory examination was more likely to trigger prompt corrective action and that "the anticipated regulatory response frequently dominates the information's implications about current bank conditions." (DeYoung, Flannery et al., 2001, p. 902). Shin (2002) mentions that banks' asset values were affected by the endogenous response of authorities during a currency crisis.

An explicit discussion of the endogeneity effect in the context of bank supervision can be found in Birchler and Facchinetti (2006). Bond, Goldstein and Prescott (2006) offer a more formal treatment of some aspects. In their model the action set of the authority is binary, i.e., it can either intervene or not intervene. They show that under reasonable parameter values, there may be multiple equilibria or no equilibria at all. A key determinant for the existence or efficiency of equilibria is the difference between the authority's and the market's prior uncertainty about bank fundamentals (the "information gap").

Another model of price-based intervention was developed by Lehar, Seppi and Strobl (2006). Using a binary intervention space as well they find that the supervisory use of market prices may distort information and incentives. The focus of the paper is on the interaction between policy response and *information acquisition*, rather than the efficient representation of *existing* information in prices.

An important difference between this literature and our paper is the modelling of supervisory action. While both Bond, Goldstein and Prescott (2006) and Lehar, Seppi and Strobl (2006) only leave a binary "yes-or-no" action to the authority, in our model the supervisory authority's action space is *continuous*. This is not only more realistic. More importantly, in a continuous action setting, a unique equilibrium is much more likely to exist than under binary action. Under a continuous intervention space with monotonous intervention cost the unique equilibrium is also *information revealing*.

The special case of binary action in our model is captured by use of a "quasi-fixed cost" of intervention. In the presence of a quasi-fixed cost the optimal action level "jumps" at some critical market price. In the presence of a quasi-fixed cost we therefore find effects similar to those in the binary setting of Bond, Goldstein and Prescott (2006). Their point of departure, "the fact that prices *affect* and *reflect* the supervisor's action at the same time makes the analysis of equilibrium outcomes [...] quite hard" (Bond, Goldstein and Prescott, 2006, p. 4), is also a good "leitmotiv" for our model.

4 The model

4.1 Assumptions

Outcomes

Our simple economy has two final outcomes; these are denoted by $\omega \in \{1, 0\}$ indicating whether a certain negative "event" has been avoided or not. We will think of the event as the failure of a bank.

The exogenous prior probability of the negative event "bank failure" is $\Pr(\omega = 0) = \pi_0$. With the complementary probability $\Pr(\omega = 1) = 1 - \pi_0$ the bank remains solvent. We assume that nature draws π_0 from a uniform distribution

$$\pi_0 \sim U\left[\frac{1}{2} - \sigma; \frac{1}{2} + \sigma\right],$$

with $\sigma \leq \frac{1}{2}$.

The authority

An authority prefers the bank to remain solvent. The risk-neutral authority considers a bank failure as a deadweight social loss of $v(\omega)$. We normalize the loss in case of solvency to zero, i.e. $v(0) = v \geq v(1) = 0$.

Based on its beliefs (to be modelled below) about the true value of π_0 the authority can take some action $a \in [0, \infty]$ to influence the posterior probability of the event π. In the context of bank supervision the authority may, for example, increase capital requirements or change bank management in order to reduce the probability of a bank default. The posterior likelihood that the bank fails is therefore a function of the prior probability of default π_0 and of the intensity of intervention, that is

$$\pi = \pi(\pi_0, a).$$

For simplicity we assume that:

$$\pi = \frac{\pi_0}{1 + a}. \quad (1)$$

The cost of intervention is given by

$$c = c(a),$$

with $\frac{\partial c}{\partial a} > 0$, $\frac{\partial^2 c}{\partial a^2} \geq 0$ and $c(0) = 0$. In addition $c(a)$ has a quasi-fixed costs component, that arises when $a > 0$. We assume that:

$$c(a) = ka + K(a), \tag{2}$$

where

$$K(a) = \left\{ \begin{array}{l} K \ \text{ if } a > 0 \\ 0 \text{ otherwise.} \end{array} \right\}$$

This implies that the authority takes action (i.e., chooses $a > 0$) only when the benefits of intervention are high enough so to justify the occurrence of the quasi-fixed costs. In Section 4.4.2, we will show that this is the case when the prior probability of bank failure exceeds some threshold. As a tie-breaker we assume that in the border case where the authority is indifferent it does not intervene.

The quasi-fixed cost implies a "jump" in the cost function. For simplicity we assumed that this jump occurs at $a = 0$. One could also assume that a jump occurs at a positive level of a, for example at the point when the authority's intervention reaches a dimension that makes it public, assuming that the authority prefers "covert" interventions.

In the context of banking supervision, the quasi-fixed costs setting appears particularly realistic. In fact, it is reasonable to assume that supervisors dislike interfering in banks' business. This is particularly true for measures that are publicly observable, like a mandatory issue of capital, a dividend reduction or a management removal as such measures may have additional negative implications, like public criticism or even panic reactions by depositors. Proposals to tie supervisory intervention to market prices (Calomiris, 1999; Evanoff and Wall, 2001) exactly aim at forcing authorities to overcome quasi-fixed cost barriers.

Individuals

The authority cannot observe π_0 directly. There is, however, a mass of homogeneous, risk-neutral individuals. Some of these (the "insiders") can observe π_0. While the realization of π_0 is private knowledge of insiders, everything else, including the distribution of π_0, is common knowledge. For reasons to be explained below, we call the other, uninformed individuals "noise traders". Each individual, insider or uninformed, is endowed with a small amount of the numeraire.

The market

There is an asset which pays one dollar if the negative event does not happen ($\omega = 1$), that is if the bank remains solvent, and nothing if the event happens ($\omega = 0$), that is if the bank fails. The asset is traded in a market free of operational cost. The asset can be bought as well as sold short. However, if investors sell the asset short, they must pledge numeraire as collateral. Nature randomly selects the order investors can trade. When it is their turn, investors submit the desired order. Given the small individual amount of the numeraire available, each individual can trade only once. The price at which the asset trades is denoted by $q \in [0; 1]$. q is publicly observable.

