Government intervention and information aggregation by prices[1]

Philip Bond[2]   Itay Goldstein[3]

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[2]University of Minnesota.

[3]University of Pennsylvania.

Abstract

Market prices are thought to contain a lot of useful information. Hence, regulators (and other agents) are often urged to use market prices to guide decisions. An important issue to consider is the endogeneity of market prices and how they are affected by the prospect of government intervention. We show that if the government learns from the price when taking a corrective action, it might 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. Diametrically opposite implications hold for the alternative case in which the government's action amplifies the effect of underlying fundamentals. We derive implications for the optimal use of market information and for the government's incentives to produce its own information.

1 Introduction

Market prices of financial securities contain a great deal of information. As such, they can provide valuable guidance for government decisions. Consistent with this, existing research establishes that government actions do indeed reflect market prices.[1] Moreover, numerous policy proposals call for governments to make even more use of market prices, particularly in the realm of bank supervision.[2] Such policy proposals are increasingly prominent in the wake of the recent economic crisis and the perceived failure of financial regulation prior to it.[3]

An important issue to be considered when discussing the use of market prices in government policy is that prices are endogenous and their information content might be affected by government policy. In the recent crisis, government actions were not only perceived to be reactions to market prices, but expectations about them were often a major driver of changes in asset prices. For example, 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 was largely driven by speculation about the government's behavior. Hence, government actions affect prices, and consequently may also affect the ability of the government to learn from prices. This may affect the desirability of market-based intervention.

To study these effects, we consider the process by which information gets aggregated into the price. Our paper analyzes the effect of market-based government policy on the trading incentives of speculators and hence on the ability of the financial market to aggregate speculators' dispersed information. We derive positive implications for the behavior of prices and government actions when the government learns from prices, and normative implications

[1] See Feldman and Schmidt (2003), Krainer and Lopez (2004), Piazzesi (2005), and Furlong and Williams (2006).

[2] See, e.g., Evanoff and Wall (2004) and Herring (2004).

[3] 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. Other recent proposals say that banks should issue contingent capital (i.e., debt that converts to equity) with market-based conversion triggers (see Flannery (2009), McDonald (2010)).

on the optimal degree of reliance on market information. We distinguish between *corrective* government policy – i.e., one that aims to help firms in trouble, for example, by bailing out struggling banks – and *amplifying* government policy – for example, shutting down bad banks – and show that they generate very different implications.

In detail, we develop a tractable version of a rational-expectations model – based on the work of Grossman and Stiglitz (1980), Hellwig (1980), and Admati (1985) – 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, and assume that it observes the market price, in addition to a privately observed signal, and uses the information to make a decision about its intervention. The intervention can be either corrective or amplifying, depending on the objective of the government, which is fully characterized in our model. 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 takes a corrective action based on information not contained in the price, but correlated with 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 in its decision on a corrective action reduces the informational content of prices.

This result has a couple of 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. This increases the informativeness of the price and enables the government to make better decisions. 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. In the case of corrective actions, 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. The key distinction is that in the first case the government reveals information about the fundamental which is the object that speculators are informed about, and so this decreases their informational advantage and their trading incentive, while in the second case the dominant effect is the decrease in uncertainty that pushes speculators to trade more aggressively.[4]

Importantly, we show that the implications change drastically once we consider the case of amplifying actions. The key effect here is opposite since the government's action based on its information amplifies the uncertainty that speculators are exposed to and decreases their trading incentives. Hence, when the government relies more on market prices it leads to an increase in trading incentives and price informativeness. In contrast to the case of corrective actions, this implies that there is a rationale for the government to commit to

[4] There are recent papers showing that transparency might be welfare reducing, e.g., Morris and Shin (2002) and Angeletos and Pavan (2007). In these papers, the source for the result is the existence of coordination motives across economic agents. In contrast, such coordination motives do not exist in our model, where, conditional on the price (which is observed to all), speculators do not care about what other speculators do.

market-based rules rather than act on the basis of its own information.[5] Overall, inferring information from the price is harder in the case of an amplifying action than in the case of a moderate corrective action.

We conclude the analysis by considering the case where the government learns from multiple securities, and show that this is not an easy solution to the problem of inferring information from prices, and in some cases adding more securities actually reduces overall informativeness. Hence, the problems we identify in this paper are not a result of market incompleteness.

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. For example, in Bond, Goldstein and Prescott (2010), the price of any traded asset after a realization of some underlying state variable θ is assumed to equal the expected payoff of the asset conditional on θ. In other words, even if information about the state variable θ is dispersed across many investors, the price is assumed to fully and efficiently aggregate this dispersed information. In this paper we are particularly interested in what is going on inside the black box, i.e., in how information gets aggregated given the expected government intervention.

[5] Other papers emphasize the commitment aspect associated with market-based rules. See Faure-Grimaud (2002), Rochet (2004), and Lehar, Seppi, and Strobl (2010).

Moreover, the model we develop enables very tractable analysis of information aggregation by prices in the presence of informational feedback to real decisions. While we focus here on market-based government intervention, our results apply more generally to many other contexts; we review a couple of them in the concluding section.

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 and the implications for the optimal use of market information. In Section 5, we analyze the implications of our model for optimal transparency. Section 6 provides an extension of the model to consider multiple securities. Section 7 concludes. All proofs are relegated to an appendix.

2 The model

We want to use the simplest and most standard framework possible to study 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 our 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 them. In $t = 1$, the government, who learns information about the expected cash flow from the price of the stock, makes a decision about its intervention. 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 θ. We refer to θ as the fundamental of the firm. It is distributed normally with mean $\overline{\theta}$ and standard deviation σ_θ. We denote the precision of prior information by $\tau_\theta \equiv \frac{1}{\sigma_\theta^2}$.

The government has the ability to affect firm cash flows. For example, the government may directly transfer cash to or from a firm; may provide liquidity support in the form of loans at below-market rates; or may directly intervene in the firm's management. Regardless of the type of intervention, we denote by T the change in the firm's cash flows.

