

# Government intervention and information aggregation by prices<sup>1</sup>

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## **Abstract**

Many policy proposals call for government intervention to be based on the information in market prices of firm securities. Most of these proposals ignore the fact that market prices are endogenous to government intervention. In particular, when the government takes a corrective action based on price, the price might become less informative. We show that the fact that the government learns from the price when taking a corrective action can reduce the incentives of speculators to trade on their information, and hence reduce price informativeness. We show that transparency may reduce trading incentives and price informativeness further.

# 1 Introduction

The perceived failure of financial regulation in the run-up to the recent economic crisis has generated a surge of policy proposals, many of which advocate the explicit use of market prices as a guide for government intervention. For example, Hart and Zingales (2009) propose a mechanism, by which the government will perform a stress test on banks whose market price deteriorates below a certain level, in order to evaluate whether there is a need for intervention. Such proposals have antecedents in the older proposals of Evanoff and Wall (2004), Herring (2004), and others about market-based bank supervision.<sup>1</sup> Also related are recent proposals that banks should issue contingent capital (i.e., debt that converts to equity) with market-based conversion triggers (see Flannery (2009), MacDonald (2010)). All these proposals share the observation that the market prices of financial securities contain a great deal of information that could serve as a useful input into government decision-making.

However, for the most part, calls to base government actions on market prices have overlooked a potentially important complication, namely that once the policy is in place, the information content of prices may change. Indeed, while in the recent crisis it was widely perceived that government bailouts were often reactions to low market prices, it was also apparent that the prospect of government help was repeatedly a major driver of changes in asset prices, both in the US and in many other economies. Good examples of this phenomenon are provided by market activity in the weeks leading up to the eventual announcement of government support for Fannie Mae and Freddie Mac, for Citigroup, and for General Motors.

Our paper analyzes the effect of *corrective* government policy – i.e., one that aims to help firms in trouble – on the informational content of market prices. We develop a model to study how market-based government intervention might affect the trading incentives of speculators and hence the ability of the financial market to aggregate speculators' dispersed information. Part of our contribution is in developing a tractable model that deals with the feedback loop between the financial market and government policy. This is in contrast to most models on this feedback loop, which are difficult to analyze. Using our model, we derive an array of results that shed light on the implications of market-based government policy.

In detail, we develop a tractable version of a rational-expectations model, where speculators possess heterogeneous information about the fundamentals of an asset and trade on it in a market that is subject to noise/liquidity shocks. We add a government to this model,

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<sup>1</sup>Evidence for the dependency of government actions on market prices exists for the period before the crisis, e.g., see Feldman and Schmidt (2003), Krainer and Lopez (2004), Piazzesi (2005), and Furlong and Williams (2006).

and assume that it observes the market price, in addition to a privately observed signal, and uses the information to make a decision about a corrective action, as defined above. The informativeness of the price in this model is determined by the trading incentives of speculators, i.e., the aggressiveness with which they trade on their information.

A key determinant of speculators' trading behavior is the uncertainty to which they are exposed. Being risk averse, they trade less when the risk is higher. In the face of such uncertainty, speculators benefit when the government uses information independent of the price, but correlated with the fundamental, to dampen the effect of swings in the fundamental. Consequently, speculators can trade more aggressively on their information, and the equilibrium price is more informative. However, if the government increases its reliance on market prices as a source of information, this benefit is lost, and speculators trade less aggressively resulting in a less informative price. Hence, the government's use of market prices reduces their informational content.

This result has a couple of interesting implications. First, even though it is *ex post* optimal for a government to apply Bayes rule to extract information from market prices, it is *ex ante* suboptimal: we show that, for a moderate corrective action, a government would always want to commit to refrain, to some extent, from fully using market prices *ex post*. Such commitment could be achieved, for example, by having an overconfident policymaker who thinks his information is more precise than it really is. Second, our model implies that the government's own information has more value than its direct effect on the efficiency of the government's decision. When the government has more precise information, it relies less on the market price, and this makes the market price more informative. Hence there are complementarities between the government's own information and the market's information, and so it is not advisable for the government to rely completely on market information.

Our paper also delivers implications about transparency. Governments are often criticized for not conveying their information or policy goals. The question is whether such disclosure is desirable when the government tries to learn from the market. We show that the type of transparency that is considered matters a lot. Disclosing the government's information about the fundamentals reduces trading incentives and price informativeness, while disclosing the government's policy goal increases them.

Our paper adds to a growing literature on the informational feedback from asset prices to real decisions; see, for example, Fishman and Hagerty (1992), Leland (1992), Khanna, Slezak, and Bradley (1994), Boot and Thakor (1997), Dow and Gorton (1997), Subrahmanyam and Titman (1999), Fulghieri and Lukin (2001), Foucault and Gehrig (2008), and Bond and Eraslan (2010). In particular, it complements papers such as Bernanke and Woodford (1997), Goldstein and Guembel (2008), Bond, Goldstein and Prescott (2010), Dow, Goldstein and

Guembel (2010), and Lehar, Seppi and Strobl (2010), which analyze distinct mechanisms via which the use of price information in real decisions might reduce the informational content of the price. Relative to these papers, our focus is on the efficiency of aggregation of dispersed information by market prices. This topic, which has long been central in economics and finance (e.g., Hellwig (1980)), has not been analyzed in any of the related papers.<sup>2</sup> Moreover, the model we develop enables very tractable analysis of information aggregation in prices in the presence of informational feedback to real decisions.

The remainder of the paper is organized as follows. Section 2 describes the model. The analysis and solution of the model are contained in Section 3. In Section 4, we provide our main results about the effect of the government’s use of the price on price informativeness. In Section 5, we analyze the implications of our model for optimal transparency. Section 6 concludes.

## 2 The model

As noted, we want to use the simplest and most standard framework possible to show how government policy can affect information aggregation. Accordingly, we build a model in the style of Grossman and Stiglitz (1980), Hellwig (1980), and Admati (1985). In this framework, informed speculators trade on heterogenous pieces of information about the fundamental value of an asset in a market that is subject to shocks unrelated to fundamental value; the literature attributes these shocks to the actions of “noise” or “liquidity” traders. The price then reflects fundamental value as well as noise, and the degree to which each one is reflected depends on the trading incentives of the informed speculators.

We focus on one firm (a financial institution, for example), whose stock is traded in the financial market. In  $t = 0$ , speculators obtain signals about the cash flow that will be generated from the firm’s operations, and trade on it. In  $t = 1$ , the government, who learns information about the expected cash flow from the price of the stock, makes a decision about a corrective action. In  $t = 2$ , cash flows are realized and speculators get paid.

### 2.1 Cash flows and government intervention

Absent government intervention, the firm generates a cash flow of  $\theta$ . We refer to  $\theta$  as the fundamental of the firm. It is distributed normally with mean  $\bar{\theta}$  and standard deviation  $\sigma_\theta$ .

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<sup>2</sup>For example, in Bond, Goldstein and Prescott (2010), the price of any traded asset after a realization of some underlying state variable  $\theta$  is assumed to equal the expected payoff of the asset conditional on  $\theta$ . In other words, even if information about the state variable  $\theta$  is dispersed across many investors, the price is assumed to fully and efficiently aggregate this dispersed information.