For most of the paper it is sufficient to think of a frictionless market in which informed individuals immediately drive the price to its equilibrium value. Yet, we prefer to use a dynamic model of market microstructure with sequential trades. Such a setting is more close to reality and the spirit of Calomiris (1999), where authorities look at the evolution of asset prices over time. Secondly, we believe that a model of sequential trades makes the derivation of the main results more intuitive.

In addition, we explicitly model the supply side of the market. As Milgrom and Stokey (1982) have shown, the existence of informed individuals, if commonly known, prevents trading: Uninformed individuals would never rationally speculate against informed individuals. Kyle (1985) argues that a positive amount of trading can occur if there are a sufficient number of noise traders who trade for reasons other than speculation. In order to allow for a positive amount of trading and prices that are free from noise we assume that the authority acts as a market maker offering to buy and sell the asset at the same price. The authority stands for the community of noise traders in the sense of Kyle (1985). Market making imposes a loss to the authority. We assume that the authority considers such loss as a sunk cost required to get valuable information from observing the equilibrium price. From a social point of view, the authority's loss is compensated by individuals' profits. Anyway it could be recovered by a lump sum tax. Our assumptions imply that there is in principle no restriction on the price setting process, as long as it optimizes the information extraction. As a corollary, we can assume without loss of generality that the bid-ask spread is always zero.

The market starts with the authority posting a price reflecting the prior probability π_0. At that price the authority gets either a buy order ($x > 0$) or a sell order ($x < 0$). After observing the direction of the trade, the authority adjusts its expectations about π_0 – down after a buy order, up after a sell order – and the price of the security. This process goes on until $x = 0$ or until the market closes.

In a general context, the current price of the security as well as its volume traded represent the market signals, $\mathbf{M}$, available to the authority. Since the authority acts as market maker and sets the price on the base of the order book, $\mathbf{M} = \{x_1; x_2; ...\} = X$ reflects the set of all trades. The price becomes a sufficient statistic of the information set of the authority. At the end of the "day", when all individuals have posted their orders, the market closes with price q. As q exhausts the authorities information, we can use it instead of $\mathbf{M}$.

Time line

Events in the model are summarized by the time line represented in Figure 1. In $t = 0$, insiders learn the true realization of π_0. In $t = 1$, the security is traded

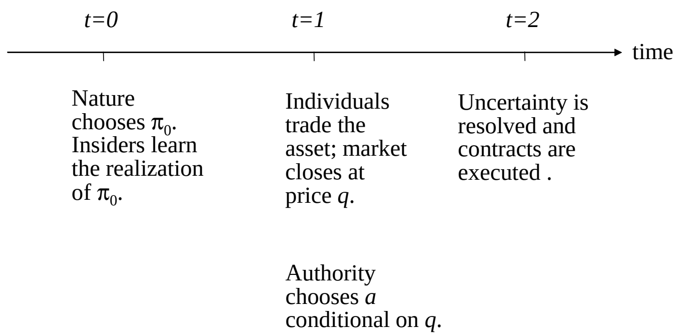

Figure 1: Time line

in the market. Still in $t = 1$, the authority, upon observing the market signals, can take its action a to reduce the probability of default. In $t = 2$, finally, nature decides whether the bank defaults or not. Individual investors get their respective payoffs from having bought or sold the asset.

4.2 Optimal strategies

The authority and individuals (among which the insiders) play a sequential game. Individuals move first (by trading), followed by the authority (choosing an action level). Solving the game backwards we first look at the authority's maximization problem.

The authority

If the authority knew the prior probability of the event, π_0, it would minimize expected loss by solving:

$$\min_a L = \pi\left(\pi_0, a\right) v + c\left(a\right). \tag{3}$$

As the authority cannot observe π_0, it has to rely on indirect evidence: The authority may try to infer the private knowledge of insiders and hence the true value of π_0 from observed market signals. The resulting beliefs are denoted by π_0^R. Throughout the paper we denote beliefs by superscripts (R for the authority, I for individuals). π_0^R is a commonly known function of market signals, $\mathbf{M}$, and a is a function of π_0^R, i.e., $\pi_0^R = \pi_0^R\left(\mathbf{M}\right)$ and $a = a\left(\pi_0^R\right)$. As mentioned above, the authority revises its beliefs π_0^R downward after observing a buy order and upwards after a sell order. Hence, $\frac{\partial \pi_0^R(\mathbf{M})}{\partial x} < 0$.[5]

Relying on such beliefs the authority solves:

$$\min_a L = \pi^R\left(\pi_0^R(q), a\right) v + c\left(a\right), \tag{4}$$

[5] In other words, informed investors always trade in the "right direction" and do not try to fake the authority. We well see that this assumption is compatible with our competitive equilibria.

where π^R is the rationally believed posterior event probability, that is the probability resulting from taking action a when the belief π_0^R is true. Remind that q sums up the authority's information $\mathbf{M}$.

Under the specification chosen in (1) and (2) the authority's problem reads:

$$\min_a L = \frac{\pi_0^R(q)}{1+a}v + ka + K(a),$$

where $K(a)$ is the quasi-fixed component of the cost function, with $K(0) = 0$ and $K(>0) = K$. As the authority takes action ($a > 0$) only if the expected gains of intervention exceed the quasi-fixed costs, i.e., if

$$K < \hat{K} = \pi_0^R v - \frac{\pi_0^R v}{1+a} - ka, \tag{5}$$

the first-order condition (FOC) is

$$\begin{aligned} a &= \left(\frac{\pi_0^R v}{k}\right)^{\frac{1}{2}} - 1 \text{ if (5) is satisfied;} \\ a &= 0 \text{ otherwise.} \end{aligned} \tag{6}$$

Individuals

Individuals maximize their expected profits from trading the asset. Remind that the asset pays one dollar if the bank ends up solvent and nothing otherwise. Competitive risk-neutral individuals therefore buy (sell) the asset as long as its price q is below (above) $1 - \pi^I$, individuals' believed posterior probability of solvency. Market equilibrium is characterized by:

$$q = 1 - \pi^I.$$

Building their beliefs, rational investors take two kinds of information into account. The first is the observed prior probability π_0. The second is the anticipation that the authority will react on the market price it will observe. This is relevant for individuals, as the authority's choice of a has a direct effect on the value of the asset. Individuals

$$\pi^I = \pi^I(\pi_0, a^I(q)), \tag{7}$$

where $a^I(q)$ denotes individuals' belief regarding the action the authority will take upon seeing the market signals. A rational belief regarding $a^I(q)$ is:

$$a^I(q) = \arg\max L,$$

that is, individuals anticipate that the bank minimizes expected loss, as expressed in (3).