In deciding on T, the government has to weigh the benefit against the cost. We assume that the government's benefit is weakly concave in the change in cash flow T. That is, the benefit from supporting firms diminishes as the support gets larger. In addition, and crucially, the government's benefit also depends on the firm's fundamentals θ. For example, the government may have a preference to help firms with poor fundamentals if doing so reduces socially inefficient liquidation of assets; or it may prefer to help firms with strong fundamentals if firms with better fundamentals contribute more to social welfare.

For tractability, we assume that the government's benefit function takes the form

$$V(T,\theta) \equiv a_2 T^2 + a_1 T + a_T T\theta + v(\theta), \tag{1}$$

where a_2, a_1 and a_T are constants, and v is a function. As noted, $a_2 \leq 0$, while the sign of a_T reflects whether the government prefers to help firms with strong ($a_T > 0$) or weak ($a_T < 0$) fundamentals.

The cost to the government of changing cash flows by T is given by $\gamma(T)$, which is a weakly convex function of T. Again, for tractability we assume that γ is quadratic.

Assuming that V and/or γ are non-linear in T, and equating marginal benefit to marginal cost, we can write the change in cash flow T that a fully-informed government would like to implement as $\lambda\left(\hat{\theta}-\theta\right)$, where λ and $\hat{\theta}$ are constants.[6] In particular, note that λ is positive if the government cares more about helping weak firms ($a_T < 0$) and negative if the government cares about helping strong firms ($a_T > 0$). We refer to the two cases as *corrective* and *amplifying* actions, respectively. In the first case, the government transfers cash to firms with fundamentals below a threshold at the expense of firms with fundamentals above a threshold. In the second case, it does the opposite. In the context of intervention in the banking sector, corrective actions often come in the form of bailing out weak banks (while potentially taxing strong banks), whereas amplifying actions can come in the form of shutting down weak banks (while potentially easing constraints on strong banks).

When the government is not fully-informed, it must base its intervention on its beliefs about the fundamental θ. In this case, it intervenes according to the following rule:

$$T \equiv \lambda\left(\hat{\theta}-E\left[\theta|I_G\right]\right), \tag{2}$$

where $E\left[\theta|I_G\right]$ 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. Note that the key benefit of the simple functional forms we have adopted for V and γ is that the policy rule is linear in θ. This helps us maintain the linear solution that is heavily used in the literature on information aggregation, 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 α is the absolute

[6] Explicitly, equating marginal cost to marginal benefit gives $2a_2T + a_1 + a_T\theta = \gamma''(0)\,T + \gamma'(0)$, and hence $T = \frac{a_1-\gamma'(0)+a_T\theta}{\gamma''(0)-2a_2}$. So, $\lambda = \frac{-a_T}{\gamma''(0)-2a_2}$ and $\hat{\theta} = \frac{a_1-\gamma'(0)}{-a_T}$.

risk aversion coefficient. Each speculator i receives a noisy signal about the fundamental:

$$s_i = \theta + \varepsilon_i, \tag{3}$$

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

Each speculator chooses a quantity x_i to trade 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:

$$x_i\left(s_i, P\right) = \arg\max_{\tilde{x}} E\left[-e^{-\alpha\tilde{x}(\theta+T-P)}|s_i, P\right]. \tag{4}$$

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

$$\int x_i\left(s_i, P\right) di = -Z. \tag{5}$$

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 θ. Second, the government observes a private signal s_G of the fundamental:

$$s_G = \theta + \varepsilon_G, \tag{6}$$

where the noise term ε_G is drawn from a normal distribution with mean 0 and standard deviation σ_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 (2) 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 (4)) and such that the market clearing condition (5) holds. In addition, here the government's choice of T is optimally based on its signal s_G and the price P, as in (2).

As is standard in almost all the literature, we focus on linear equilibria in which the price P is a linear function of the average signal realization—which equals the fundamental θ—and the supply shock $-Z$.[7]

Proposition 1 below formally establishes the existence of a linear equilibrium. Before stating the proposition, we now provide a less formal derivation focusing on the informativeness of the equilibrium price.

In a linear equilibrium, the price can be written as

$$P = p_0 + p_Z(\rho\theta + Z), \tag{7}$$

for some parameters p_0, p_Z and ρ. In particular, ρ measures the informativeness of the price, since the informational content of the price is the same as the linear transformation $\frac{1}{\rho p_Z}(P - p_0) = \theta + \rho^{-1}Z$. 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 ρ. Intuitively, the price of the security is affected by both changes in the fundamental θ and

[7] In a linear equilibrium, an individual speculator's demand is linear in his own signal, as we show below. Consequently, total speculator demand is a linear function of the average signal realization, which equals θ.

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.

It is worth highlighting that our measure of informativeness relates to the fundamental θ, and not the cash flow $\theta + T$ (as would be the case in measures of price efficiency). This is because the government is attempting to learn the fundamental θ from the price, and so the informativeness about θ is the relevant object for the government's ability to take an appropriate action attempting to maximize its objective.

