BIS Working Papers

No 386

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BANK FOR INTERNATIONAL SETTLEMENTS

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This publication is available on the BIS website (www.bis.org).

ISSN 1020-0959 (print)

ISSN 1682-7678 (online)

The Social Value of Policy Signals*

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September 3, 2012

Abstract

Do public policy signals improve the alignment of market outcomes with economic fundamentals? Existing work contends that, when individual players have an incentive to coordinate their actions, public policy signals could steer these actions away from the fundamentals. We argue that such a conclusion rests on a restricted information structure, predicated on markets being segmented. Public policy signals are unambiguously beneficial in an integrated market, where they refine other public information that prices generate endogenously. An implication of this finding is that policy authorities have an important role to play in collecting and disseminating data on aggregate market positions.

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*We would like to thank Claudio Borio, Stephen Morris, Kostas Tsatsaronis, Jochen Schanz and seminar participants at the BIS, the 2012 INFINITI Conference in Dublin, and the 2012 EEA Meetings in Malaga for useful comments on an earlier draft of the paper. The views expressed in this paper are our own, not necessarily those of the BIS.

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1 Introduction

Should policy authorities release public information about economic fundamentals? Morris and Shin (2002) warn that a public policy signal is a doubled-edged sword: even though it improves individual decisions, the inevitable noise in it may coordinate aggregate actions *away* from fundamentals. And the noisier the policy signal, the more likely is the latter effect to prevail. Svensson (2006) challenges this warning by arguing that authorities have enough knowledge to ensure net benefits from policy signals. In addition, Hellwig (2005) as well as Angeletos and Pavan (2007) show that the case against the release of public signals is valid only under specific distortions between social objectives and the private usage of information. Finally, Colombo et al (2012) argue that the social benefits of public signals increase if private agents optimize over the effort they spend in collecting private information.

We contribute to this debate by examining markets' capacity to process and reveal information, thus influencing private agents' knowledge of fundamentals. Morris and Shin (2002) abstract from this capacity by focusing on an "island economy", where the market is segmented: agents live on different islands, there are different, island-specific prices for the same asset, and each agent observes only the price on her own island. By contrast, in the spirit of the literature on rational expectations equilibria (see Grossman (1989)), we investigate the impact of allowing economic agents to learn from the common price in an *integrated market*.

We find that, in an integrated market, public policy signals bring market outcomes *unambiguously* closer to economic fundamentals. Importantly, this result does not depend on how informed the policy authority is and holds even if the authority can signal only with a lag. And the result remains qualitatively the same irrespective of whether the policy signal is *direct*, i.e. an explicit official statement about the fundamentals, or *indirect*, i.e. deduced from centrally provided data about aggregate market positions.

We base our argument on the model of Allen et al (2006), in which profit-optimizing risk-averse traders are uncertain about the fundamental value of the traded asset but learn about it from various signals. Each trader observes an exogenous *private signal*. In addition, all traders observe the *same public signals*, which may be exogenous to the marketplace (e.g. media news) or arise endogenously from market clearing (e.g. price-based signals). Finally, a policy authority can refine (i.e. reduce the noise in) the available public information by releasing a *public policy signal*.

Just as in Morris and Shin (2002), profit-optimizing traders in our model have two key incentives: to pay attention to *all* the available information about the fundamentals;

and to *coordinate* their actions.[1] Considered in isolation, the first incentive implies that the release of a policy signal would lead to better informed decisions, which would bring asset prices closer to the underlying fundamentals (i.e. closer to the full-information price level). By contrast, the second incentive induces traders to use the policy signal, as well as any other public signal, as a coordination device.

The key insight of Morris and Shin (2002) is that the coordination role of public (policy) signals distorts market outcomes. Because of this role, public signals crowd out socially valuable private information and acquire a disproportionate weight in traders' decisions. This amplifies the wedge that the noise in these signals drives between prices and fundamentals.[2]

That said, unobservable *non-fundamental shocks* to the net supply of the asset also drive a wedge between prices and fundamentals. In practice, such shocks could come from "noise traders" selling an asset in search of instant liquidity or making *information-insensitive* trades. By informing profit-optimizing traders about the fundamentals, a policy signal helps them see through non-fundamental shocks and arbitrage away their impact on market prices. Thus, the larger the volatility of non-fundamental shocks, the stronger is the beneficial information role of the policy signal.