4.3 Equilibrium: Benchmark cases

Perfect information

Under perfect information, the authority can directly observe π_0. It then chooses a according to (3). The problem of the authority reads

$$\min_a L = \frac{\pi_0 v}{1+a} + ka + K(a)$$

and the FOC is

$$\begin{aligned} a &= \left(\frac{\pi_0 v}{k}\right)^{\frac{1}{2}} - 1 \text{ if (5) is satisfied;} \\ a &= 0 \text{ otherwise.} \end{aligned}$$

The level of action that solves the problem of the authority under perfect information is first best and we call it a^*.

No information

Under no information neither the authority nor individuals can observe the prior event probability π_0. What action would the authority choose?

The rational belief about π_0 would be its expectation

$$\pi_0^R = E(\pi_0) = 0.5$$

Under this belief, the optimal action is:

$$a = \left(\frac{v}{2k}\right)^{\frac{1}{2}} - 1$$

if (5) is satisfied and 0 otherwise. Therefore the equilibrium price of the security with no informed individuals, is

$$q_0 = 1 - \left(\frac{k}{2v}\right)^{\frac{1}{2}}$$

if the authority intervenes (if K is low enough) and 0.5 if it does not intervene.

4.4 Equilibrium: Asymmetric information

4.4.1 No quasi-fixed costs

Consider first the simplest albeit unrealistic case characterized by two assumptions:

1. There is an infinite number of informed investors endowed with a small amount of the numeraire but no uninformed investor.

2. There is no quasi-fixed cost of intervention, i.e., $K = 0$.

Remind that after every buy (sell) order the authority reduces (increases) its beliefs π_0^R by a small amount and that the security price always reflects the beliefs of the authority, i.e., $\frac{\partial \pi_0^R}{\partial x} < 0$ and $q = 1 - \left(\frac{\pi_0^R k}{v}\right)^{\frac{1}{2}}$. Therefore, $\frac{\partial q}{\partial x} = -\frac{\partial \pi_0^R}{\partial x}\left(\frac{k}{4\pi_0^R v}\right)^{\frac{1}{2}} > 0$. Finally, how the authority updates its beliefs is common knowledge.

The authority solves (4). Investors anticipate and trade the asset at a closing price reflecting rational expectations (7). We will show that in such a setting the following holds:

Proposition 1 *In equilibrium the insiders reveal all their private information. As a result the authority and the informed investors have the same beliefs about the probability of default, that is* $\pi_0^R\left(q^C\right) = \pi_0$*, where* q^C *is the equilibrium price of the security. This implies*

$$a^I = a^* = \left(\frac{\pi_0 v}{k}\right)^{\frac{1}{2}} - 1$$

and

$$q^C = 1 - \frac{\pi_0}{1+a^*} = 1 - \left(\frac{\pi_0 k}{v}\right)^{\frac{1}{2}}.$$

The PBE is unique and first best, since the chosen level of protection is optimal given π_0.

Proof. Existence follows directly since the level of protection is optimal and the price reflects the true probability of default, so that no trader is willing to trade the security. Moreover, the beliefs $\frac{\partial \pi_0^R}{\partial x} < 0$ are compatible with the equilibrium: At any price an insider will sell (buy) a security only if its price exceeds (is lower than) its fundamental value (FV), i.e., if $1 - \left(\frac{\pi_0^R k}{v}\right)^{\frac{1}{2}} > (<) 1 - \left(\frac{\pi_0^2 k}{\pi_0^R v}\right)^{\frac{1}{2}}$. This condition holds for $\pi_0 > (<) \pi_0^R$.

In order to prove uniqueness remember first that by sequential rationality the insiders know in advance the beliefs of the authority $\pi_0^{R\prime}$ and hence the degree of intervention a', which will be ultimately chosen by the authority for a given price q'. Moreover, in every competitive equilibrium the price of the security for a predicted level of protection must equal the insiders' beliefs about the probability of default, i.e., $q' = 1 - \frac{\pi_0}{1+a^I}$ with $a^I = a'$. If this does not hold, there is always an incentive for some insiders to trade the security. In fact, suppose $q' > 1 - \frac{\pi_0}{1+a'}$. Since (6) is a smooth function of π_0^R and π_0^R is a smooth function of the order book, an informed investor could then sell a contract (which would decrease q respectively increase a by a small amount) and still make profits. As a result the equilibrium value of q must reveal the beliefs of the informed investors, which the authority knows they represent the true probability of default. Hence, it is not possible that $\pi_0^R\left(q^C\right) \neq \pi_0$. Uniqueness follows directly. ■

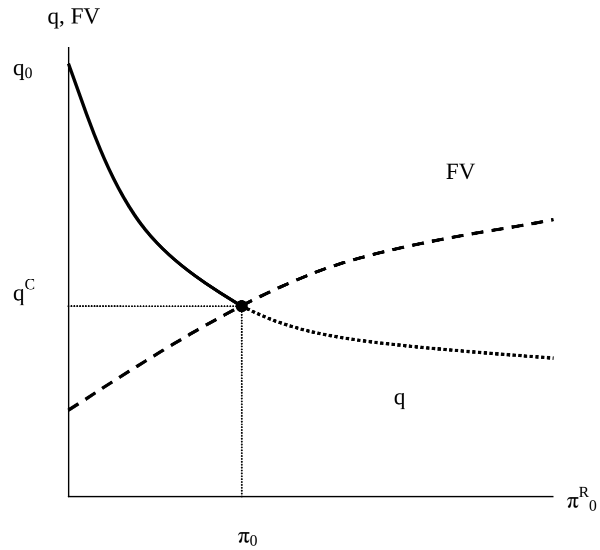

Figure 2: Equilibrium without quasi-fixed cost ($K = 0$).