Given normality of the fundamental θ and the supply shock $-Z$, the price P is itself normal. Consequently, given normality of the error term ε_G, the government's posterior of the fundamental θ 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

$$E[\theta | s_G, P] = K_\theta \bar{\theta} + K_P \frac{1}{\rho p_Z} (P - p_0) + w(\rho) s_G, \tag{8}$$

where K_θ, 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.[8] By the standard application of Bayes' rule to normal distributions it is given by:

$$w(\rho) \equiv \frac{\tau_G}{\tau_\theta + \rho^2 \tau_z + \tau_G}. \tag{9}$$

The weight that the government puts on its own signal is the precision of this signal (τ_G) divided by the sum of precisions of the government's signal, the prior information (τ_θ) and the signal from the price ($\rho^2 \tau_z$). As one would expect, the government puts more weight on its own signal when it is precise (τ_G is high) and less when the price is informative (ρ is

[8] Of course, the constants K_θ and K_P also depend on the price informativeness ρ, but for expositional ease we do not make this dependence explicit.

high). Given the policy rule (2), the intervention is

$$T\left(s_G, P\right) = \lambda\hat{\theta} - \lambda w\left(\rho\right)\left(\theta + \varepsilon_G\right) - \lambda K_P \frac{1}{\rho p_Z}\left(P - p_0\right) - \lambda K_\theta \bar{\theta}. \tag{10}$$

Similar to the government, each speculator assigns a normal posterior (conditional on his own signal s_i and price P) to the fundamental θ. Moreover, from (10), 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,

$$x_i\left(s_i, P\right) = \frac{E\left[\theta + T | s_i, P\right] - P}{\alpha var\left[\theta + T | s_i, P\right]}. \tag{11}$$

Thus, the amount traded is the difference between the expected value of the security (fundamental + 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 δ to the fundamental θ and $-\delta\rho$ to Z. By construction (see (7)), this shock leaves the price P unchanged. Moreover, the market clearing condition (5) must hold for all realizations of θ and Z. Consequently,

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

Substituting in (10) and (11) yields equilibrium price informativeness:

$$\rho = \frac{1}{\alpha}\frac{\frac{\partial}{\partial s_i}E\left[\theta + T | s_i, P\right]}{var\left[\theta + T | s_i, P\right]} = \frac{1}{\alpha}\frac{\left(1 - \lambda w\left(\rho\right)\right)\frac{\partial}{\partial s_i}E\left[\theta | s_i, P\right]}{\left(1 - \lambda w\left(\rho\right)\right)^2 var\left[\theta | s_i, P\right] + \left(\lambda w\left(\rho\right)\right)^2 \tau_G^{-1}}. \tag{12}$$

Here, the informativeness of the price is essentially determined by how much speculators trade on their information about θ. 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 intervention based on its signal. The variance of the expected value, which appears in the denominator, is a function of two components: the expected variance due to the fundamental θ and the variance of the noise in government information. The relative importance of these two components is determined by λ, the strength of the government's action, and by w, the extent to which the government relies on its own signal.

Proposition 1 *For $\lambda \leq 1$, a linear equilibrium exists. Equilibrium price informativeness ρ satisfies (12). For any λ 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 (12) has a unique solution given by

$$\rho = \frac{1}{\alpha} \frac{\frac{\partial}{\partial s_i} E\left[\theta | s_i, P\right]}{var\left[\theta | s_i, P\right]} = \frac{1}{\alpha} \frac{\frac{\tau_\varepsilon}{\tau_\theta + \rho^2 \tau_z + \tau_\varepsilon}}{\frac{1}{\tau_\theta + \rho^2 \tau_z + \tau_\varepsilon}} = \frac{\tau_\varepsilon}{\alpha}. \tag{13}$$

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 government puts on its own information was exogenous and unaffected by the price informativeness ρ. However, due to the effect of the informativeness of the price on the weight that the government puts on its information in the intervention decision, our model sometimes exhibits multiple equilibria. This is because, as we see in (12), the informativeness ρ affects the weight w, which in turn affects ρ, so we have to solve a fixed-point problem, which sometimes has multiple solutions. Economically, as the price informativeness increases, traders are exposed to less residual risk, which induces them to trade more aggressively resulting in a more informative price. Indeed, for a large enough corrective action ($\lambda >> 0$), 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 λ is small in absolute value, and so multiplicity does not arise. As we discuss below, the results that we highlight depend on λ being sufficiently small in absolute value. Numerical calculations (see details in Appendix B) suggest that these results hold for a wide range of values of λ. For example, for the case of corrective actions, they hold 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 λ strike us as much less realistic. For this reason we focus on these results.

4 Government policy and price informativeness

In this section we study how the government's decision to use prices as a basis for intervention affects the informativeness of the equilibrium price and what implications this has for the optimal use of market prices. 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 (8)),

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

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 (10)),

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

Equilibrium price informativeness when the government ignores the price is then given by (12), with the weight that the government puts on it own signal, $w\left(\rho\right)$, replaced by $w_{-P} > w\left(\rho\right)$.

Below, we will analyze how the reliance on market price (which shifts the weight on the government's own signal from w_{-P} to $w\left(\rho\right)$) affects the informativeness ρ. To understand the results that follow, it is helpful to keep in mind the following three key properties of the standard model *without* government intervention, i.e., where $\lambda = 0$.

Property 1: In the standard model, price informativeness is greater when cash flows depend *less* on the fundamental. To see this, suppose that the traded asset pays $\nu\theta$ instead of θ, where ν is some constant. From (13), the price informativeness is $\frac{\tau_\varepsilon}{\nu\alpha}$. Hence, when the importance of the fundamental is lowered, i.e., $\nu < 1$, price informativeness is increased. Economically, reducing the importance of the fundamental has two opposite effects. It reduces the usefulness of a trader's signal in forecasting cash flows (the numerator in (13)), which causes traders to trade *less* aggressively and pushes price informativeness *down*. It also reduces the risk to which traders are exposed (the denominator in (13)), which causes traders to trade *more* aggressively and pushes price informativeness *up*. As is clear from (13), the second effect is the dominant one, so the net effect is an increase in price informativeness.

Property 2: Any change to the cash flow that is a deterministic function of price has no effect on price informativeness. To see this, consider again (13), and simply replace θ with $\theta + h\left(P\right)$, where h is an arbitrary function. It is clear that neither the numerator nor the denominator is affected. Economically, since the price is common knowledge, traders' trading decisions, and hence price informativeness, are determined only by the moments of cash flow after conditioning on the price.

Property 3: In the standard model, price informativeness is unrelated to the tightness of traders' priors (τ_θ) about the fundamental θ. Inspecting (13), we see that changes in τ_θ affect both the usefulness of a trader's signal in forecasting cash flows (the numerator), and the the risk to which traders are exposed (the denominator), but the two effects exactly offset one another.