We denote the precision of prior information by  $\tau_\theta \equiv \frac{1}{\sigma_\theta^2}$ . The government's objective is to provide resources to firms that are performing poorly. Because these transfers must be funded, the government also wishes to tax well-performing firms. For tractability, we work with a linear policy rule, such that the transfer  $T$  provided to the firm is given by:

$$T \equiv \lambda \left( \widehat{\theta} - E[\theta|I_G] \right). \quad (1)$$

Here,  $E[\theta|I_G]$  is the expected cash flow of the firm given the information available to the government  $I_G$ . We will elaborate below on the sources of government information.  $\widehat{\theta}$  is a threshold cash flow, such that firms with a lower cash flow receive a transfer from the government, while firms with a higher cash flow are taxed by the government. We focus on the case in which the parameter  $\lambda$  is positive, corresponding to corrective government actions that help firms with low fundamentals. The linear policy rule helps us maintain the linear solution that is heavily used in this literature, and thus is important for the tractability of the model.

## 2.2 Information and trading

There is a continuum  $[0, 1]$  of speculators in the financial market with constant absolute risk aversion (CARA) utility,  $u(c) = -e^{-\alpha c}$ , where  $c$  denotes consumption and  $\alpha$  is the absolute risk aversion coefficient. Each speculator  $i$  receives a noisy signal about the fundamental:

$$s_i = \theta + \varepsilon_i, \quad (2)$$

where the noise term  $\varepsilon_i$  is independently and identically distributed across speculators. It is drawn from a normal distribution with mean 0 and standard deviation  $\sigma_\varepsilon$ . We use  $\tau_\varepsilon \equiv \frac{1}{\sigma_\varepsilon^2}$  to denote the precision of speculators' signals.

Each speculator chooses a quantity to trade  $x_i$  to maximize his expected utility given his private signal  $s_i$  and the price  $P$  that is set in the market for the firm's stock:

$$x_i(s_i, P) = \arg \max_{\tilde{x}} E \left[ -e^{-\alpha \tilde{x}(\theta + T - P)} | s_i, P \right]. \quad (3)$$

Here, trading a quantity  $x_i$ , the speculator will have an overall wealth of  $x_i \cdot (\theta + T - P)$ , where  $\theta + T$  is the cash flow from the security after intervention, and  $P$  is the price paid for it. The speculator's information consists of his private signal  $s_i$  and the market price  $P$ .

In addition to the informed trading by speculators, there is a noisy supply shock,  $-Z$ , which is distributed normally with mean 0 and standard deviation  $\sigma_z$ . We again use the

notation  $\tau_z \equiv \frac{1}{\sigma_z^2}$ . In equilibrium, the market clears and so:

$$\int x_i(s_i, P) di = -Z. \quad (4)$$

The government's information  $I_G$  consists of two components. First, the government observes the price  $P$ , which provides a noisy signal of the fundamental  $\theta$ . Second, the government observes a private signal  $s_G$  of the fundamental:

$$s_G = \theta + \varepsilon_G, \quad (5)$$

where the noise term  $\varepsilon_G$  is drawn from a normal distribution with mean 0 and standard deviation  $\sigma_G$ . We use  $\tau_G \equiv \frac{1}{\sigma_G^2}$  to denote the precision of the government's signal. The government then sets  $T$  based on the rule in (1) using its two pieces of information  $P$  and  $s_G$ .

### 3 Analysis

An equilibrium consists of a mapping from signal realizations and the supply shock  $Z$  to price  $P$ , and individual demands  $x_i(s_i, P)$ , such that individual speculators' demands maximize utility given  $s_i$  and  $P$  (according to (3)) and such that the market clearing condition (4) holds. In addition, here the government's choice of  $T$  is optimally based on its signal  $s_G$  and the price  $P$ , as in (1).

As is standard in almost all the literature, we focus on linear equilibria. In a linear equilibrium, individual demand  $x_i(s_i, P)$  is a linear function of the signal  $s_i$  and the price  $P$ , the government's intervention is a linear function of the signal  $s_G$  and the price  $P$ , and the price  $P$  is a linear function of the fundamental  $\theta$  and the supply shock  $-Z$ . (Note that, given linearity,  $P$  depends only on the average realization of individuals' signals, i.e., on the fundamental  $\theta$ .)

Proposition 1 below formally establishes the existence of a linear equilibrium. In the main text, we provide a less formal derivation focusing on our main object of interest, namely the informativeness of the equilibrium price. In a linear equilibrium, the price can be written as

$$P = p_0 + p_Z(\rho\theta + Z), \quad (6)$$

for some parameters  $p_0$ ,  $p_Z$  and  $\rho$ . In particular,  $\rho$  measures the informativeness of the price, since the informational content of the price is the same as the linear transformation  $\frac{1}{p_Z}(P - p_0) = \theta + \rho^{-1}Z$ . This transformation is an unbiased estimate of the fundamental

with precision  $\rho^2\tau_Z$ , where as one would expect, precision increases in price informativeness  $\rho$ . Intuitively, the price of the security is affected by both changes in the fundamental  $\theta$  and changes in the noise variable  $Z$ . The informativeness of the price about the fundamental can be summarized by the ratio between the effect of the fundamental on the price and the effect of noise on the price.

Given normality of the fundamental  $\theta$  and the supply shock  $-Z$ , the price  $P$  is itself normal. Consequently, given normality of the error term  $\varepsilon_G$ , the government's posterior of the fundamental  $\theta$  is normal. Moreover, the government's estimate of the fundamental is linear in its own signal,  $s_G = \theta + \varepsilon_G$ , and in the price  $P$ . The government's estimate of the fundamental is consequently

$$E[\theta|s_G, P] = K_\theta\bar{\theta} + K_P\frac{1}{\rho p_Z}(P - p_0) + w(\rho)s_G, \quad (7)$$

where  $K_\theta$ ,  $K_P$  and  $w(\rho)$  are weights that sum to one. In particular,  $w(\rho)$  is the weight the government puts on its own signal in estimating the fundamental, which depends on the information available in the price.<sup>3</sup> By the standard application of Bayes' rule to normal distributions it is given by:

$$w(\rho) \equiv \frac{\tau_G}{\tau_\theta + \rho^2\tau_z + \tau_G}. \quad (8)$$

The weight that the government puts on its own signal is the precision of this signal ( $\tau_G$ ) divided by the sum of precisions of the government's signal, the prior information ( $\tau_\theta$ ) and the price ( $\rho^2\tau_z$ ). As one would expect, the government puts more weight on its own signal when it is precise ( $\tau_G$  is high) and less when the price is informative ( $\rho$  is high). Given the policy rule (1), the intervention is

$$T(s_G, P) = \lambda\hat{\theta} - \lambda w(\rho)(\theta + \varepsilon_G) - \lambda K_P\frac{1}{\rho p_Z}(P - p_0) - \lambda K_\theta\bar{\theta}. \quad (9)$$

Similar to the government, each speculator assigns a normal posterior (conditional on his own signal  $s_i$  and price  $P$ ) to the fundamental  $\theta$ . Moreover, from (9) each speculator also assigns a normal posterior to the size of the intervention  $T$ . Consequently, the well known expression for a CARA individual's demand for a normally distributed stock applies,

$$x_i(s_i, P) = \frac{E[\theta + T|s_i, P] - P}{\alpha \text{var}[\theta + T|s_i, P]}. \quad (10)$$

Thus, the amount traded is the difference between the expected value of the security (funda-

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<sup>3</sup>Of course, the constants  $K_\theta$  and  $K_P$  also depend on the price informativeness  $\rho$ , but for expositional ease we do not make this dependence explicit.

mental + intervention) and the price, divided by the variance of the expected value multiplied by the risk aversion coefficient. Intuitively, speculators want to trade more when they expect a higher gap between the value of the security and the price, but, due to risk aversion, this tendency is reduced by the variance in expected security value.