As an example, assume that nature chooses $\pi_0 > 0.5$. In this case the fundamental value of the contract, which is known by the insiders, is less than the competitive price before the insiders learn π_0.[6] As the informed investors start to sell contracts short, q falls, since after each sell order the authority updates its beliefs and π_0^R goes up. At the same time the expectations of the insiders about the degree of intervention ultimately chosen by the authority increase too. As long as $\pi_0^R < \pi_0$ however, some investors want to sell the security and the updating process continues. This will eventually end when the equilibrium values described in Proposition 1 are reached (see Figure 2).

Note that the specific functional form of π_0^R does not play any role for the level of the equilibrium price, as long as $\frac{\partial \pi_0^R}{\partial x} < 0$. On the other hand, $q = 1 - \left(\frac{\pi_0^R k}{v}\right)^{\frac{1}{2}}$ is the only pricing process that leads to an equilibrium. To see this, remember that trading stops only if the price equals the fundamental value of the security, that is, if $q = FV = 1 - \left(\frac{\pi_0^2 k}{\pi_0^R v}\right)^{\frac{1}{2}}$. Hence, when insiders cease to trade the authority can infer π_0 from q. However, this presupposes that π_0^R does not change after trading stops. For all π_0, this is only possible when $q = 1 - \left(\frac{\pi_0^R k}{v}\right)^{\frac{1}{2}}$.

[6] $\left(\frac{\pi_0 k}{v}\right)^{\frac{1}{2}} > \left(\frac{k}{2v}\right)^{\frac{1}{2}}$.

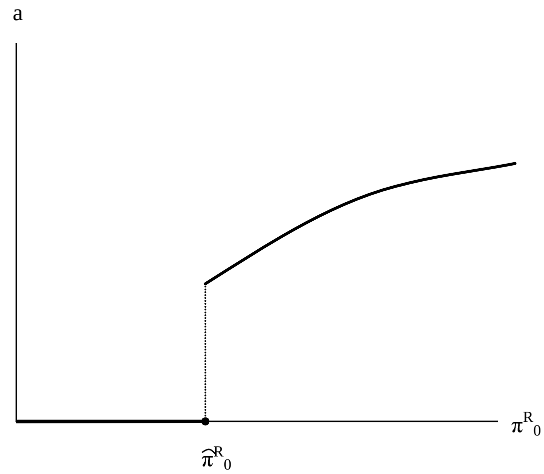

Figure 3: Reaction function of the authority with quasi-fixed cost

With a little bit of comparative static, some interesting results may be derived from this simple model. Suppose, for instance, that $k = 0$. I.e., the authority can intervene at no cost and is always successful so that the probability that the bank will ever go bust is zero as long as $\pi_0^R > 0$. Given the assumptions made above $\pi_0^R = 0$ only if $q = 1$. Is this an equilibrium? Yes, but only if the authority intervenes ($a \to \infty$) also although it thinks that the probability of default is zero. Otherwise no equilibrium exists, since as long as the authority is thought to intervene, the equilibrium price can only be $q = 1$. But if it does not intervene when $q = 1$, the bond becomes risky. This paradox arises in more realistic settings, as shown in the next section.

4.4.2 Quasi-fixed costs

Even if the number of informed investors is infinite, the introduction of quasi-fixed costs has important effects for the equilibrium. In particular, the authority begins to intervene only if its beliefs about the original probability of default are high enough so that the expected gains of intervention cover the quasi-fixed costs. This is the case when $\pi_0^R > \widehat{\pi}_0^R$,[7] as shown in Figure 3. As a result the (hypothetical) degree of intervention a would be a non-continuous function of π_0^R. In particular, when the threshold $\widehat{\pi}_0^R$ is reached, the next sell order will let the implied degree of intervention jump at the level described by (6).[8]

Suppose again that $\frac{\partial \pi_0^R}{\partial x} < 0$ and that the security price always reflects the

[7] See the appendix for a derivation of $\widehat{\pi}_0$ and $\widehat{\pi}_0^R$.

[8] The jump in the authority's action level introduces an element of binary decisions as used in Bond et al. (2006). Note that under a binary action space there is no meaningful distinction between fixed, variable or quasi-fixed cost of intervention.

beliefs of the authority. Then, the authority intervenes only if the price of the security when the market closes is greater than the price implied by $\widehat{\pi}_0^R$, which we call $\hat{q}$. But if the investors are rational, they anticipate that the authority will intervene if the security price goes beyond this specific level. This leads to the following result:

Proposition 2 *In a competitive environment with quasi-fixed costs, the authority begins to intervene only if its beliefs π_0^R are high enough. But when this threshold is reached, the degree of protection jumps at the level described by (6). Hence, there is a discontinuity in the "reaction function" of the authority that can considerably reduce the potential for information extraction. As a result, equilibrium may be suboptimal.*

Proof. Obviously, neither "do not intervene in any case" nor "always set a according to (6)" can be equilibrium strategies. Given $\frac{\partial \pi_0^R}{\partial x} < 0$, the best thing the authority can do is to intervene when π_0^R is high enough, i.e., when the price of the security falls below some value $\widetilde{q}$. In such an equilibrium the competitive price of the security must be equal to $1 - \pi_0$ if the probability of default is less or equal to $1 - \widetilde{q}$. Moreover, since (5) is a smooth function of π_0^R, at $\widetilde{q}$ the authority must be indifferent between intervening or not, i.e., $\pi_0^R = \widehat{\pi}_0^R$. This implies that if there is a one to one relationship between π_0 and then security price, $\widetilde{q}$ must be equal to $\hat{q}$. We will show that this is not the case. In fact, suppose that $\pi_0 = 1 - \hat{q} + \varepsilon$ (ε small) and the price of the security is currently $\hat{q}$. An informed investor will sell short an additional security when

$$\begin{aligned} 1 - \pi\left(\pi_0, a^I \mid \text{ex trade}\right) &< \hat{q} \\ 1 - \frac{1 - \hat{q} + \varepsilon}{1 + a^I_{\text{ex trade}}} &< \hat{q} \\ \varepsilon &> a^I_{\text{ex trade}} (1 - \hat{q}) \end{aligned}$$

with

$$a^I_{\text{ex trade}} = \left[\frac{\left(\pi_0^R \mid \text{ex trade}\right) v}{k} \right]^{\frac{1}{2}} - 1$$