The damaging coordination role of a policy signal dominates its beneficial information role only when two conditions are satisfied simultaneously. First, the public information that policy and other public signals *jointly* bring to the marketplace needs to be sufficiently less precise than the private information that these signals crowd out through their coordination role. Second, the volatility of non-fundamental shocks needs to be sufficiently small so that (i) the information benefit of releasing a policy signal is limited and (ii) the noise in public signals is the main driver of deviations between prices and fundamentals.

An island-economy setting, which arises as a special case in our model, does not impose any restrictions on the relationship between various signals and non-fundamental shocks. Markets are segregated in such a setting and, as a result, the outcomes of aggregate market behavior are unobservable and traders have access only to *exogenous* private and public signals. And since the parameters governing the precision of such signals do not depend on the volatility of non-fundamental shocks, these parameters can be chosen so that the two necessary conditions above are satisfied simultaneously.

At an intuitive level, this need not be the case in an integrated market, where some

[1] The recognition of rational agents' incentive to coordinate dates back at least to Keynes (1934). For more recent analyses of this incentive, see Avery and Zemsky (1998) and Shiller (2000).

[2] In contrast to Allen et al (2006), who analyze exclusively the coordination role of policy signals, we study the *overall* impact of such signals on market prices.

signals are *endogenous* and do depend on the volatility of non-fundamental shocks. A commonly observed *price* in such a market would aggregate private signals in an endogenous public signal, which would carry more information about the fundamentals when non-fundamental shocks are smaller. Concretely, the precision of overall public information in an integrated market would increase relative to that of private information as the volatility of non-fundamental shocks decreases.

Indeed, our key formal result is that, in the integrated market setting we study, it is impossible to satisfy simultaneously the two necessary conditions for a policy signal to drive prices away from the underlying fundamentals. If the volatility of non-fundamental shocks is small – i.e. the second condition is met – then the market is quite successful in processing information. The result is a price-based public signal that is sufficiently precise (relative to the private signals it aggregates) so that the first necessary condition is violated. Released in such a context, a policy signal would play a beneficial information role that dominates its damaging coordination role.

We discuss two real-world examples that illustrate the practical relevance of policy signals. We first examine the overpricing of structured-finance products, which occurred in the run-up to the global financial crisis and eventually led to sizeable investment losses. Then, we look at the cross-currency funding of exposures to such products. This involved massive reliance on short-term US-dollar funding, which suddenly dried up in 2008, necessitating official emergency interventions on an unprecedented scale. We argue that, in these examples, individual investors inaccurately assessed the risks they were taking, in part because they lacked a bird's eye view of the market. Thus, an official release of statistics about aggregate market positions could have been a valuable public policy signal. Such information could have helped investors to bring the prices of structured-finance instruments in line with the underlying fundamentals. More generally, by helping the system to see itself, a policy signal would have helped the system to govern itself.

The rest of the paper is organized as follows. In the next section, we present our model in its most general form, leaving the market structure unspecified. In Section 3, we study the segregated market of an island economy, which allows us to replicate the key argument in Morris and Shin (2002). The core of our analysis is in Section 4, where we study an integrated market, in which prices convey public information about the economic fundamentals. We examine both direct and indirect policy signals as well as policy signals revealed with a lag. In Section 5, we relate our main findings to evidence of information deficiencies in real world financial markets. We conclude with Section 6.

2 General model

Our framework follows closely Allen et al (2006) and allows us, inter alia, to fully capture the spirit of the analysis in Morris and Shin (2002). There are three dates, $T-2$, $T-1$ and T. The single asset in the economy is traded on dates $T-2$ and $T-1$ and matures on date T. The intrinsic value of this asset – henceforth, the *fundamentals* – equals θ, which becomes common knowledge at maturity, date T. The prior distribution of θ is uniform, with support on the entire real line.

2.1 Private sector

There are two types of agents in the model. Agents of the first type are rational utility-maximizing traders who invest in the risky asset on the basis of all the available signals about the fundamentals. In turn, agents of the second type are noise traders who buy or sell the same asset for reasons unrelated to the fundamentals.