4.1 The case of corrective actions ($\lambda > 0$)

Returning to the case of government intervention, we now explore the effect of the government's usage of the information in the price when taking a corrective action.

4.1.1 Price informativeness

Property 1 described above implies that corrective actions tend to increase price informativeness: the corrective nature of the intervention reduces the importance of the fundamental in determining cash flows. However, this is true only for corrective actions that are based to some degree on the government's own signal. If instead the government based its decision *only* on the price, Property 2 above implies that price informativeness is the same as without government intervention. Comparing the two cases, the more weight the government puts on the price the less informative prices become. There is a counter effect, however, as the reliance of the government on its own signal introduces another source of variance that speculators are exposed to: the noise in the government's signal. This reduces speculators' incentive to trade and hence price informativeness. Overall, the following proposition shows that the counter effect is weaker when the corrective action is mild (λ is small and positive).

Proposition 2 *For mild corrective actions (λ small and positive) price informativeness is reduced when the government uses the price as a basis of policy.*

As one can see from (12), if instead λ is large and positive, the dominant factor determining a speculator's residual uncertainty about $\theta + T$ is the government's error term ε_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 λ is well above 30%, which we find unrealistic for most cases.

4.1.2 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 θ. In our framework, given that $P = p_0 + p_Z(\rho\theta + Z)$, excess volatility is given by:

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

It is clear from the above expression that excess volatility is negatively related to price informativeness ρ. 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.

4.1.3 Optimal use of market information

After characterizing the effect of the use of the information in the price on price informativeness, we now consider the implications that this has for the government's objective function by asking what is the optimal use of the information in the price by the government. 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 (10). 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 defined by weights $\tilde{w}$, $\tilde{K}_P$ and $\tilde{K}_\theta$,

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

The government aims to maximize, by choice of weights $\tilde{w}$, $\tilde{K}_P$ and $\tilde{K}_\theta$, its objective:

$$E_{s_G,P}\left[E\left[V\left(\tilde{T}\left(s_G, P; \tilde{w}, \tilde{K}_P, \tilde{K}_\theta\right), \theta\right) - \gamma\left(\tilde{T}\left(s_G, P; \tilde{w}, \tilde{K}_P, \tilde{K}_\theta\right)\right)|s_G, P\right]\right].$$

By construction, for a given price informativeness ρ, the weights $w(\rho)$, K_P and K_θ maximize

$$E\left[V\left(\tilde{T}\left(s_G, P; \tilde{w}, \tilde{K}_P, \tilde{K}_\theta\right), \theta\right) - \gamma\left(\tilde{T}\left(s_G, P; \tilde{w}, \tilde{K}_P, \tilde{K}_\theta\right)\right)|s_G, P\right]$$

for any realization of s_G and P. Hence, 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 ρ. 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, and hence increases the government's welfare. 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.[9] Formally:

[9] 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

Proposition 3 *Consider a mild corrective action (λ small and positive), and let ρ 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. In other words, the government does not care about price informativeness per se; it cares about it only to the extent that it allows it to make better decisions and achieve greater welfare, and this implies using the information in the price to some extent.

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.

exposure of speculators to risk and encourages them to trade more aggressively on their information, making the price more informative.

4.1.4 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, τ_G, is a choice variable. What would be the benefits of increasing τ_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 θ. More interesting, however, is that an increase in τ_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 τ_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.[10]

[10] 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

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

4.2 The case of amplifying actions ($\lambda < 0$)

So far, we considered the case of corrective actions. To recap, in the case of a moderate corrective action, the government reduces price informativeness when it bases interventions on the market price, as opposed to relying solely on its own information. Consequently, to maximize its objective, the government would like to commit to (at least slightly) overweight its own information. Related, the accuracy of its own information (τ_G) is a complement to the use of market prices, since it leads naturally to the government placing more weight on its own information, which increases price informativeness.

The key force driving these results is Property 1 described above: when the fundamental has a weaker effect on the cash flow from the security, as in the case of corrective actions, price informativeness is increased, because traders are exposed to less risk and trade more aggressively. (Recall that, due to Property 2, this occurs only as long as the corrective action is based to some degree on the government's private information.) If instead the action is amplifying, Property 1 generates an effect in the opposite direction—traders are now exposed to more risk and trade less aggressively—and the above results are reversed. Summarizing:

Proposition 5 *Consider an amplifying action $\lambda < 0$:*

(A) Price informativeness is increased when the government uses the price as a basis of policy.

(B) 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.

---

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.

(C) For $|\lambda|$ sufficiently small, an increase in the precision of the government's information (τ_G) reduces the informativeness of the price.

Note that in the case of amplifying actions, the distinction between moderate and non-moderate actions matters less than in the case of corrective actions. The main result in part (A) holds independently of the size of the amplifying action. This is because the decrease in exposure to government noise when the government relies more on market price strengthens the increased incentive to trade and the increase in price informativeness.

An interesting insight stemming from of part (B) of Proposition 5 is that there is a force that pushes the government towards the adoption of clear (market-based) rules, rather than acting in a discretionary way based on its own information. The implication is that acting based on clear rules is desirable when the government's action is amplifying, e.g., when the government shuts down bad banks, but not when it is corrective, e.g., when the government provides support to struggling banks.

Finally, it is interesting to consider how price informativeness varies with the intervention parameter λ (recall that λ is derived from the objective function of the government). Based on Property 1, amplifying actions ($\lambda < 0$) lead to lower price informativeness than the benchmark case of no-intervention, whereas mild corrective actions ($\lambda > 0$ but not too large) lead to greater price informativeness than the benchmark (this can also be seen from (12)). Consequently, there is a sense in which corrective actions are easier for a government to implement effectively. The result is summarized in the following proposition.