But since $a^I_{\text{ex trade}} > 0$ given that the authority intervene when $q < \hat{q}$, for values of ε small enough the investors have no incentive to signal, that $\pi_0 > 1 - \hat{q}$. As a result, only if π_0 exceeds some threshold $\overline{\pi}_0$, the investors would let the price decrease below $\hat{q}$. The threshold $\overline{\pi}_0$ is the level of π_0 that implies an equilibrium price as defined in Proposition 1 that is not greater than $\hat{q}$. The problem is then that at $q = \hat{q}$ there would be a jump in the beliefs of the authority since

$$\begin{aligned} \left(\pi_0^R \mid q > \hat{q}\right) &= 1 - q \\ \left(\pi_0^R \mid q = \hat{q}\right) &= \frac{(1 - \hat{q}) + \overline{\pi}_0}{2} \\ \left(\pi_0^R \mid q < \hat{q}\right) &> \overline{\pi}_0. \end{aligned}$$

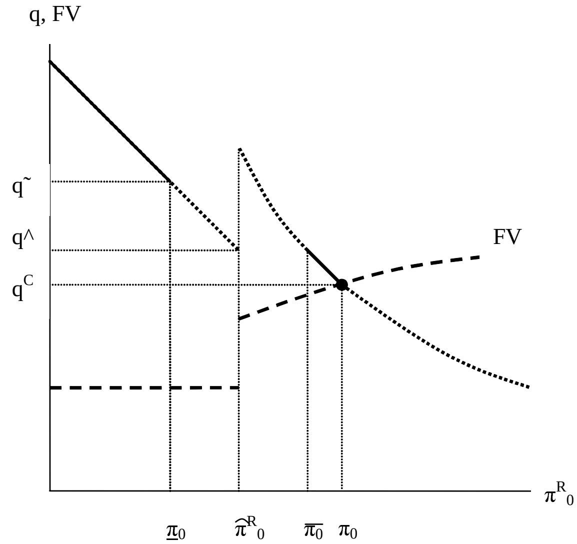

Figure 4: Fully revealing equilibrium with quasi-fixed cost.

In other words, $\left(\pi_0^R \mid q = \hat{q}\right)$ is greater than $\widehat{\pi}_0^R$. But then it would be unambiguously optimal for the authority to intervene when $q = \hat{q}$. This induces the investors not to let q rise to $\hat{q}$ also when $\pi_0 = 1 - \hat{q}$. But then the authority has to adjust again his beliefs when it observes a price slightly lower than $\hat{q}$. At the trigger price $\widetilde{q}$ the following condition must hold

$$\left(\pi_0^R \mid q = \widetilde{q}\right) = \frac{(1-\widetilde{q}) + \overline{\pi}_0}{2} = \frac{\underline{\pi}_0 + \overline{\pi}_0}{2} = \widehat{\pi}_0^R.$$

Hence, for $\pi_0 \in [\underline{\pi}_0, \overline{\pi}_0]$ the last trade takes place slightly above $\widetilde{q}$. Therefore, there is no one to one relationship between π_0 and the security price, which may be a very imprecise signal of the true value of π_0 (see Figure 4). For $\pi_0 \leq \widehat{\pi}_0$ this has no welfare implications as $a > 0$ would not be efficient. But for $\pi_0 \in [\widehat{\pi}_0, \overline{\pi}_0]$ the equilibrium is not first best is terms of welfare, as optimal intervention would cover the quasi-fixed costs for all $\pi_0 > \widehat{\pi}_0$.

The beliefs $\frac{\partial \pi_0^R}{\partial x} < 0$ are again compatible with the equilibrium. As opposed to the setting without quasi-fixed costs, π_0^R is not a smooth function of the trading volume, though. For instance, when an insider sells a security at $q = \hat{q}$, the beliefs of the authority increase from π_0^R to above $\overline{\pi}_0$. ■

Clearly, for a subset of π_0 a fully revealing equilibrium exists. Suppose, for instance, that $\widetilde{q} > \overline{\pi}_0$. Then, the insiders have the incentive the security also at the price that triggers supervisory intervention, since they know that the final price/FV of the security will be $q^C < \hat{q}$ (see Figure 5). Note that the security price actually never equals $\widetilde{q}$. After the sell order just above $\widetilde{q}$ the price jumps to

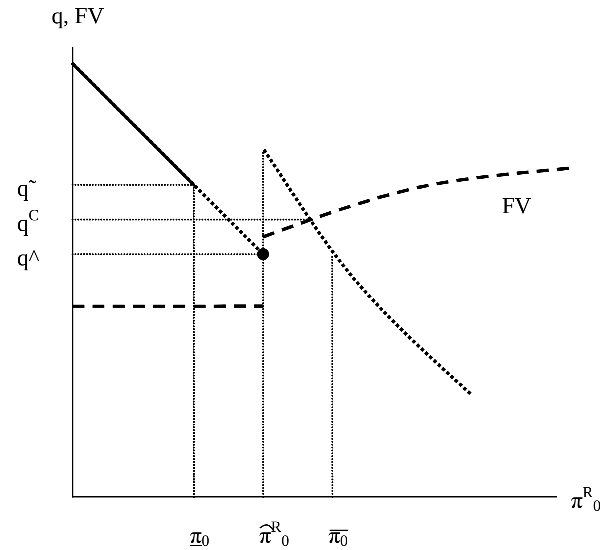

Figure 5: Partially revealing equilibrium with quasi-fixed cost.

$\hat{q}$ since $\pi_0^R = \widehat{\pi}_0^R$. Instead, when an insider sells at $\hat{q}$, the beliefs of the authority jumps from $\widehat{\pi}_0^R$ to $\overline{\pi}_0$ but the price of the security decreases only slightly.[9]

The higher the difference between π_0^R and $\overline{\pi}_0$, the more likely the price will be an imprecise signal of the true value of π_0. In particular, this is the case when the quasi-fixed cost component K in the loss function of the authority is relatively high.

Again, the case with $k = 0$, is particularly interesting. The basic paradox described in Section 3 is very similar to the case where the authority faces only quasi-fixed costs. In such a case, the authority reduces the probability of default to zero, whenever the price of the contract falls below some threshold, so that also the value of the security rises to one. Note that in this case $\overline{\pi}_0 = 1$ so that for no insider trades at q_0 if (5) is satisfied at the outset of the game and $\pi_0 < \frac{1}{2}$. The case of pure strategies with $k = 0$ may be interpreted as a case in which the authority has a particular rule for intervention (e.g., intervene if the spread on subordinated debt exceeds 3%) and when it intervenes, it is always successful.