A key aspect of the model is investment myopia, whereby rational traders focus on short-term price movements. Allen et al (2006) argue that long-lived agents with a preference for smoothing consumption over time would exhibit myopia. However, in the interest of tractability, they introduce myopia through short-lived traders. Using the same approach, we assume that a new generation of rational traders is born on each of the two trading dates and lives for one period. On each $t \in \{T-2, T-1\}$, there is a continuum of active traders, which we index by i and which are distributed uniformly on the unit interval. Let p_t denote the price of the asset on date $t \in \{T-2, T-1, T\}$, with $p_T = \theta$.

All rational traders are born with the same endowment, denoted by e. A trader i who is active on date $t \in \{T-2, T-1\}$ invests in the asset an amount that we label as $q_{i,t}$ (with $q_{i,t} > (<)\, 0$ reflecting a long or a short position, respectively). After reversing the trade on date $t+1$, she consumes

$$c_{i,t+1} = e + (p_{t+1} - p_t)\, q_{i,t} \tag{1}$$

and then disappears.

Each trader has the following utility function:

$$u\,(c_{i,t+1}) = -\exp\left(-\frac{c_{i,t+1}}{\tau}\right) \text{ for } t \in \{T-2, T-1\} \tag{2}$$

which implies constant absolute risk aversion, with coefficient $1/\tau$.

In addition, noise traders generate stochastic net supply of the asset on each date.

We refer to this net supply as a *non-fundamental shock*, denote it by $\xi_t \sim N\left(0, \sigma_\xi^2\right)$ and assume it to be i.i.d. over time. Market clearing then requires that ξ_t should equal rational traders' net demand:

$$\xi_t = \int_0^1 q_{i,t} di \text{ on each date } t \in \{T-2, T-1\} \tag{3}$$

An equilibrium in this setting is a set of prices consistent with the market clearing condition (3) and with rational traders maximizing their utility in (2), subject to their budget constraint in (1). Henceforth, we discuss explicitly only the rational traders, keeping noise traders in the background.

Given their short investment horizon, traders forecast only tomorrow's asset price and not the fundamentals *per se*. By equations (1) and (2), this implies that date $T-2$ traders pin their investment decisions *entirely* on their perceptions of p_{T-1} and are concerned with the asset fundamentals, θ, only to the extent that they affect p_{T-1}. As we will see below, if there is a reason to believe that date $T-1$ traders will settle on a low (high) p_{T-1}, then date $T-2$ traders will be more likely to also settle on a low (high) p_{T-2}, for any given perceptions about θ. In other words, there is *strategic complementarity* of actions across time.

2.2 Policy Authority

We study a policy authority that can influence traders' information sets by releasing either a direct or an indirect signal. A direct signal can be thought of as an explicit announcement about the fundamentals. By contrast, an indirect signal helps traders refine their knowledge of the fundamentals by providing information about the size of non-fundamental shocks. Following Morris and Shin (2002) and Allen et al (2006), we assume that the authority judges a policy signal to be beneficial only if it reduces the volatility of prices around fundamentals:[3]

$$V\left(p_{T-2}|\theta\right) \text{ and } V\left(p_{T-1}|\theta\right)$$

In general, there are several reasons why deviations of prices away from fundamentals are undesirable from a public policy perspective. When such deviations are persistent, for example, they can distort relative prices and ultimately lead to substantial misal-

[3] Just like Morris and Shin (2002), we study the volatility of prices around fundamentals in the presence of strategic complementarity of individual actions. Morris and Shin (2002) assume strategic complementarity and then derive endogenously that social welfare decreases in the volatility of prices around fundamentals. By contrast, we simply assume this property of social welfare but let our model give rise endogenously to strategic complementarity.

location of resources across the economy. In addition, a wedge between the price of a financial asset and its intrinsic value would lead to excessive risk taking in the case of overpricing, or the evaporation of market liquidity in the case of underpricing. And high volatility of prices around the fundamentals of certain widely-owned asset classes, e.g. housing, would hurt non-professional investors, such as first-time home buyers.[4]

2.3 Model Specifications

In Sections 3 and 4, we complete the model in three alternative ways. The three modeling specifications we examine differ from each other in terms of the underlying market structure and/or the type of policy signal.

We study two market structures. The first is a *segregated* market (Section 3), where individual traders act on separate "islands" and optimize their utility by choosing the price on their island, without observing the prices on other islands. This market structure delivers the message of Morris and Shin (2002).[5] Second, we consider an *integrated* market where individual traders take the publicly observable price as given and optimize over investment quantities (Section 4). In equilibrium, this price generates public information endogenously, by aggregating the private information of individual traders. The aggregation is only partial (i.e. the price-based signal is noisy) because of the uncertainty stemming from non-fundamental shocks.