Proposition 6 *Price informativeness is greater in the case of mild corrective actions than for amplifying actions.*

5 Transparency

Governments are often criticized for not being transparent enough about their information and policy goals. But is government transparency actually 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 7 summarizes the effect that the government's disclosure of its signal s_G has on the informativeness of the price and consequently on the government's objective.

Proposition 7 *For mild corrective actions, the disclosure of the government's signal s_G reduces equilibrium price informativeness and hence the value of the government's objective function.*

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 (12) that price informativeness is given by

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

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,

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

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 (12)).

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. This is essentially Property 3 described above. The result is then driven by a combination of Property 1 and Property 2. 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 (and is not reflected in the price). 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.

Finally, note that the net effect is opposite in the case where the government takes an amplifying action. In this case, revealing the government's signal increases price informativeness and improves the value of the government's objective function.

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 resources into the firm. Suppose that speculators believe that $\hat{\theta}$ is drawn from some normal distribution. Obviously, the government knows $\hat{\theta}$. Proposition 8 summarizes the effect that the government's disclosure of its policy goal $\hat{\theta}$ has on the informativeness of the price and consequently on the value of its objective function.

Proposition 8 *For mild actions (λ sufficiently close to zero),*[11] *the disclosure of the government's policy goal $\hat{\theta}$ increases equilibrium price informativeness and hence the value of*

[11] The condition that λ is sufficiently close to zero is needed only to guarentee 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 $\hat{\theta}$.

the government's objective function.

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. The government is then better off as it can make more informed decisions.

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

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

where I denotes the information available to speculators. The intervention T continues to be given by (10). 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 $\frac{\partial}{\partial s_i}E\left[\theta+T|I\right]$ 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 $var\left[\theta+T|I\right]$ in case speculators do not know $\hat{\theta}$ is

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

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. Note that this result does not depend on whether the government takes a corrective action or an amplifying action.

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.

6 Adding Another Security

Our analysis in previous sections assumed that the traded security is a claim on the value of the firm $\theta + T$. Under the case of a corrective action, we found that the government reduces the informativeness of the price when it uses the information in the price in its intervention decision. An interesting question is whether the government can do better when there are more securities traded in the market, so that the market is closer to completeness. In particular, suppose that in addition to the traditional security, there is a security that provides a claim on the fundamental cash flow of the firm θ. In this section, we analyze the equilibrium outcomes under the assumption that both a security on θ and a security on $\theta + T$ are traded.

The only difference between the version of the model studied in this section and the one in previous sections is that we now assume that speculators can trade two securities; the first one is a claim on $\theta + T$ and the other one is a claim on θ. In each market, there is a noisy supply shock: $-Z_{\theta+T}$ in the market for the $\theta + T$ security and $-Z_\theta$ in the market for the θ security. Both $Z_{\theta+T}$ and Z_θ are distributed normally with mean 0 and standard deviation σ_z (as before, $\tau_z \equiv \frac{1}{\sigma_z^2}$). We denote the prices in the two markets $P_{\theta+T}$ and P_θ, respectively.

To make our analysis as transparent as possible, we assume that the noise shocks $Z_{\theta+T}$ and Z_θ are independent of each other. While this assumption can be relaxed, it has the benefit of making the informational content of the price vector particularly easy to describe. Concretely, the lack of complete correlation between $Z_{\theta+T}$ and Z_θ reflects an assumption that some noise trades are truly random, rather than stemming entirely from hedging motives.

Using the expressions for a CARA individual's demand for a normally distributed asset in a framework with multiple assets (see Admati (1985)), a speculator i's demands for the two securities, $x_{i,\theta+T}$ and $x_{i,\theta}$, are as follows:

$$x_{i,\theta+T}\left(s_i, P_{\theta+T}, P_\theta\right) = \frac{var\left(\theta\right)\left(E\left[\theta+T\right]-P_{\theta+T}\right) - cov\left(\theta,\theta+T\right)\cdot\left(E\left[\theta\right]-P_\theta\right)}{\alpha\left(var\left(\theta+T\right)var\left(\theta\right) - cov\left(\theta,\theta+T\right)^2\right)}, \qquad (15)$$

$$x_{i,\theta}\left(s_i, P_{\theta+T}, P_\theta\right) = \frac{var\left(\theta+T\right)\left(E\left[\theta\right]-P_{\theta}\right) - cov\left(\theta,\theta+T\right)\cdot\left(E\left[\theta+T\right]-P_{\theta+T}\right)}{\alpha\left(var\left(\theta+T\right)var\left(\theta\right) - cov\left(\theta,\theta+T\right)^2\right)}, \qquad (16)$$

where all the expectation, variance, and covariance terms are conditional on the information available to speculator i: s_i, $P_{\theta+T}$, and P_θ.

These expressions reveal the complex nature of demands for assets in a framework with multiple correlated assets. Consider the numerator in each of the two expressions. The first term in the numerator reflects the speculative motive for trading: An increase in the expected payoff of the asset relative to its price leads the speculator to increase the quantity of the asset that he demands. The second term in the numerator reflects the hedging motive for trading: If the two assets are positively correlated, an increase in the expected payoff of the other asset relative to its price leads the speculator to decrease the quantity of the asset that he demands, as he uses the asset to hedge against his exposure in the other asset. As we will see, these conflicting motives for trade can severely reduce the informativeness of price of a given asset, and so the overall effect of adding a security on the informativeness of the price system might end up being negative.