What about semi-separating equilibria and mixed strategies? The authority would randomize only when indifferent between intervening or not, that is when $\pi_0^R = \widehat{\pi}_0^R$. For all other beliefs there is a single optimal action. As long as the probability of $a > 0$ is strictly greater than zero at $\widehat{\pi}_0^R$, the investors will never let the price decrease to $\widetilde{q}$ when $\pi_0 \in [\underline{\pi}_0, \overline{\pi}_0]$, so that in this case the equilibrium

[9]Figure 5 is a continuous action version of Figure 1 in Bond et al. (2006).

price equals $\widetilde{q} - \varepsilon$.

4.4.3 Noise traders

Let us go back to the setting with $K = 0$. Clearly, the assumption that only informed traders enter the market is very unrealistic. In fact, speculative markets in which a large amount of investors possess clear information advantages usually do not set up in reality. No uninformed speculative investor respectively market maker is willing to trade in such a market, since they know they can only lose money. Above market liquidity was supplied by the authority, however under the strong assumption that its loss function does not include trading income.

As noted in Section 4.1, Kyle (1985) shows that with a sufficient amount of noise trading it is possible to overcome this adverse selection problem.

We model noise trading in a very simple way:

$$\Pr(x > 0 \mid \text{noise trade}) < \Pr(x < 0 \mid \text{noise trade}) \text{ if } q > q_0$$
$$\Pr(x > 0 \mid \text{noise trade}) > \Pr(x < 0 \mid \text{noise trade}) \text{ if } q < q_0$$

that is, if the current price of the security is more (less) than the equilibrium price without asymmetric information, the probability of a buy order from a noise trader is less (more) than the probability of a sell order. In other words, the noise trader is more inclined to buy the security if the current price of the security is less than the equilibrium price without asymmetric information. One can interpret noise traders as naive "insiders" that have uniformly distributed beliefs about π_0 and do not use public information q in their trading strategy. We assume, in addition, that at every trade the market maker and the authority do not know whether they face an informed or a noise investor.

Under those assumptions the risk-neutral insiders will trade the security until the price reflect the intrinsic value of the contract, as in Section 4.4.1. This is because the insider knows that at this price the probability of an unfavorable trade – a noise sell (buy) order if the insider just purchased (sold) the security, which decreases (increases) a – is less than the probability of a favorable trade.[10] Moreover when noise trades shift the price away from its equilibrium value, the informed investors ensure that the price goes back to q^C. Hence, Proposition 1 applies.[11]

The introduction of noise traders can even lead to the existence of a fully revealing equilibrium with quasi-fixed costs for all values of π_0. This is because there is always a non-zero probability of a noise trade at the price that triggers supervisory intervention. Hence, insiders can trade until this price and then wait

[10] Note that since $\frac{\partial^2 a}{\partial(\widehat{\pi}_0^R)^2} < 0$, this is always true only when the effect of each trade on the price (and hence on a) is small. If $\frac{\partial a}{\partial x}$ is large, the difference between $\Pr(x > 0 \mid$noise trade) and $\Pr(x < 0 \mid$noise trade) must high enough, so to compensate for the convexity of the reaction function of the supervisor.

[11] If the last trade before market closing is a noise trade the equilibrium values described in Proposition 1 hold only approximately.

until a noise trader triggers supervisory intervention (this may require several attempts, as the direction of the next noise trade is unknown). Note that since the supervisor does not know whether he faces an insider or a noise trader, he can not be sure that the trade at the trigger price is a noise trade, which would imply $\frac{\partial \pi_0^R}{\partial x} = 0$. In fact, remember that for some values of π_0, insiders would also trade at the trigger price. As a corollary noise traders can not realize when trading at the trigger price leads to a sure loss and hence assuming a non-zero probability of a noise trade (buy or sell order) is not inconsistent.

5 Discussion

5.1 The mechanics behind the endogeneity problem

We modelled the strategic interaction between an insider who knows the ex ante probability of an event and an authority who would like to prevent the event from happening. The interaction is implemented by a market for a contract written on the event. The authority offers the contract, insiders can buy. The authority observes the price and/or the order book, infers the ex ante probability of the event, and intervenes to prevent it. This is a game with private information by the insiders and hidden action by the authority.

We have found that the market breaks down, if government intervention is costless and always successful to one hundred per cent. Any deviation of the asset price from unity would lead to full prevention of the event ("zero tolerance"). More surprisingly, we have found that if intervention is costly (i.e., if marginal prevention-cost is positive but the quasi-fixed cost is zero), not only does the market not break down: The equilibrium is even first best with full revelation of private information. There is an equilibrium in which insiders correctly predict the authority's action (the level of preventive effort) and the authority correctly interprets the contract price paid by investors.

If the authority dislikes intervention per se (modelled as a quasi-fixed cost), an equilibrium may or may not exist. Even if an equilibrium exists the authority may choose an inefficient intervention level. The results from the quasi-fixed cost model seem to contradict the well known result (see, e.g., Brunnermeier, 2001) that in this type of model private information is revealed in prices if everything else is common knowledge. However, that result rests on the assumption of complete markets. In our model markets are not complete in the sense that there is no asset written on the authority's action.[12] In the absence of a quasi-fixed cost this is not a problem, because the action can be inferred. Under a quasi-fixed cost this is no longer true, and market incompleteness takes its toll.

The assumption of a quasi-fixed cost seems quite plausible not only a priori, but also in the light of our result. We find that in the presence of quasi-fixed cost, the market price of an asset written on bank solvency is not a monotonous function of the prior (pre-intervention) probability of failure. This helps understand

[12] This is why in (Bond et al., 2006) the introduction of a "regulator security" leads to unique revealing equilibrium.

the otherwise "perverse" reaction of bank debt prices reported in DeYoung, Flannery et al. (2001), namely an *increase* after unexpectedly bad examination results (suggesting that the intervention threshold was passed).