To characterize the equilibrium informativeness of the stock price, consider simultaneous small shocks of  $\delta$  to the fundamental  $\theta$  and  $-\delta\rho$  to  $Z$ . By construction (see (6)), this shock leaves the price  $P$  unchanged. Moreover, the market clearing condition (4) must hold for all realizations of  $\theta$  and  $Z$ . Consequently,

$$\delta \frac{\partial}{\partial \theta} \int x_i(s_i, P) di = \delta \rho.$$

Substituting in (9) and (10) yields equilibrium price informativeness:

$$\rho = \frac{1}{\alpha} \frac{\frac{\partial}{\partial s_i} E[\theta + T|s_i, P]}{\text{var}[\theta + T|s_i, P]} = \frac{1}{\alpha} \frac{(1 - \lambda w(\rho)) \frac{\partial}{\partial s_i} E[\theta|s_i, P]}{(1 - \lambda w(\rho))^2 \text{var}[\theta|s_i, P] + (\lambda w(\rho))^2 \tau_G^{-1}}. \quad (11)$$

Here, the informativeness of the price is essentially determined by how much speculators trade on their information about  $\theta$ . As explained above, this is determined by two factors: the relation between the information and the value of the asset, which appears in the numerator, and the variance in the value of the asset, which appears in the denominator. Regarding the first one, we see in the numerator that a \$1 change in the expected fundamental changes expected value by  $(1 - \lambda w)$ , due to the government's corrective action. The variance of the expected value, which appears in the denominator, is a function of two components: the expected variance of the fundamental  $\theta$  and the variance of the noise in government information. The relative importance of these two components is determined by  $\lambda$ , the strength of the corrective action.

**Proposition 1** *For  $\lambda \leq 1$ , a linear equilibrium exists. Equilibrium price informativeness  $\rho$  satisfies (11). For any  $\lambda$  sufficiently close to 0, there is a unique linear equilibrium.*

(All proofs are in the appendix.) Note that the original Grossman-Stiglitz model featured a unique linear equilibrium. We can see this in our model by assuming that there is no government intervention, i.e., by setting  $\lambda = 0$ . In this case, equation (11) has a unique solution given by

$$\rho = \frac{1}{\alpha} \frac{\frac{\partial}{\partial s_i} E[\theta|s_i, P]}{\text{var}[\theta|s_i, P]} = \frac{1}{\alpha} \frac{\frac{\tau_\varepsilon}{\tau_\theta + \rho^2 \tau_z + \tau_\varepsilon}}{\frac{1}{\tau_\theta + \rho^2 \tau_z + \tau_\varepsilon}} = \frac{\tau_\varepsilon}{\alpha}. \quad (12)$$

Moreover, as can be easily verified from the proof of Proposition 1, even with government intervention, our model would feature a unique equilibrium if the weight  $w$  that the govern-

ment puts on its own information was exogenous and unaffected by the price informativeness  $\rho$ . However, due to the effect of the informativeness of the price on the weight that the government puts on its information in the corrective action decision, our model sometimes exhibits multiple equilibria. Indeed, for a large enough corrective action ( $\lambda \gg 0$ ), we can construct examples where our model has multiple equilibria. Our paper is not the first to show that the uniqueness of equilibrium in Grossman and Stiglitz (1980) is not robust to extensions of the model. For example, Ganguli and Yang (2008) show that introducing private information about the aggregate liquidity shock may lead to multiplicity of equilibria.

Below, we focus on the case where  $\lambda$  is small, and so multiplicity does not arise. As we discuss below, the results that we highlight depend on  $\lambda$  being sufficiently small. Numerical calculations (see details in Appendix B) suggest that these results hold for a wide range of values of  $\lambda$ ; at least up to a level of  $\lambda = 30\%$ , and often much higher. This range seems to us to be both economically meaningful and realistic. That is, in the real world, government interventions implied by  $\lambda = 30\%$  correspond to very substantial transfers, and so those corresponding to significantly higher values of  $\lambda$  strike us as much less realistic. For this reason we focus on these results.

## 4 Government policy and price informativeness

Our main interest in this paper is in how the government's decision to use prices as a basis for intervention affects the informativeness of the equilibrium price. For comparison, consider the benchmark case in which the government completely ignores the price. In this case, the government's estimate of the fundamental is (analogous to (7)),

$$E[\theta|s_G] = \tilde{K}_\theta \bar{\theta} + w_{-P} s_G,$$

where  $\tilde{K}_\theta$  is a constant and  $w_{-P}$  is the weight the government puts on its own signal when it ignores the price,

$$w_{-P} \equiv \frac{\tau_G}{\tau_\theta + \tau_G}.$$

The government's intervention is then (analogous to (9)),

$$T_{-P}(s_G) = \lambda \hat{\theta} - \lambda w_{-P} \cdot (\theta + \varepsilon_G) - \lambda \tilde{K}_\theta \bar{\theta}.$$

Equilibrium price informativeness when the government ignores the price is then given by (11), with the weight that the government puts on its own signal,  $w(\rho)$ , replaced by  $w_{-P} > w(\rho)$ .

To gain intuition, let us inspect the expression for  $\rho$  in (11) more closely. We can see that the weight  $w$  that the government puts on its own information enters the expression three times. First, a high  $w$  reduces the expected change in firm value following an increase in signal  $s_i$  about the fundamental (this is captured by  $(1 - \lambda w) \frac{\partial}{\partial s_i} E[\theta|s_i, P]$  in the numerator of the expression). This reduces the incentive to trade and hence price informativeness. The intuition is that, conditional on the price, the government's action is more correlated with speculators' signals when the government places more weight on its private information (which is, of course, correlated with speculators' information). Since the government's action is corrective, its action goes against the direction of the signal and reduces the expected change in firm value. Let us stress that the conditioning on the price is an important part of the intuition. The speculators do not trade on the information in the price which is publicly known. They only trade on their private information and care how it is related to the government's action and to the firm's value.

The other two effects of  $w$  on price informativeness are via the variance in the denominator of (11). In general, recall that a high variance reduces the incentive of speculators to trade on their information, and thus reduces price informativeness. A high  $w$  reduces fundamental variance (captured by  $(1 - \lambda w)^2 \text{var}[\theta|s_i, P]$ ) for speculators, as it implies that, conditional on the price, speculators' signals will be more correlated with a corrective government action. On the other hand, a high  $w$  increases variance from the noise in the government's signal (captured by  $(\lambda w)^2 \tau_G^{-1}$ ), as it implies that the government is putting more weight on this signal and thus its action – and ultimately firm value – are more exposed to errors in the government's information.