In parallel, we study two types of policy signals. We examine a *direct* signal, which could be interpreted as an explicit official statement about the fundamentals, in both the segregated and integrated market settings (Sections 3 and 4.1, respectively). In an integrated market, we also consider an *indirect* policy signal, whereby the authority improves the information content of prices by partially revealing the aggregate net supply of the asset, ξ_t (Section 4.2). We do not consider such a signal under market segmentation, where it would not enrich traders' information sets and thus would not affect outcomes.

3 Island economy

In an "island economy" of the type studied by Phelps (1970) and Lucas (1972, 1973), traders take long or short positions in the same asset but on different islands. These islands, which we index with j, form a continuum of measure one. On each island,

[4]For in-depth discussions of these issues, see Case and Shiller (1989), Poterba (2000), Gilchrist and Leahy (2002), Case and Shiller (2003), and Dupor (2005).

[5]Assuming the same market structure, James and Lawler (2011) have argued that, if an authority could affect the economic fundamentals directly, policy signals would not be beneficial.

there are two local traders who make their investment decisions *entirely* on the basis of island-specific information. Since this leads to island-specific pricing, the market is segregated.

Concretely, on each island j and date $t \in \{T-2, T-1\}$, the two traders share the *same* information set:

$$I_{j,t} = \{x_{j,t}, y\},$$

which consists of a time varying *island-specific* signal

$$x_{j,t} = \theta + \varepsilon_{j,t}, \text{ where } \varepsilon_{j,t} \sim N\left(0, \frac{1}{\beta}\right) \text{ is i.i.d. across } j \text{ and } t \tag{4}$$

and a time invariant *public signal*

$$y = \theta + \eta, \text{ where } \eta \sim N\left(0, \frac{1}{\gamma}\right) \tag{5}$$

that is observed simultaneously on all islands (hence the lack of j and t subscripts). We refer to β and γ as the precision of the private and public signals, respectively.

In the current setting, the public signal y could have two components: (i) all public information, e.g. media news or credit ratings, that is outside the control of the policy authority; and (ii) a publicly observed policy signal. We start the analysis by assuming that there is no policy signal. Then, in Section 3.3, we introduce a policy signal that improves the overall precision of public information, γ.

A fixed *indivisible* quantity of the asset is supplied on each island j and date $t \in \{T-2, T-1\}$. This quantity is the *same* on each island but is i.i.d. over time. In terms of the market-clearing condition (3), this means that the stochastic supply of the asset, ξ_t, determines the equilibrium demand on each island: $\xi_t = q_{j,t}$ for each j.

Each of the two traders on an island announces a price at which she is ready to trade ξ_t of the asset. When $\xi_t > 0$ ($\xi_t < 0$), the trader announcing the higher (lower) price buys (shorts) the asset. In case the two traders announce the same price, the buyer (short-seller) is determined with a coin toss. In announcing her price, each trader maximizes her expected utility:

$$\max_{p_{j,t}} E\left(u\left(c_{t+1}\right)|I_{j,t}\right) \Longleftrightarrow \max_{p_{j,t}} \left\{\xi_t\left(E\left(p_{t+1}|I_{j,t}\right) - p_{j,t}\right) - \frac{\xi_t^2}{2\tau} V\left(p_{t+1}|I_{j,t}\right)\right\} \tag{6}$$

where the latter expression incorporates equations (1) and (2), with E and V denoting the expectation and variance operators, respectively.[6] In order to facilitate comparisons

[6]Since date-t traders perceive p_{t+1} as a normal variable, it follows that $E\left(\exp\left(p_{t+1}\right)|I_{j,t}\right) =$

with the implications of alternative market structures (examined in Section 4), we have assumed that each trader's payoff depends on the *average* price (across all islands) on the next date: $p_{t+1} \equiv \int_0^1 p_{j,t+1} dj$. Importantly, since this average price is not observed by the currently active traders on any island, it does not affect their investment decisions.[7]

The optimization problem in (6) is a standard Bertrand duopoly problem. In *Appendix A*, we show that it gives rise to a unique price on each island j and date t:

$$p_{j,t} = \underbrace{E\left(p_{t+1}|I_{j,t}\right)}_{\text{expected payoff}} - \underbrace{\frac{\xi_t}{2\tau} V\left(p_{t+1}|I_{j,t}\right)}_{\text{risk premium}} \tag{7}$$