They results from the quasi-fixed cost model also lend a formal underpinning to the intuition formulated in Bond, Goldstein and Prescott (2006, p. 5f.): "The inference from the price is non-trivial. For example, a low price may indicate that the fundamentals are bad, and thus call for the authority's intervention. It may also indicate that fundamentals are not bad enough to justify intervention in which case the price is low because no intervention is expected" (Bond, Goldstein and Prescott, 2006, p. 5f.).

All results from our model depend on one crucial assumption: that players rationally guess each others actions and that rationality is common knowledge. As is well known in game theory, out-of-equilibrium beliefs are hard to model; if one assumes that one party behaves irrationally or anticipates another party to do so, not much can be said about the outcome without some further assumptions.

A crucial issue not treated in the paper is noise. We assumed that the authority is a "perfect" market maker, setting a bid-ask spread of zero. In a more realistic setting, where trade is made possible by noise traders, prices would become noisy, making prediction difficult. In reality, market prices are not very informative in areas where the noise in prices is high relative to the level of risk. A striking example is the airline industry. In theory one would expect passengers to be ready to pay a bit more for a ticket on a safe flight than on a risky trip. Yet, airfares, even on the same flight, differ so widely relative to the very low probability of an accident. Therefore, nobody has ever proposed to read the risk of a crash of different companies or of different aircraft from observed airfares.

5.2 A way around endogeneity: Price neutral intervention

Our model rests on one assumption we have not explicitly discussed yet: The existence of one single asset paying one dollar if the bank remains solvent and nothing if it fails. We will now relax this assumption in order to show a way around the double endogeneity effect. The idea is to construct an asset with an expected payoff that depends only on the bank's pre-intervention solvency but not on the degree of supervisory intervention.[13]

Think of an asset that pays nothing if the bank defaults (if $\omega = 0$). If the bank remains solvent ($\omega = 1$) the asset pays $h(a)$, where h stands for "haircut", with $h(0) = 1$ and $h' < 0$. In words: If the authority intervenes ($a > 0$)), the nominal value of the asset is reduced to a fraction h. The stronger the intervention, the stronger the reduction or the "shorter" the haircut.

The asset is insulated from the effect of supervisory intervention if the following condition holds: The increase in real value (expected payoff) caused by

[13]We read the proposal in Bond et al. (2006) to link intervention with a tax on those who benefit from intervention as a binary action space version of the proposal made in the text.

an intervention must exactly be compensated by the concomitant reduction in its nominal value. This yields the following condition for the "neutral" haircut function $h(a)$:

$$\left(1 - \frac{\pi_0}{1+a}\right) h(a) = 1 - \pi_0. \tag{8}$$

The left-hand side is the expected return on the asset *with* an intervention a; the right-hand side is the expected return *without* any intervention. If h satisfies the equality between both sides the expected payoff of the asset does not react to intervention; it is always $1-\pi_0$. From the market value of the asset (still assuming there is a competitive market), the authority can directly read the prior probability of failure π_0.

Solving (8) for $h(a)$ yields:

$$h(a) = \frac{(1+a)(1-\pi_0)}{1+a-\pi_0}. \tag{9}$$

This is the price-neutral haircut function. It assures that the competitive price of the asset q always reflects the original failure probability, $q = 1 - \pi_0$. The asset with payoffs $\{0, h\}$ thus is the ideal indicator asset. Its price reflects the prior default probability even if it is common knowledge that the authority will intervene and that the posterior default probability will differ from the prior probability.

Two remarks apply, one theoretical, one practical. From a theory point of view, (9) seems to violate our assumptions: It implies an asset indirectly written on the prior probability of failure π_0 which is unobservable and thus not contractible. However, it is straightforward to show[14] that the haircut function (9) based on the beliefs of the authority π_0^R together with the competitive market provide a truth-telling mechanism: An insider who learns π_0 has a incentive to reveal π_0 directly by trading at a price $q = 1 - \pi_0^R$.

The intervention-neutral asset may seem a theoretical artefact without any resemblance in reality. Yet, there exist arrangements with a striking similarity to such an asset. For example the 1991 FDICIA includes a provision authorizing the FDIC to settle uninsured and unsecured claims on an institution in receivership with a final settlement payment which must reflect an average of the FDIC's receivership recovery experience.[15] Such a settlement would imply a haircut to creditors' nominal claims reflecting expected losses. It tends to insulate the market value of these claims from the intervention by the receiver (the FDIC). Although safeguarding the informational value of debt prices was probably not the legislator's purpose, the provisions seem to work in that direction.

In practice, a security subject to a price-neutral haircut function may hardly be implementable via private contracts alone. Rather, the intervention-contingent

[14] See appendix 2.

[15] FDICIA, Title IV, Subtitle B.

haircut would have to be implemented by a combination of private contracts and rules on bank insolvency or restructuring, as in the FDICIA example. The following set of rules for the authority would seem to do the job:

1. Define an "indicator security" (e.g. subordinated debt);
2. Declare in advance that in case of intervention the nominal value of the indicator security will be cut to a fraction h of the original nominal value.
3. Set h to pre-intervention the market value of the indicator security in percentage of an otherwise equivalent risk free security.

These rules implement the price-neutral haircut function. It is straightforward to verify that the (competitive) market price of the indicator security, or more precisely: its risk spread, is a direct and unbiased measure of the bank's default probability as seen by the market insiders.[16]

6 Conclusions

Can—and should—bank supervisors base prompt corrective action on market data? The literature on the information content of market data, like prices for bank debt and equity, would at least partially suggest so. Yet, we have found that the right answer is mixed.

To begin with, market prices have to be used with caution. Not because market data are too noisy or because markets are sometimes wrong, but because the expected use of market data *feeds back* on these data. The simple example is a high subordinated debt spread which triggers a successful supervisory intervention and thus belies itself. The spread becomes a "self-defeating prophecy." This is the double endogeneity effect of an action which is (i) price-dependent and (ii) rationally predicted (and priced). It seems that this effect has been largely overlooked in a supervisory context, although inspiration could be taken from the literature on exchange rates or on central banks and asset bubbles.

The double endogeneity effect may not invalidate prices as guides for action in all cases. A job candidate may be right to reject a job offer in the light of a recent sharp drop in the share price of the company (Allen, 1993). The impact of the candidate on the value of the company is small; it is unlikely that the fall in the share price reflects market anticipations that the candidate will reject the job although she is the only person who could save the company.