To analyze the informativeness of the price system, we again focus on linear equilibria of the form:[12]

$$
\begin{aligned}
P_{\theta+T} &= \bar{p}_1 + p_{1\theta}\theta + p_{11}Z_{\theta+T} + p_{12}Z_{\theta}, \\
P_{\theta} &= \bar{p}_2 + p_{2\theta}\theta + p_{21}Z_{\theta+T} + p_{22}Z_{\theta}.
\end{aligned}
\tag{17}
$$

A little manipulation implies that the informational content of observing $P_{\theta+T}$ and P_θ is the same as observing the linear transformations:

$$
\begin{aligned}
\tilde{P}_{\theta+T} &\equiv \frac{\frac{p_{22}}{p_{2\theta}}\frac{P_{\theta+T}-\bar{p}_1}{p_{1\theta}} - \frac{p_{12}}{p_{1\theta}}\frac{P_{\theta}-\bar{p}_2}{p_{2\theta}}}{\frac{p_{22}}{p_{2\theta}} - \frac{p_{12}}{p_{1\theta}}} = \theta + \rho_{\theta+T}^{-1}Z_{\theta+T}, \\
\tilde{P}_{\theta} &\equiv \frac{\frac{p_{11}}{p_{1\theta}}\frac{P_{\theta}-\bar{p}_2}{p_{2\theta}} - \frac{p_{21}}{p_{2\theta}}\frac{P_{\theta+T}-\bar{p}_1}{p_{1\theta}}}{\frac{p_{11}}{p_{1\theta}} - \frac{p_{21}}{p_{2\theta}}} = \theta + \rho_{\theta}^{-1}Z_{\theta},
\end{aligned}
\tag{18}
$$

where

$$
\begin{aligned}
\rho_{\theta+T} &\equiv \frac{\frac{p_{22}}{p_{2\theta}} - \frac{p_{12}}{p_{1\theta}}}{\frac{p_{22}}{p_{2\theta}}\frac{p_{11}}{p_{1\theta}} - \frac{p_{12}}{p_{1\theta}}\frac{p_{21}}{p_{2\theta}}}, \\
\rho_{\theta} &\equiv \frac{\frac{p_{11}}{p_{1\theta}} - \frac{p_{21}}{p_{2\theta}}}{\frac{p_{11}}{p_{1\theta}}\frac{p_{22}}{p_{2\theta}} - \frac{p_{21}}{p_{2\theta}}\frac{p_{12}}{p_{1\theta}}}.
\end{aligned}
\tag{19}
$$

Similarly to the parameter ρ in the main model, $\rho_{\theta+T}$ and ρ_θ, together, capture here the informativeness of the price system.

Extending the logic in our main model, consider simultaneous small shocks of δ to the fundamental θ, $-\rho_{\theta+T}\delta$ to $Z_{\theta+T}$, and $-\rho_\theta\delta$ to Z_θ. By construction, these shocks leave the prices unchanged. Moreover, the market clearing conditions in both markets must hold for all realizations of θ, $Z_{\theta+T}$, and Z_θ. As a result:

$$
\begin{aligned}
\rho_{\theta+T} &= \frac{var(\theta)\frac{\partial}{\partial s_i}E[\theta+T] - cov(\theta,\theta+T)\cdot\frac{\partial}{\partial s_i}E[\theta]}{\alpha\left(var(\theta+T)\,var(\theta) - cov(\theta,\theta+T)^2\right)}, \\
\rho_{\theta} &= \frac{var(\theta+T)\frac{\partial}{\partial s_i}E[\theta] - cov(\theta,\theta+T)\cdot\frac{\partial}{\partial s_i}E[\theta+T]}{\alpha\left(var(\theta+T)\,var(\theta) - cov(\theta,\theta+T)^2\right)},
\end{aligned}
\tag{20}
$$

[12] A formal proof of the existence of a linear equilibrium is available from the authors upon request.

where again all the expectation, variance, and covariance terms are conditional on the information available to a speculator i: s_i, $P_{\theta+T}$, and P_θ.

Now, as in our main model,

$$T\left(s_G, \tilde{P}_{\theta+T}, \tilde{P}_\theta\right) = -\lambda w\left(\theta + \varepsilon_G\right) + B(\tilde{P}_{\theta+T}, \tilde{P}_\theta), \tag{21}$$

where $B(\tilde{P}_{\theta+T}, \tilde{P}_\theta)$ is linear in the two price signals. Hence, we get explicit expressions for the following objects:

$$\begin{aligned}
var\left(\theta+T\right) &= \left(1-\lambda w\right)^2 var\left(\theta\right) + \left(\lambda w\right)^2 var\left(\varepsilon_G\right), \\
cov\left(\theta, \theta+T\right) &= \left(1-\lambda w\right) var\left(\theta\right), \\
\frac{\partial}{\partial s_i} E\left[\theta+T\right] &= \left(1-\lambda w\right) \frac{\partial}{\partial s_i} E\left[\theta\right].
\end{aligned}$$

Plugging these expressions in (20), and after some algebra, we get:

$$\begin{aligned}
\rho_{\theta+T} &= 0, \\
\rho_\theta &= \frac{\frac{\partial}{\partial s_i} E\left[\theta\right]}{\alpha var\left(\theta\right)} = \frac{\tau_\varepsilon}{\alpha}.
\end{aligned} \tag{22}$$

So, the overall informativeness of the price system is $\frac{\tau_\varepsilon}{\alpha}$. This is the same level of informativeness as in a model where the only traded security is a claim on θ. It is lower (higher) than the level of informativeness in a model where the only traded security is a claim on $\theta + T$ and the government takes a moderate corrective (amplifying) action.

Intuitively, traders have information about θ, but not about the noise in the government's signal, ε_G. Consequently, the trade size in the $\theta + T$ security is determined entirely by the trade size in the θ security and the price difference between the two securities; but it is independent of a trader's information s_i. Given this, the price of the $\theta + T$ security reveals no information beyond the price of the θ security. Hence, the informativeness of the price system is identical to what it would be if the only traded security was a claim on θ. Since under a corrective action, the informativeness is higher with only a $\theta + T$ security than with only a θ security (because of the effect discussed earlier, that the government's corrective action based on its own information reduces volatility and encourages trading), adding a θ security on top of a $\theta + T$ security harms informativeness overall and makes the government worse off.