This equilibrium price has two intuitive components. First, it is increasing in the expected payoff of the asset, $E\left(p_{t+1}|I_{j,t}\right)$. Second, supposing that there is a net positive supply (i.e. $\xi_t > 0$), a risk-premium component depresses the price below the expected payoff, ensuring that the risk averse trader is compensated for the consumption risk she incurs by purchasing the asset. All else constant, the risk-premium component increases with the uncertainty about tomorrow's price, $V\left(p_{t+1}|I_{j,t}\right)$, and decreases with traders' risk appetite, τ. In addition, the risk-premium increases in the investment size, ξ_t. This is because, as equation (1) indicates, a higher ξ_t implies a higher covariance between the source of risk, p_{t+1}, and the trader's consumption, c_{t+1}, thus prompting greater compensation for the same level of uncertainty about p_{t+1}. The same logic applies when $\xi_t < 0$, in which case the trader sells the asset at a premium.

3.1 Market outcomes

Market-clearing prices define the (unique) equilibrium in the island economy. Using equations (4) and (5) to write equation (7) explicitly leads to the following average price on each date:[8]

$\exp\left(E\left(p_{t+1}|I_{j,t}\right) + \frac{1}{2}V\left(p_{t+1}|I_{j,t}\right)\right)$, where $V\left(p_{t+1}|I_{j,t}\right)$ does not depend on the *values* of the signals $x_{j,t}$ and y but depends on the statistical properties of these signals.

[7] None of the key implications of the island-economy setting would change if we assumed that each indivisible quantity of the asset is bought at t and sold at $t+1$ on the same island, at *island-specific prices*. Such an assumption would not change the optimization problem of date $T-1$ traders because the date T price of the asset is the same across islands: it is equal to θ. By contrast, date $T-2$ traders need to consider the noise in the island-specific private signals, which would affect island-specific prices on $T-1$. That said, the effect of this noise would be indistinguishable from the effect of greater uncertainty about the net supply of the asset on $T-1$.

[8] To obtain the explicit solution, we implement Bayesian updating in the context of normal distributions. See DeGroot (1970).

$$p_{T-1} = \underbrace{\frac{\beta}{\beta+\gamma}\theta + \left(1 - \frac{\beta}{\beta+\gamma}\right) y}_{\text{expected payoff}} - \underbrace{\frac{V_{T-1}(\theta)}{2\tau}}_{\text{risk premium}}\xi_{T-1} \tag{8}$$

$$p_{T-2} = \underbrace{\left(\frac{\beta}{\beta+\gamma}\right)^2 \theta + \left(1 - \left(\frac{\beta}{\beta+\gamma}\right)^2\right) y}_{\text{expected payoff}} - \underbrace{\frac{V_{T-2}(p_{T-1})}{2\tau}}_{\text{risk premium}}\xi_{T-2}$$

where $\phi\left(\cdot\,;\theta, \frac{1}{\beta}\right)$ is the PDF of private signals, $V_{T-1}(\theta) = 1/(\beta+\gamma)$ and $V_{T-2}(p_{T-1}) = \beta^2/(\beta+\gamma)^3 + (1/2(\beta+\gamma))^2 (\sigma_\xi/\tau)^2$.

We first consider the expected-payoff terms in these prices. On each date, the expected payoff is a linear combination of the true value of the fundamentals, θ, and the realization of the public signal, y. The coefficients on θ and y are the weights that each trader assigns to her private and public signals, respectively, in determining the price she is willing to pay for the asset. Although θ is not observed directly, it appears in these expressions because the noise in the private signals, $x_{j,t}$, washes out in the aggregate. By contrast, since there is only one, albeit unbiased, public signal, y, the noise in it does not wash out in the cross-section of traders and thus affects market prices.