An authority, by contrast, is not atomistically small. Its decisions, unlike those of a job candidate, have a measurable influence on the fundamentals on

[16] The legal applicability of such rules depends on the particular legislation. A necessary condition is the existence of some bank liability—like subordinated debt or preferred equity—that can be reduced by the supervisor without liquidation of a bank. The Swiss banking act, for example, empowers the supervisory authority to reduce non-protected creditors' claims as part of mandatory restructuring.[17] It does not require such a haircut to be "price-neutral" in the above-defined sense, though.

which prices are based. If market prices incorporate really *all* information available to the market, this includes information or beliefs about what the supervisor is going to do. Market prices for bank debt, for example, if used as a basis for supervisory decisions, become subject to the endogeneity problem.

Still this does not invalidate market prices. We have shown that when the authority is "predictable" (when its reaction function is common knowledge), an equilibrium may still exist. However, market prices in such an equilibrium have to be read correctly: They do not reflect the probability of a bank failure to which the authority should perhaps react, but rather the probability of bank failure *after* the authority has taken the action expected by the market. A failure to recognize the double endogeneity effect could lead authorities astray.

We have also shown that an equilibrium is less likely to exist when the authority dislikes to exceed some particular level of intervention. We used a quasi-fixed cost of any action exceeding a level of zero. But this level could arbitrarily be set. A realistic assumption is that the cost function has an upward jump at the point where an intervention becomes public.

Advocates of market based intervention have stressed the disciplining effect on the supervisory authority of a price-based rule, for example of a subordinated debt spread policy. Our findings suggest that in that very case, when a rule would be most needed because the authority has a dislike to intervene (or to transcend a certain level), an equilibrium may not exist, or the market may fail entirely.

Our message that market prices may lose their information content if authorities try to use them for preventive purposes is applicable to other fields as well. For example, the claim that the market for "terrorism futures" proposed by an U.S. ministry of defense agency in July 2003, was "a good idea with bad press" (Hal Varian) would only be supported by our model under very restrictive assumptions. These assumptions are unlikely to hold in reality.

There are several assumptions needed for an equilibrium with revealing prices that may not be met in reality, like: (i) sufficiently low noise, (ii) common knowledge of preferences (the authority's prevention cost function and individuals' attitudes towards risk), (iii) perfect competition among informed individuals. We have to leave it to further research to clarify the impact of factors like noise in prices on the double endogeneity effect.

While our paper starts from the question "Should bank supervisory look at and act on market prices?" it ends at the different question: "How do securities and intervention rules have to be designed in order to make market prices meaningful guides for intervention?" This question led us to the notion of a price-neutral intervention using an information preserving "haircut function". The use of such a haircut function (in practice: a combination between security design and insolvency rules) can be seen as the supervisory discipline that preserves the informational basis of direct and indirect market discipline. We think here lies a promising direction of further supervisory research and policy.

Appendix

Appendix 1: The trigger value of π_0

In a model with quasi-fixed costs, it is efficient for the authority to intervene only if π_0 exceeds some value $\widehat{\pi}_0$. This trigger value $\widehat{\pi}_0$ solves

$$\begin{aligned} K &= \widehat{\pi}_0 v - \frac{\widehat{\pi}_0 v}{1+a} - ka \\ \text{with } a &= \left(\frac{\widehat{\pi}_0 v}{k}\right)^{\frac{1}{2}} - 1 \end{aligned} \tag{10}$$

The first equation reduces to

$$\begin{aligned} K &= \widehat{\pi}_0 v \left(\frac{a}{1+a}\right) - ka \\ &= a\left(\frac{\widehat{\pi}_0 v}{1+a} - k\right) \end{aligned}$$

Inserting (10)

$$\begin{aligned} K &= \left[\left(\frac{\widehat{\pi}_0 v}{k}\right)^{\frac{1}{2}} - 1\right]\left[(k\widehat{\pi}_0 v)^{\frac{1}{2}} - k\right] \\ K &= \widehat{\pi}_0 v - 2\,(k\widehat{\pi}_0 v)^{\frac{1}{2}} + k \\ K &= \left[(\widehat{\pi}_0 v)^{\frac{1}{2}} - k^{\frac{1}{2}}\right]^2 \\ K^{\frac{1}{2}} &= (\widehat{\pi}_0 v)^{\frac{1}{2}} - k^{\frac{1}{2}} \end{aligned}$$

so that

$$\widehat{\pi}_0 = \frac{k + 2\,(kK)^{\frac{1}{2}} + K}{v}.$$

Accordingly, the authority intervenes only when

$$\widehat{\pi}_0^R > \frac{k + 2\,(kK)^{\frac{1}{2}} + K}{v}.$$

As one would expect, this condition is more likely to be satisfied when the costs of intervention (variable k and quasi-fixed K) are low and the gains (v) are high.

Appendix 2: Equilibrium with price neutral intervention

Suppose that the asset traded has an expected payoff that depends on the degree of supervisory intervention, that is it pays nothing if the bank defaults and pays $h(a)$ otherwise. $h(a)$ is set by the authority as follows:

$$h(a) = \frac{(1+a)(1-\pi_0^R)}{1+a-\pi_0^R}. \tag{11}$$

When the authority as market maker sets the price of the security q equal to its beliefs about the fundamental value, we have

$$\begin{aligned} q &= \left(1 - \pi^R\right) h(a) \\ &= 1 - \pi_0^R. \end{aligned}$$

Note that the price of the security is a smooth function of π_0^R even in the presence of quasi-fixed costs.

For the investor the fundamental value of the security is given by

$$\begin{aligned} FV &= (1 - \pi) h(a) \\ &= \left(1 - \pi_0^R\right) \frac{1 + a - \pi_0}{1 + a - \pi_0^R}. \end{aligned}$$

In a competitive setting investors trade the security as long as its price differs from its fundamental value. For instance the investors buy securities when $FV > q$. But $FV > q$ only when $\pi_0 < \pi_0^R$. Given the beliefs $\frac{\partial \pi_0^R}{\partial x} < 0$, we can have a unique competitive equilibrium with $q = FV$ only if $\pi_0^R = \pi_0$, i.e., the equilibrium is fully revealing.

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