The overall effect of the government's use of information in the price on price informativeness is determined by the sum of the above three forces. Our formal results in Proposition 2 focus on the case of a small  $\lambda$ . For this, it is useful to consider the following approximation of (11) for small values of  $\lambda$ ,

$$\rho = \frac{1}{\alpha} \frac{1 - \lambda w}{1 - 2\lambda w} \frac{\frac{\partial}{\partial s_i} E[\theta|s_i, P]}{\text{var}[\theta|s_i, P]} = \frac{1}{\alpha} \frac{1 - \lambda w}{1 - 2\lambda w} \tau_\varepsilon. \quad (13)$$

When  $\lambda$  is positive—that is, when the government's policy is corrective—the term  $\frac{1 - \lambda w}{1 - 2\lambda w}$  is increasing in  $w$ . This implies that the use of the information in the price by the government reduces the quality of this information.

The intuition is based on the idea of diversification. For a small  $\lambda$ , speculators are exposed to substantial fundamental uncertainty when they trade on their private information. When the government uses its own information, which is correlated with speculators' signals, speculators enjoy the benefit of diversification, as they become less exposed to the

fundamental uncertainty and more exposed to the independent noise in the government's information. This effect is so strong that it overcomes the decrease in the information that the signal contains on the mean value of the security. Overall, speculators then trade more aggressively on their information, leading the price to be more informative.

Note that the opposite is true if instead  $\lambda$  is negative, so that the government's policy amplifies the fundamental  $\theta$ . Here, the government's use of its own information both adds to the fundamental risk and introduces the risk in the government's noise, so that traders are unambiguously exposed to more risk. As a result, they trade less aggressively, and the price becomes less informative.

**Proposition 2** *For mild corrective actions ( $\lambda$  small and positive) price informativeness is reduced when the government uses the price as a basis of policy. In contrast, for amplifying actions ( $\lambda$  negative) price informativeness is increased.*

As we noted in the previous section, Proposition 2 and the next results are predicated on corrective actions being mild, i.e., on  $\lambda$  being small and positive. As one can see from (11), if instead  $\lambda$  is large and positive, the dominant factor determining a speculator's residual uncertainty about  $\theta + T$  is the government's error term  $\varepsilon_G$ . In this case, if the government puts more weight on its own signal  $s_G$  by putting less weight on the price, it only increases a speculator's residual uncertainty, and consequently, it reduces equilibrium price informativeness. As we noted above, however, numerical simulations (see details in Appendix B) show that this will happen only when  $\lambda$  is well above 30%, which we find unrealistic for most cases.

## 4.1 Excess volatility

A direct implication of Proposition 2 is that in the case of a mild corrective action, the government's use of market information increases the excess volatility in stock prices. Excess volatility is usually defined as the fraction of volatility of prices that is not attributable to changes in the fundamental  $\theta$ . In our framework, given that  $P = p_0 + p_Z(\rho\theta + Z)$ , excess volatility is given by:

$$\left( \frac{p_Z^2 \tau_Z^{-1}}{\rho^2 p_Z^2 \tau_\theta^{-1} + p_Z^2 \tau_Z^{-1}} \right)^{1/2} = \left( \frac{\tau_\theta}{\rho^2 \tau_Z + \tau_\theta} \right)^{1/2}. \quad (14)$$

It is clear from the above expression that excess volatility is negatively related to price informativeness  $\rho$ . This is because when the price provides less precise information about the fundamental, it is affected more by shifts in noise trading, and this leads to excess volatility.

Hence, when the government uses the information in the price for its decision on a mild corrective action, it increases excess volatility.

## 4.2 Optimal use of market information

Proposition 2 suggests that the government faces a trade-off. Ex post, using the price allows it to make a better decision. However, doing so decreases the informativeness of the price. If the government can ex ante commit to a policy rule, the optimal policy balances these two effects.

Formally, the ex post optimal intervention for the government is given by (9). However, if the government can commit, this is just one of an infinite number of policy rules the government might follow. In particular, consider the class of linear policy rules

$$\tilde{T}(s_G, P) = \lambda \hat{\theta} - \lambda \tilde{w} s_G - \lambda \tilde{K}_P \frac{1}{\rho p_Z} (P - p_0) - \lambda \tilde{K}_\theta \bar{\theta}$$

such that the weights  $\tilde{w}$ ,  $\tilde{K}_P$  and  $\tilde{K}_\theta$  sum to one. A fully informed government would intervene in the amount  $\lambda (\hat{\theta} - \theta)$ , and so a natural ranking of such policy rules is

$$\text{var} \left( \tilde{T}(s_G, P) - \lambda (\hat{\theta} - \theta) \right),$$

which equals

$$\lambda^2 \text{var} \left( \tilde{w} (\theta + \varepsilon_G) + \tilde{K}_P (\theta + \rho^{-1} Z) - \theta \right).$$

By the envelope theorem, a small increase in  $\tilde{w}$  away from the ex post optimal weight  $w(\rho)$  has an effect only via changes in equilibrium price informativeness  $\rho$ . For mild corrective actions, this effect is positive (this is just a local version of Proposition 2), and so a government's commitment to overweight its own signal increases the accuracy of its intervention. The reason is that ex post overweighting of the government's signal generates a first-order improvement of price informativeness, but has only a second-order cost in terms of how effectively the government makes use of available information.<sup>4</sup> Formally:

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<sup>4</sup>A related result is developed by Goldstein, Ozdenoren, and Yuan (2010). In their model, the central bank learns from speculators on the desirability of maintaining a fixed exchange rate regime. This sometimes leads speculators to coordinate on trading on correlated information, reducing the efficiency of the central bank's decision. By putting less weight on market outcomes, the central bank can then reduce the tendency for coordination and increase efficiency. In contrast, here, there is no issue of coordination and correlated information. By committing to place lower weight on market information, the government reduces the exposure of speculators to risk and encourages them to trade more aggressively on their information, making the price more informative.

**Proposition 3** *Consider a mild corrective action ( $\lambda$  small and positive), and let  $\rho$  be the equilibrium price informativeness if the government uses information in an ex post optimal way. Then there exists  $\tilde{w} > w(\rho)$  such that the government would do better by ex ante committing to place weight  $\tilde{w}$  on its own signal.*

While Proposition 3 implies that the government can gain by committing to overweight its own signal and underweight the price ex post, it is clear that it should never go to the extreme of completely ignoring the stock price. This is because the only reason to reduce the weight on the price is to increase price informativeness, but this is of no use if the government does not learn from the information in the price at all.

An important question regarding the result in Proposition 3 is how such commitment can be implemented. Given that no one sees the government’s signal but the government itself, how can the government credibly commit to put more weight on its signal than is ex-post optimal? One way to achieve such commitment is to choose a policymaker who is overconfident about the precision of his own signal. Such a policymaker will put more weight on his signal—and less on both the price and his prior—than is ex-post optimal simply because his bias leads him to think that his signal should receive a larger weight. Having such a bias is then beneficial ex ante by making prices more informative.