The weights on private and public signals evolve over time. One period before maturity, date $T-1$ traders are concerned *entirely* with the fundamental value of the asset, θ. As a result, the weights on private and public signals on that date match *exactly* the relative precision with which these signals allow traders to forecast θ. Thus, the public signal has only an *information role* on date $T-1$. By contrast, date $T-2$ traders are concerned with tomorrow's price, p_{T-1}, which depends both on θ and on the public signal about it, y. And since y is a noiseless signal about itself, it carries more information about the payoff of date $T-2$ traders (p_{T-1}) than about that of date $T-1$ traders (θ). As a result, rational traders place a larger weight on y at date $T-2$ than at $T-1$: in expression (8), $1-\left(\frac{\beta}{\beta+\gamma}\right)^2 > 1 - \frac{\beta}{\beta+\gamma}$. This inequality implies that a high (low) realization of y would shift p_{T-2} upwards (downwards) to a *greater* extent than what is warranted by the precision of y as a signal of θ. It is in this sense that, as shown by Allen et al (2006), intertemporal strategic complementarity endows the public signal with a *damaging coordination role*.

Next, we turn to the risk-premium terms in expression (8). Higher precision of the public signal, i.e. a larger γ, lowers each of these terms. There are two underlying forces at work. First, a more precise public signal means more information in the marketplace, which is equivalent to lower perceived payoff risk, i.e. lower $V_{T-2}(p_{T-1})$ and $V_{T-1}(\theta)$.

Second, since each generation of traders observes the *same* public signal, y, greater reliance of date $T-1$ traders on this signal results in date $T-2$ traders knowing with certainty a bigger portion of p_{T-1} and, thus, perceiving a lower variance of this price. As result, by raising the reliance of date $T-1$ traders on y, a larger γ has an additional negative impact on $V_{T-2}(p_{T-1})$.

3.2 Deviation of market outcomes from fundamentals

Expression (8) implies that the volatility of prices around the fundamentals is:

$$
\begin{aligned}
V(p_{T-1}|\theta) &= \underbrace{\left(1-\frac{\beta}{\beta+\gamma}\right)^2\frac{1}{\gamma}}_{\text{from expected payoff}} + \underbrace{\frac{\sigma_\xi^2/(2\tau)^2}{(\beta+\gamma)^2}}_{\text{from risk premium}} \\
V(p_{T-2}|\theta) &= \underbrace{\left(1-\left(\frac{\beta}{\beta+\gamma}\right)^2\right)^2\frac{1}{\gamma}}_{\text{from expected payoff}} + \underbrace{\left(\frac{\beta^2}{(\beta+\gamma)^3}+\frac{\sigma_\xi^2/(2\tau)^2}{(\beta+\gamma)^2}\right)^2\frac{\sigma_\xi^2}{(2\tau)^2}}_{\text{from risk premium}}.
\end{aligned} \tag{9}
$$

The key implication of this expression is that a more precise public signal (a higher γ) *may* result in higher price volatility. To see why, suppose that the impact of non-fundamental shocks is zero, i.e. $\sigma_\xi/\tau = 0$, and suppose that private signals contain some information about θ, i.e. $\beta > 0$.[9] Consider first the expected-payoff term in $V(p_{T-1}|\theta)$. Graph 1 (left-hand panel) illustrates that, as γ increases from zero, this term also increases from zero, then peaks and eventually asymptotes back to zero as γ tends to infinity. At the two extremes, this signal is either discarded by traders because it reveals no information ($\gamma = 0$), or it is the only signal traders take into account as it reveals θ directly ($\gamma \to \infty$). Thus, at either extreme, the public signal does not drive a wedge between p_{T-1} and θ. For intermediate values of γ, the noise in the public signal affects traders' expectations about θ and, by extension, p_{T-1}. The story is qualitatively similar on date $T-2$. Moreover, the coordination role of the public signal on date $T-2$ amplifies the wedge between p_{T-2} and θ.

We formalize these observations in *Appendix B*, where we prove that, for any given

[9] The standard deviation of non-fundamental shocks, σ_ξ, and the risk aversion parameter, τ, appear only as σ_ξ/τ in all expressions for equilibrium prices. Thus, in order to alleviate the exposition, we often refer to this fraction as "the volatility of non-fundamental shocks".