Finally, we have also analyzed a model where the two traded securities are a claim on $\theta + T$ and a claim on T. In such a model, both securities have a level of informativeness of $\frac{\tau_\varepsilon}{\alpha}$. Hence, the comparison with a model with only a $\theta + T$ security under a corrective action yields ambiguous results. On the one hand, adding a T security adds an independent signal, which improves overall informativeness. On the other hand, it reduces the informativeness of the $\theta + T$ security, which reduces informativeness overall.

In summary, adding traded securities might reduce the informativeness of the price system, and hence it is not always a solution to the government's problem of inferring information from prices. The key complication arises due to conflicting trading motives – speculation and hedging – that are introduced into the model once there are multiple securities, which might harm informativeness. We show, via a concrete example, that adding a security may be bad for the government's ability to learn from the price and consequently may reduce the value of its objective function.[13] This insight should be considered on top of the fact that adding securities is not easy to implement, given that markets have to be liquid enough and that there should be a reasonable way to verify the payoffs for securities to be implementable.[14]

[13] For related analysis, see Cao (1999) and Bhattacharya, Reny and Spiegel (1995). Our result is different than those in both papers: Cao (1995) studies the effect on costly information acquisition, while Bhattacharya, Reny and Spiegel's (1995) analysis is based on the complete breakdown of a trading equilibrium.

[14] θ is likely to be non-verifiable, as it is not the actual cash flow generated by the firm. Instead, $\theta + T$ is the actual cash flow, and hence the object that is likely to be verifiable.

7 Conclusion

Our paper analyzes how market-based 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 opposite happens when the government takes an amplifying action.

Our analysis shows 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, in some cases the government would be better off limiting its reliance on market prices and increasing their informational content. Yet, some reliance on market prices is always optimal. Also, and counter to common belief, transparency by the government might be a bad idea in that it might reduce trading incentives and price informativeness, leading to a lower value for the government's objective function.

While we focus in this paper on market-based government policy, our analysis and results apply more generally for *any* 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 suggests that it could reduce the information in the price and hence the efficiency of the conversion trigger.

Our model postulates a quadratic objective function for the government, which proves to be very useful for tractability and allows us to focus on the interaction between government actions and market prices. In future research, it would be interesting to derive the government's objective function from first principles, relying on some market friction that makes government intervention desirable. It would also be interesting to consider non-linear equilibria where intervention is a discrete event.[15] It is a significant challenge to consider such extensions while maintaining tractability.

Another direction for future research is to consider different motives for market-based government actions. Our analysis focuses on the informational role of prices, which implies that relying on prices enables the government to make more efficient decisions. Another rationale for market-based actions is that they enable the government to commit to take welfare-improving actions when it has different objectives that might lead it to deviate from maximizing overall welfare. It would be interesting to understand the feedback loop between prices and actions in such a model.

Finally, inferring information from prices might be difficult for other reasons than those highlighted by our paper. In practice, speculators trade on various dimensions of information; only some of them are interesting to the government. Hence, it might be hard for the government to elicit exactly the type of information it desires. Such considerations can be introduced into our model in future research.

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A Appendix

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

Rewriting (8) more explicitly, the government's estimate of the fundamental, conditional on the price and its own signal s_G, is

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

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

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

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

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

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

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

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

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

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

From (11), total demand by all speculators is

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

This is a linear expression in the random variables θ and Z. Consequently, market clearing (5) is satisfied for all θ and Z if and only if the coefficients on θ and Z both equal zero (the price intercept p_0 is then chosen to make sure total speculator demand equals supply $-Z$), i.e.,

$$-\lambda \frac{\rho^2 \tau_Z}{T_G\left(\rho\right)} + \left(1 - \lambda w\left(\rho\right)\right)\left(\frac{\rho^2 \tau_Z}{T_\varepsilon\left(\rho\right)} + \frac{\tau_\varepsilon}{T_\varepsilon\left(\rho\right)}\right) - \rho p_Z = 0 \tag{23}$$

and

$$-\rho^{-1}\lambda \frac{\rho^2 \tau_Z}{T_G\left(\rho\right)} + \rho^{-1}\left(1 - \lambda w\left(\rho\right)\right) \frac{\rho^2 \tau_Z}{T_\varepsilon\left(\rho\right)} - p_Z + \alpha\left(\left(1 - \lambda w\left(\rho\right)\right)^2 T_\varepsilon\left(\rho\right)^{-1} + \left(\lambda w\left(\rho\right)\right)^2 \tau_G^{-1}\right) = 0. \tag{24}$$

Subtracting (23) from ρ times (24) yields

$$-\left(1 - \lambda w\left(\rho\right)\right) \frac{\tau_\varepsilon}{T_\varepsilon\left(\rho\right)} + \alpha\rho\left(\left(1 - \lambda w\left(\rho\right)\right)^2 T_\varepsilon\left(\rho\right)^{-1} + \left(\lambda w\left(\rho\right)\right)^2 \tau_G^{-1}\right) = 0, \tag{25}$$

an equation of ρ only (observe that this matches equation (12) in the main text). Note that the pair of equations (23) and (24) hold if and only if the pair (23) and (25) hold. So to complete the proof of equilibrium existence, it suffices to show that there exists ρ solving (25), since p_Z can then be chosen freely to solve (23).

Since $\left(1 - \lambda w\right)^2 = 1 - \lambda w - \lambda w\left(1 - \lambda w\right)$, equation (25) can be rewritten as

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

Defining

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

equation (25) is equivalent to

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

Note that $w(\rho)$ is decreasing in ρ, with $w(\rho) < 1$ for $\rho = 0$, and $w(\rho) \to 0$ as $\rho \to \infty$. So $F(\rho, w(\rho))$ approaches $-\infty$ as ρ approaches 0, and approaches 1 as $\rho \to \infty$. By continuity, it follows that (25) 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 λ, 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 $\rho \geq \underline{\rho}$ 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 λ 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 $\left[\underline{\rho}, \frac{\tau_\varepsilon}{\alpha} - \delta\right] \cup \left[\frac{\tau_\varepsilon}{\alpha} + \delta, \bar{\rho}\right]$; and has no solution below $\underline{\rho}$ or above $\bar{\rho}$. Finally, a parallel proof implies uniqueness for the case of λ strictly negative and sufficiently close to 0. ■

Proof of Proposition 2: Let ρ^* and ρ_{-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, respectively. Let $F(\rho, w)$ be as defined in the proof of Proposition 1.