Finally, Proposition 3 also implies that the government can potentially gain by ex post overweighting *both* its own signal and the price, at the expense of underweighting its prior  $\bar{\theta}$ . Note, however, that either government overconfidence about the precision of its own information, or underconfidence about the precision of the price, lead to simultaneously overweighting own information  $s_G$  and underweighting the price.

### 4.3 The importance of the government’s own information

It is tempting to interpret policy proposals to use market information as implying that governments do not need to engage in costly collection of information on their own. For example, in the context of banking supervision, one might imagine that the government could substantially reduce the number of bank regulators. Our framework enables analysis of this issue when the usefulness of market information is endogenous and affected by the government’s use of this information. We find that in the case of a mild corrective action, the government’s own information exhibits complementarity with the market’s information, as the informativeness of the price increases when the government has more precise information and relies less on the price. Hence, the usual argument that market information can easily replace the government’s own information is incorrect.

Formally, suppose that the precision of the government’s information,  $\tau_G$ , is a choice

variable. What would be the benefits of increasing  $\tau_G$ ? Given that the price aggregates speculators' information imperfectly, the government is using both the price and its private information  $s_G$  when making its intervention decision. Then, an increase in the precision of its private signal has a direct positive effect on the quality of the government's overall information about the fundamental  $\theta$ . More interesting, however, is that an increase in  $\tau_G$  also has a positive indirect effect, in that more accurate government information leads to more informative prices. The logic follows the previous results on the effect of the government's use of market information on the quality of this information: An increase in  $\tau_G$  increases the weight  $w$  that the government puts on its own information, which, in the case of mild corrective action, increases the equilibrium price informativeness. Hence, the government should be willing to spend more on producing its own information than the direct contribution of this information to its decision making would imply.

The result is summarized in the following proposition.<sup>5</sup>

**Proposition 4** *For mild corrective actions ( $\lambda$  small and positive), an increase in the precision of the government's information ( $\tau_G$ ) increases the informativeness of the price.*

## 5 Transparency

Governments are often criticized for not being transparent enough about their information and policy goals. But, is government transparency desirable when the government itself is trying to elicit information from the price? Does the release of information by the government increase or decrease speculators' incentives to trade on their information? We analyze these questions for the case where the government is taking a mild corrective action based on its own information and the information in the price. We find that the results are very different depending on the type of transparency in question, i.e., transparency about the government's information versus about its policy goals.

### 5.1 Transparency about the government's information

Proposition 5 summarizes the effect that the government's disclosure of its signal  $s_G$  has on the informativeness of the price.

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<sup>5</sup>Bond, Goldstein, and Prescott (2010) also note that the government's own information helps the government make use of market information. However, in that model, the market price perfectly reveals the expected value of the firm, and the problem is that the expected value does not provide clear guidance as to the optimal intervention decision. Hence, the government's information can complement the market information in enabling the government to figure out the optimal intervention decision. Here, on the other hand, the fact that the government is more informed encourages speculators to trade more aggressively, and thus leads the price to reflect the expected value more precisely.

**Proposition 5** *For mild corrective actions, the disclosure of the government’s signal  $s_G$  reduces equilibrium price informativeness.*

This result is rather surprising as it implies that the government’s disclosure of its own information is detrimental. Essentially, the fact that the government reveals its information reduces the incentive of speculators to trade on their information, resulting in a lower level of price informativeness. Thus, the government is better off not revealing its information.

To understand this result, recall from (11) that price informativeness is given by

$$\rho = \frac{1}{\alpha} \frac{\frac{\partial}{\partial s_i} E[\theta + T | s_i, P, s_G]}{\text{var}[\theta + T | s_i, P, s_G]},$$

where we have added  $s_G$  to the speculators’ information set to account for the government’s disclosure of information. Now, given that speculators know the government’s signal, conditional on the price  $P$ , they know what the government’s intervention  $T$  will be, and so, given no uncertainty about  $T$ ,

$$\rho = \frac{1}{\alpha} \frac{\frac{\partial}{\partial s_i} E[\theta | s_i, P, s_G]}{\text{var}[\theta | s_i, P, s_G]} = \frac{\tau_\varepsilon}{\alpha}.$$

This is lower than the informativeness without transparency, which for mild corrective actions is approximately  $\frac{1}{\alpha} \frac{1-\lambda w}{1-2\lambda w} \tau_\varepsilon$  (see (13)).

Economically, transparency reduces speculators’ residual uncertainty about the fundamental, but also reduces the extent to which each speculator’s private signal affects his forecast of this fundamental. These forces have opposite effects on price informativeness and cancel out with each other. The result is then driven by the correlation between the government’s action and the private information that speculators have (which is not reflected in the price). As in Proposition 2, for moderate corrective actions, speculators like the reduction in uncertainty induced by the government taking an action that is correlated with their private information. This effect is lost when the government reveals its signal, as then the government’s signal is already reflected in the price, and, conditional on the price, is not correlated anymore with speculators’ signals.

## 5.2 Transparency about the government’s policy goal

Now, suppose that speculators do not know the government’s policy goal. In particular, they do not know exactly the fundamental threshold  $\hat{\theta}$ , below which the government would like to inject capital into the firm. Suppose that speculators believe that  $\hat{\theta}$  is drawn from some normal distribution. Obviously, the government knows  $\hat{\theta}$ . Proposition 6 summarizes

the effect that the government's disclosure of its policy goal  $\hat{\theta}$  has on the informativeness of the price.

**Proposition 6** *For mild actions ( $\lambda$  sufficiently close to zero),<sup>6</sup> the disclosure of the government's policy goal  $\hat{\theta}$  increases equilibrium price informativeness.*

This result captures what is perhaps the usual intuition about transparency and the reason why it is strongly advocated. The idea is that when the government reveals its policy goal, it reduces uncertainty for speculators. This encourages them to trade more aggressively, resulting in higher price informativeness.

For illustration, note that, just like before, the equilibrium price informativeness is given by the ratio:

$$\frac{1}{\alpha} \frac{\frac{\partial}{\partial s_i} E[\theta + T|I]}{\text{var}[\theta + T|I]},$$

where  $I$  denotes the information available to speculators. The intervention  $T$  continues to be given by (9). The only difference from before is that now  $\hat{\theta}$  may be unknown (depending on whether the government discloses it or not).

Whether or not the government discloses its policy threshold, the numerator  $\frac{\partial}{\partial s_i} E[\theta + T|s_i, P]$  in the price informativeness expression is unchanged from before. This is because the signal  $s_i$  does not tell a speculator anything about the government's policy threshold. In contrast, the denominator  $\text{var}[\theta + T|s_i, P]$  in case speculators do not know  $\hat{\theta}$  is

$$(1 - \lambda w)^2 \text{var}[\theta|s_i, P] + (\lambda w)^2 \tau_G^{-1} + \lambda^2 \text{var}(\hat{\theta}).$$

As a result, the level of informativeness is higher when the government discloses the policy goal, as then speculators are exposed to less risk and are willing to trade more aggressively.

Economically, it matters whether the government discloses information about something that the speculators have some information about or not. In the first case, when the government discloses information about the fundamental, this has an ambiguous effect on speculators' incentive to trade, as the information both reduces the value of their signal and the risk they are exposed to. In the second case, when the government discloses information on its policy goal, the effect on trading incentives is unambiguous, since this only reduces the risk that speculators are exposed to.

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<sup>6</sup>The condition that  $\lambda$  is sufficiently close to zero is needed only to guarantee equilibrium uniqueness (see Proposition 1). However, even when there are multiple equilibria, both the minimum and maximum equilibrium levels of informativeness are higher under transparency about  $\hat{\theta}$ .

## 6 Conclusion

Our paper analyzes how market-based corrective government policy affects the trading incentives of risk-averse speculators in a rational-expectations model of financial markets. We show that when the government takes a moderate corrective action, basing this action on the market price creates more trading risks for speculators. This harms their trading incentives, and hence the ability of the financial market to aggregate information and the informativeness of the price as a signal for government policy.

The conclusion is that the use of market prices as an input for policy might not come for free and might damage the informational content of market prices themselves. Hence, a government might benefit from limiting its reliance on market prices and thereby increasing their informational content. Also, and counter to common belief, transparency by the government might be a bad idea in that it might reduce trading incentives and hence price informativeness.

While we focus in this paper on market-based government policy, our analysis and results apply more generally for *any* corrective action that is based on the price. For example, similar effects will arise if a corporate-governance action – such as replacement of the CEO – is taken by the board of directors upon a decrease in market valuation. Another example is the idea of contingent capital that is gaining momentum recently as a potential solution to banking crises. Financing banks with contingent capital implies that a bank’s debt will be converted into equity upon reduction in its market value. This is in order to allow banks financing flexibility when it is most needed. Since such market-based conversion is essentially a market-based corrective action, our analysis in this paper implies that it will reduce the information in the price and hence the efficiency of the conversion trigger.

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## A Appendix

**Proof of Proposition 1:** We show that it is possible to choose constants  $p_0$ ,  $\rho$  and  $p_Z$  such that  $P = p_0 + \rho p_Z \theta + p_Z Z$  is an equilibrium.

Rewriting (7) more explicitly, the government’s estimate of the fundamental, conditional on the price and its own signal  $s_G$ , is

$$E[\theta | s_G, P] = \frac{\tau_\theta \bar{\theta} + \rho^2 \tau_Z \tilde{P} + \tau_G s_G}{T_G(\rho)},$$

where  $\tilde{P} \equiv \frac{1}{\rho p_Z} (P - p_0)$  and  $T_G(\rho) \equiv \tau_\theta + \rho^2 \tau_z + \tau_G$  is the precision of the government's estimate of  $\theta$ . So the government's intervention is

$$T = \lambda \left( \hat{\theta} - \frac{\tau_\theta \bar{\theta} + \rho^2 \tau_z \tilde{P} + \tau_G s_G}{T_G(\rho)} \right) = \lambda \left( \hat{\theta} - \frac{\tau_\theta \bar{\theta} + \rho^2 \tau_z \tilde{P}}{T_G(\rho)} - w(\rho) \theta - w(\rho) \varepsilon_G \right),$$

where  $w(\rho) = \frac{\tau_G}{T_G(\rho)}$  is the weight the government puts on its own signal in estimating  $\theta$ .

Conditional on seeing signal  $s_i$  and price  $P$ , a speculator's conditional expectation of the government signal  $s_G$  is

$$E[s_G | s_i, P] = E[\theta | s_i, P] = \frac{\tau_\theta \bar{\theta} + \rho^2 \tau_z \tilde{P} + \tau_\varepsilon s_i}{T_\varepsilon(\rho)},$$

where  $T_\varepsilon(\rho) \equiv \tau_\theta + \rho^2 \tau_z + \tau_\varepsilon$  is the precision of the investor's estimate of  $\theta$ . Hence an investor's estimate of the cash flow net of intervention,  $\theta + T$ , is

$$E[\theta + T | s_i, P] = \lambda \left( \hat{\theta} - \frac{\tau_\theta \bar{\theta} + \rho^2 \tau_z \tilde{P}}{T_G(\rho)} \right) + (1 - \lambda w(\rho)) E[\theta | s_i, P],$$

and the precision of his estimate of  $\theta + T$  is

$$((1 - \lambda w(\rho))^2 T_\varepsilon(\rho)^{-1} + (\lambda w(\rho))^2 \tau_G^{-1})^{-1}.$$

From (10), total demand by all speculators is

$$\int x_i(s_i, P) di = \frac{1}{\alpha} \frac{\lambda \left( \hat{\theta} - \frac{\tau_\theta \bar{\theta} + \rho^2 \tau_z \tilde{P}}{T_G(\rho)} \right) + (1 - \lambda w(\rho)) \frac{\tau_\theta \bar{\theta} + \rho^2 \tau_z \tilde{P} + \tau_\varepsilon \theta}{T_\varepsilon(\rho)} - P}{(1 - \lambda w(\rho))^2 T_\varepsilon(\rho)^{-1} + (\lambda w(\rho))^2 \tau_G^{-1}}.$$

This is a linear expression in the random variables  $\theta$  and  $Z$ . Consequently, market clearing (4) is satisfied for all  $\theta$  and  $Z$  if and only if the coefficients on  $\theta$  and  $Z$  both equal zero (the price intercept  $p_0$  is then chosen to make sure total speculator demand equals supply  $-Z$ ), i.e.,

$$-\lambda \frac{\rho^2 \tau_z}{T_G(\rho)} + (1 - \lambda w(\rho)) \left( \frac{\rho^2 \tau_z}{T_\varepsilon(\rho)} + \frac{\tau_\varepsilon}{T_\varepsilon(\rho)} \right) - \rho p_Z = 0 \quad (15)$$

and

$$-\rho^{-1} \lambda \frac{\rho^2 \tau_z}{T_G(\rho)} + \rho^{-1} (1 - \lambda w(\rho)) \frac{\rho^2 \tau_z}{T_\varepsilon(\rho)} - p_Z + \alpha ((1 - \lambda w(\rho))^2 T_\varepsilon(\rho)^{-1} + (\lambda w(\rho))^2 \tau_G^{-1}) = 0. \quad (16)$$

Subtracting (15) from  $\rho$  times (16) yields

$$-(1 - \lambda w(\rho)) \frac{\tau_\varepsilon}{T_\varepsilon(\rho)} + \alpha \rho \left( (1 - \lambda w(\rho))^2 T_\varepsilon(\rho)^{-1} + (\lambda w(\rho))^2 \tau_G^{-1} \right) = 0, \quad (17)$$

an equation of  $\rho$  only (observe that this matches equation (11) in the main text). Note that the pair of equations (15) and (16) hold if and only if the pair (15) and (17) hold. So to complete the proof of equilibrium existence, it suffices to show that there exists  $\rho$  solving (17), since  $p_Z$  can then be chosen freely to solve (15).