We now show that for λ positive and sufficiently small, $\rho_{-P} > \rho^*$. As λ approaches 0, both ρ_{-P} and ρ^* approach $\frac{\tau_\varepsilon}{\alpha}$ (and moreover, ρ^* is uniquely defined by Proposition 1). Fix $\delta > 0$, and choose $\hat{\lambda}$ such that if $\lambda \in \left(0, \hat{\lambda}\right)$, then both ρ_{-P} and ρ^* lie within δ of $\frac{\tau_\varepsilon}{\alpha}$. Because $w_{-P} > w(\rho)$, there exists $\check{\lambda} \in \left(0, \hat{\lambda}\right)$ such that if $\lambda \in \left(0, \check{\lambda}\right)$ then $F(\rho, w(\rho)) > F(\rho, w_{-P})$ for all ρ within δ of $\frac{\tau_\varepsilon}{\alpha}$. Consequently, if $\lambda \in \left(0, \check{\lambda}\right)$ then $0 = F(\rho^*, w(\rho^*)) > F(\rho^*, w_{-P})$, which since $F_\rho > 0$ implies $\rho_{-P} > \rho^*$.■

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 λ 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

$$\begin{aligned} 0 &= \frac{d\rho}{d\tau_G}\left(F_\rho(\rho, w(\rho)) + w'(\rho) F_w(\rho, w(\rho))\right) \\ &\quad + \frac{dw(\rho)}{d\tau_G} F_w(\rho, w(\rho)) + \frac{d}{d\tau_G} F(\rho, w(\rho)). \end{aligned} \tag{26}$$

As in the proof of Proposition 3, $F_w(\rho, w(\rho)) < 0$ for λ 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 λ strictly positive and sufficiently close to 0, completing the proof. ■

Proof of Proposition 5: Part (A) follows on the proof of Proposition 2: for the case of $\lambda < 0$, $F_w > 0$, and so, $0 = F(\rho^*, w(\rho^*)) < F(\rho^*, w_{-P})$, which since $F_\rho > 0$ implies $\rho_{-P} < \rho^*$. Similarly, part (B) follows from straightforward adaptation of the analogous result in Proposition 3. Part (C) also builds on the proof of Proposition 4. Note that

$$\begin{aligned} F_\rho(\rho, w(\rho)) + w'(\rho) F_w(\rho, w(\rho)) &= \frac{\tau_\varepsilon}{\alpha\rho^2} + \text{terms in } \lambda \\ \frac{dw(\rho)}{d\tau_G} F_w(\rho, w(\rho)) &= -\lambda \frac{dw(\rho)}{d\tau_G} + \text{terms in } \lambda^2 \\ \frac{d}{d\tau_G} F(\rho, w(\rho)) &= \text{terms in } \lambda^2. \end{aligned}$$

So for $\lambda < 0$ sufficiently close to 0, it follows from (26) that $\frac{d\rho}{d\tau_G} < 0$, completing the proof. ■

Proof of Proposition 6: Given the main text, it is sufficient to formally show that equilibrium price informativeness is increasing in λ for $\lambda > 0$ and sufficiently small. 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 $\frac{d\rho}{d\lambda}$ satisfies

$$0 = \frac{d\rho}{d\lambda}\left(F_\rho(\rho, w(\rho)) + w'(\rho) F_w(\rho, w(\rho))\right) + \frac{d}{d\lambda} F(\rho, w(\rho)).$$

As in the proof of Proposition 4, we know $F_\rho > 0$, $w'(\rho) < 0$; and when λ is positive and sufficiently close to 0, $F_w(\rho, w(\rho)) < 0$. Moreover, $\frac{d}{d\lambda} F$ is negative for λ sufficiently close to zero. Hence $\frac{d\rho}{d\lambda} > 0$ for λ positive and sufficiently close to 0. ■

Proof of Proposition 7: See the main text following Proposition 7. ■

Proof of Proposition 8: The equilibrium condition under transparency is (25) (see proof of Proposition 1). The equilibrium condition without transparency has an additional term $\alpha\rho\lambda^2 var\left(\hat{\theta}\right)$ on the lefthand side, but it otherwise identical. The lefthand side of both conditions is negative for ρ sufficiently small, and positive for ρ sufficiently large. Consequently, both the minimum and maximum equilibrium levels of informativeness are higher under transparency. The equilibrium is unique in both cases when λ 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 ρ solves $F(\rho, w(\rho)) = 0$, where F is as defined in the proof. Dividing by $w(\rho)$ implies that ρ 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

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

or equivalently

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

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

$$\begin{aligned} 0 &= \alpha\tau_z^2\rho^5 - \tau_\varepsilon\tau_z^2\rho^4 + [2\tau_\theta + (2-\lambda)\tau_G + \lambda(\lambda-1)\tau_G]\tau_z\alpha\rho^3 \\ &\quad -[2\tau_\theta + (2-\lambda)\tau_G]\tau_\varepsilon\tau_z\rho^2 + A\alpha\rho - B \end{aligned} \tag{27}$$

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

B.2 Numerical simulations

The parameters of the model are α, τ_θ, τ_G, τ_ε and τ_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 ϕ denote the fraction of price fluctuations that are not attributable to changes in the fundamental θ, for the case in which government intervention is completely absent. From the paper,

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

and so

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

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

We simulate the model for values of ϕ (the fraction of price fluctuations that are not attributable to changes in the fundamental θ) of 10%, 50%, and 90%. Likewise, we simulate the model for values of τ_ε/τ_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 ρ (this is the condition for which we need λ to be sufficiently small in our analysis).

For values of λ 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 λ is even higher than 30%.