Since  $(1 - \lambda w)^2 = 1 - \lambda w - \lambda w(1 - \lambda w)$ , equation (17) can be rewritten as

$$(\alpha \rho - \tau_\varepsilon)(1 - \lambda w(\rho)) - \alpha \rho \left( \lambda w(\rho)(1 - \lambda w(\rho)) - (\lambda w(\rho))^2 \tau_G^{-1} T_\varepsilon(\rho) \right) = 0.$$

Defining

$$F(\rho, w) \equiv 1 - \frac{\tau_\varepsilon}{\alpha \rho} - \lambda w + \frac{\lambda^2 w^2}{1 - \lambda w} \frac{T_\varepsilon(\rho)}{\tau_G},$$

equation (17) is equivalent to

$$F(\rho, w(\rho)) = 0.$$

Note that  $w(\rho)$  is decreasing in  $\rho$ , with  $w(\rho) < 1$  for  $\rho = 0$ , and  $w(\rho) \rightarrow 0$  as  $\rho \rightarrow \infty$ . So  $F(\rho, w(\rho))$  approaches  $-\infty$  as  $\rho$  approaches 0, and approaches 1 as  $\rho \rightarrow \infty$ . By continuity, it follows that (17) has a solution, completing the proof of equilibrium existence.

For uniqueness, first note that at  $\lambda = 0$ , the unique solution of  $F(\rho, w(\rho)) = 0$  is  $\rho = \frac{\tau_\varepsilon}{\alpha}$ . To establish uniqueness for sufficiently small but strictly positive values of  $\lambda$ , proceed as follows. Fix  $\bar{\lambda} \in (0, 1)$ ; choose  $\underline{\rho}$  such that  $F(\rho, w(\rho)) < 0$  for all  $\rho \leq \underline{\rho}$  and  $\lambda \in [0, \bar{\lambda}]$ ; and choose  $\bar{\rho} > \underline{\rho}$  such that  $F(\rho, w(\rho)) > 0$  for all  $\rho \geq \bar{\rho}$  and  $\lambda \in [0, \bar{\lambda}]$  (the existence of  $\underline{\rho}$  and  $\bar{\rho}$  with these properties is easily established). At  $\lambda = 0$ ,  $\frac{d}{d\rho} F(\rho, w(\rho))|_{\rho=\frac{\tau_\varepsilon}{\alpha}} > 0$ . Consequently, there exists some  $\delta > 0$  such that for all  $\lambda \in [0, \bar{\lambda}]$ ,  $\frac{d}{d\rho} F(\rho, w(\rho)) > 0$  for all  $\rho \in \left(\frac{\tau_\varepsilon}{\alpha} - \delta, \frac{\tau_\varepsilon}{\alpha} + \delta\right)$ . So for all  $\lambda$  sufficiently small,  $F(\rho, w(\rho)) = 0$  has a unique solution in  $\left(\frac{\tau_\varepsilon}{\alpha} - \delta, \frac{\tau_\varepsilon}{\alpha} + \delta\right)$ ; by uniform convergence has no solution in the compact set  $[\underline{\rho}, \frac{\tau_\varepsilon}{\alpha} - \delta] \cup [\frac{\tau_\varepsilon}{\alpha} + \delta, \bar{\rho}]$ ; and has no solution below  $\underline{\rho}$  or above  $\bar{\rho}$ . Finally, a parallel proof implies uniqueness for the case of  $\lambda$  strictly negative and sufficiently close to 0. ■

**Proof of Proposition 2:** Let  $\rho^*$  and  $\rho_{-P}$  denote equilibrium price informativeness for the cases in which the government uses the price in an ex post optimal way, and in which the government completely ignores the price. Let  $F(\rho, w)$  be as defined in the proof of Proposition 1.

We first show that for  $\lambda$  positive and sufficiently small,  $\rho_{-P} > \rho^*$ . As  $\lambda$  approaches 0, both  $\rho_{-P}$  and  $\rho^*$  approach  $\frac{\tau_\varepsilon}{\alpha}$  (and moreover,  $\rho^*$  is uniquely defined by Proposition 1). Fix

$\delta > 0$ , and choose  $\hat{\lambda}$  such that if  $\lambda \in (0, \hat{\lambda})$ , then both  $\rho_{-P}$  and  $\rho^*$  lie within  $\delta$  of  $\frac{\tau_e}{\alpha}$ . Because  $w_{-P} > w(\rho)$ , there exists  $\check{\lambda} \in (0, \hat{\lambda})$  such that if  $\lambda \in (0, \check{\lambda})$  then  $F(\rho, w(\rho)) > F(\rho, w_{-P})$  for all  $\rho$  within  $\delta$  of  $\frac{\tau_e}{\alpha}$ . Consequently, if  $\lambda \in (0, \check{\lambda})$  then  $0 = F(\rho^*, w(\rho^*)) > F(\rho^*, w_{-P})$ , which since  $F_\rho > 0$  implies  $\rho_{-P} > \rho^*$ .

Finally, for the case of  $\lambda < 0$ , note that  $F_w > 0$ . So  $0 = F(\rho^*, w(\rho^*)) < F(\rho^*, w_{-P})$ , which since  $F_\rho > 0$  implies  $\rho_{-P} < \rho^*$ . Note that this argument applies even if there are multiple equilibria for the case in which the government uses the price. ■

**Proof of Proposition 3:** From the paragraph prior to the statement of Proposition 3, it suffices to show that a small increase in  $\tilde{w}$  above  $w(\rho)$  increases equilibrium price informativeness. Let  $F(\rho, w)$  be as defined in the proof of Proposition 1, so that  $F(\rho, w(\rho)) = 0$ . Because  $F_\rho > 0$ , we must show  $F_w(\rho, w(\rho)) < 0$ . This is indeed the case for all  $\lambda$  strictly positive and sufficiently close to 0, completing the proof. ■

**Proof of Proposition 4:** Let  $F(\rho, w)$  be as defined in the proof of Proposition 1, so that equilibrium price informativeness satisfies  $F(\rho, w(\rho)) = 0$ . Hence  $\frac{d\rho}{d\tau_G}$  satisfies

$$0 = \frac{d\rho}{d\tau_G} (F_\rho(\rho, w(\rho)) + w'(\rho) F_w(\rho, w(\rho))) + \frac{dw(\rho)}{d\tau_G} F_w(\rho, w(\rho)) + \frac{d}{d\tau_G} F(\rho, w(\rho)).$$

As in the proof of Proposition 3,  $F_w(\rho, w(\rho)) < 0$  for  $\lambda$  strictly positive and sufficiently close to 0. Moreover,  $F_\rho > 0$ ,  $w'(\rho) < 0$ ,  $\frac{dw(\rho)}{d\tau_G} > 0$ , and  $\frac{dF}{d\tau_G} < 0$ . Hence  $\frac{d\rho}{d\tau_G} > 0$  for  $\lambda$  strictly positive and sufficiently close to 0, completing the proof. ■

**Proof of Proposition 5:** See the main text following Proposition 5. ■

**Proof of Proposition 6:** The equilibrium condition under transparency is (17) (see proof of Proposition 1). The equilibrium condition without transparency has an additional term  $\alpha\rho\lambda^2 var(\hat{\theta})$  on the lefthand side, but it otherwise identical. The lefthand side of both conditions is negative for  $\rho$  sufficiently small, and positive for  $\rho$  sufficiently large. Consequently, both the minimum and maximum equilibrium levels of informativeness are higher under transparency. The equilibrium is unique in both cases when  $\lambda$  is sufficiently close to 0 (see Proposition 1), implying the result. ■

## B Additional numerical appendix

As we note in the main text, the effect of government corrective actions on price informativeness depends on the size of the corrective action. In the main text we focus on the case in which the corrective action is “mild,” or, more mathematically, “sufficiently small.” We

emphasize in the main text that this does not mean economically small, and refer to numerical simulations that show that corrective actions as large as  $\lambda = 30\%$  are still sufficiently small for all our results to hold. Here, we present the details of these numerical simulations.

## B.1 Numerical solution of the model

We start by detailing the numerical solution of the model. As shown in the proof of Proposition 1, equilibrium price informativeness  $\rho$  solves  $F(\rho, w(\rho)) = 0$ , where  $F$  is as defined in the proof. Dividing by  $w(\rho)$  implies that  $\rho$  solves

$$0 = \frac{1}{w(\rho)} \left(1 - \frac{\tau_\varepsilon}{\alpha\rho}\right) - \lambda + \frac{\lambda^2}{\frac{1}{w(\rho)} - \lambda} \frac{\tau_z\rho^2 + \tau_\theta + \tau_\varepsilon}{\tau_G},$$

or equivalently

$$0 = \frac{1}{\tau_G} (\tau_z\rho^2 + \tau_\theta + \tau_G) \left(1 - \frac{\tau_\varepsilon}{\alpha\rho}\right) - \lambda + \lambda^2 \frac{\tau_z\rho^2 + \tau_\theta + \tau_\varepsilon}{\tau_z\rho^2 + \tau_\theta + \tau_G - \lambda\tau_G},$$

or equivalently

$$\begin{aligned} 0 &= (\tau_z\rho^2 + \tau_\theta + \tau_G - \lambda\tau_G) (\tau_z\rho^2 + \tau_\theta + \tau_G) (\alpha\rho - \tau_\varepsilon) \\ &\quad - \lambda\alpha\tau_G\rho (\tau_z\rho^2 + \tau_\theta + \tau_G - \lambda\tau_G) + \lambda^2\alpha\tau_G\rho (\tau_z\rho^2 + \tau_\theta + \tau_\varepsilon), \end{aligned}$$

or equivalently

$$\begin{aligned} 0 &= [\tau_z^2\rho^4 + \tau_z(2\tau_\theta + (2 - \lambda)\tau_G)\rho^2 + (\tau_\theta + \tau_G)(\tau_\theta + (1 - \lambda)\tau_G)](\alpha\rho - \tau_\varepsilon) \\ &\quad + \lambda\alpha\tau_G\rho[(\lambda - 1)\tau_z\rho^2 - (\tau_\theta + (1 - \lambda)\tau_G) + \lambda(\tau_\theta + \tau_\varepsilon)]. \end{aligned}$$

Rewriting a final time, the equilibrium condition is equivalent to the fifth-degree polynomial

$$\begin{aligned} 0 &= \alpha\tau_z^2\rho^5 - \tau_\varepsilon\tau_z^2\rho^4 + [2\tau_\theta + (2 - \lambda)\tau_G + \lambda(\lambda - 1)\tau_G]\tau_z\alpha\rho^3 \\ &\quad - [2\tau_\theta + (2 - \lambda)\tau_G]\tau_\varepsilon\tau_z\rho^2 + A\alpha\rho - B \end{aligned} \tag{18}$$

where

$$\begin{aligned} A &= (\tau_\theta + \tau_G)(\tau_\theta + (1 - \lambda)\tau_G) - \lambda\tau_G(\tau_\theta + (1 - \lambda)\tau_G) + \lambda^2\tau_G(\tau_\theta + \tau_\varepsilon) \\ &= (\tau_\theta + (1 - \lambda)\tau_G)^2 + \lambda^2\tau_G(\tau_\theta + \tau_\varepsilon) \\ B &= \tau_\varepsilon(\tau_\theta + \tau_G)(\tau_\theta + (1 - \lambda)\tau_G). \end{aligned}$$

Solutions to (18) can be found using any standard numerical procedure for finding the roots of polynomials.

## B.2 Numerical simulations

The parameters of the model are  $\alpha$ ,  $\tau_\theta$ ,  $\tau_G$ ,  $\tau_\varepsilon$  and  $\tau_Z$ . Note first that the equilibrium condition  $F(\rho, w(\rho)) = 0$  is homogeneous of degree zero in the vector of these five parameters. Consequently, it is sufficient to specify the four ratios  $\frac{\tau_\theta}{\alpha}$ ,  $\frac{\tau_Z}{\alpha}$ ,  $\frac{\tau_G}{\tau_\theta}$  and  $\frac{\tau_\varepsilon}{\tau_G}$ .

Let  $\phi$  denote the fraction of price fluctuations that are not attributable to changes in the fundamental  $\theta$ , for the case in which government intervention is completely absent. From the paper,

$$\phi = \left( \frac{\tau_\theta}{\frac{\tau_\varepsilon^2 \tau_Z}{\alpha^2} + \tau_\theta} \right)^{1/2} = \left( \frac{\tau_\varepsilon^2 \tau_Z}{\alpha^2 \tau_\theta} + 1 \right)^{-1/2} = \left( \frac{\left( \frac{\tau_\varepsilon \tau_G \tau_\theta}{\tau_G \tau_\theta \alpha} \right)^2 \frac{\tau_Z}{\alpha}}{\frac{\tau_\theta}{\alpha}} + 1 \right)^{-1/2},$$

and so

$$\frac{\tau_Z}{\alpha} = \frac{(\phi^{-2} - 1) \frac{\tau_\theta}{\alpha}}{\left( \frac{\tau_\varepsilon \tau_G \tau_\theta}{\tau_G \tau_\theta \alpha} \right)^2}.$$

Consequently, it is sufficient to specify  $\frac{\tau_\theta}{\alpha}$ ,  $\frac{\tau_G}{\tau_\theta}$ ,  $\frac{\tau_\varepsilon}{\tau_G}$ , together with  $\phi$ .

We simulate the model for values of  $\phi$  (the fraction of price fluctuations that are not attributable to changes in the fundamental  $\theta$ ) of 10%, 50%, and 90%. Likewise, we simulate the model for values of  $\tau_\varepsilon/\tau_G$  (the ratio of the precisions of an *individual* speculator's private forecast to the government's) of 10%, 50%, and 90%. In both cases, these ranges more than cover what most people would regard as reasonable values of these parameters.

We have much weaker priors for reasonable values of  $\frac{\tau_\theta}{\alpha}$  and  $\frac{\tau_G}{\tau_\theta}$ . For these parameters, we simply simulate the model over a fine grid of possible values for both parameters, ranging from 1/100 up to 100.

We simulate the model for each possible combination of these four parameters. For each combination of parameter values, we check whether the equilibrium is unique, and whether the derivative  $F_w$  (the function  $F$  is as defined in the proof of Proposition 1) is negative at the equilibrium value of  $\rho$  (this is the condition for which we need  $\lambda$  to be sufficiently small in our analysis).

For values of  $\lambda$  up to  $\lambda = 30\%$ , we find that both conditions are satisfied *for all* parameter values in the ranges detailed above. As we note in the main text, a corrective action of 30% is economically large, and indeed is considerably above our prior of the likely scale of government interventions. Moreover, we also emphasize that both conditions above are also

satisfied for many parameter values even when  $\lambda$  is even higher than 30%.