$\beta > 0$, there exist $\Gamma > 0$, which increases in β, and $\Sigma^L > 0$ such that:

$$\begin{aligned} V\left(p_{T-2}|\theta\right) &> V\left(p_{T-1}|\theta\right) \text{ for } \gamma > 0 \text{ and } \frac{\sigma_\xi}{\tau} \in \left(0, \Sigma^L\right) \\ \frac{dV\left(p_{T-2}|\theta\right)}{d\gamma} &> \frac{dV\left(p_{T-1}|\theta\right)}{d\gamma} > 0 \text{ for } \gamma \in (0, \Gamma) \text{ and } \frac{\sigma_\xi}{\tau} \in \left(0, \Sigma^L\right) \end{aligned} \tag{10}$$

– Graph 1 –

When the impact of non-fundamental shocks on prices is strong (i.e. when σ_ξ/τ is large), the story changes drastically. In this case, market outcomes depend mostly on the extent to which traders are willing to step in and arbitrage away the effect of non-fundamental shocks on prices. By improving the information available to traders, the release of a policy signal strengthens the arbitrage forces and is, thus, unambiguously beneficial (Graph 1, right-hand panel). More concretely, we prove in *Appendix B* that there exists a finite $\Sigma^H > 0$ such that:

$$\frac{dV\left(p_{T-2}|\theta\right)}{d\gamma} < 0 \text{ and } \frac{dV\left(p_{T-1}|\theta\right)}{d\gamma} < 0 \text{ for } \gamma \geq 0,\ \beta \geq 0 \text{ and } \frac{\sigma_\xi}{\tau} \geq \Sigma^H \tag{11}$$

3.3 Policy signal

For direct comparison with the analysis of Morris and Shin (2002), we first note that releasing a public policy signal in the island economy is equivalent to increasing the precision of the overall public information, i.e. increasing γ. Their argument that a public policy signal can drive prices away from fundamentals can then be restated as follows. Start by assuming away non-fundamental shocks, which corresponds to $\sigma_\xi/\tau = 0 < \Sigma^L$. Next, taking the precision of private signals, β, as given, let the initial precision of public information be $\gamma < \Gamma$. Expression (10) then implies that the release of an *imprecise* policy signal, e.g. a signal that does not raise γ above Γ, would increase the wedge between prices and fundamentals. In terms of Graph 1 (left-hand panel), this scenario corresponds to a move from point A to point B.

More generally, there are two *necessary* conditions for the damaging coordination role of a policy signal to be stronger than its beneficial information role. First, *the policy signal should be imprecise*. Or, as implied by the second line of (10), overall public information should remain sufficiently less precise than private signals even after the release of a policy signal, that is $\gamma < \Gamma$. Second, the *volatility of non-fundamental shocks should be small* (second line of (10), $\sigma_\xi/\tau < \Sigma^L$). In other words, the wedge that these shocks drive between prices and the fundamentals, i.e. the wedge that a policy signal would help traders arbitrage away, should be sufficiently small. When these conditions hold *simultaneously*, the information role of the policy signal is weak enough to imply that the coordination role would decouple the precision of this signal from its impact on market prices.

Within the general setup outlined in Section 2 above, it is possible to challenge the message of Morris and Shin (2002) in two ways. First, Svensson (2005) argues that, in practice, public authorities have enough information to formulate a very precise policy signal. In terms of Graph 1, he argues that a realistic policy signal would take the economy from point A to point C and, thus, tighten the alignment between market outcomes and fundamentals. Second, and more generally, we show that the market structure in an island economy is quite restrictive. In the next section, we model an *integrated market* where traders observe a common equilibrium price. The information structure in such a market renders the policy signal *unambiguously* beneficial, irrespective of its precision.

4 Integrated market

In this section, we examine an *integrated market* where the continuum of traders observe a common market price on each date. They take this price as given and decide how much to invest in (or short-sell of) the asset. Concretely, investors maximize their utility over $q_{i,t}$:

$$\max_{q_{i,t}} E\left(u\left(c_{t+1}\right)|I_{i,t}\right) \Longleftrightarrow \max_{q_{i,t}} \left\{ q_{i,t}\left(E\left(p_{t+1}|I_{i,t}\right) - p_t\right) - \frac{q_{i,t}^2}{2\tau} V\left(p_{t+1}|I_{i,t}\right) \right\}, \tag{12}$$

where $I_{i,t}$ denotes the information set of trader i at time t. We specify $I_{i,t}$ below.

Solving (12) yields the demand of trader i for the asset:

$$q_{i,t} = \tau \frac{E\left(p_{t+1}|I_{i,t}\right) - p_t}{V\left(p_{t+1}|I_{i,t}\right)}. \tag{13}$$

The quantity demanded increases in the expected one-period price appreciation, $E\left(p_{t+1}|I_{i,t}\right) - p_t$, and in the investor's risk appetite, τ. Conversely, it decreases in the perceived variance of tomorrow's price, $V\left(p_{t+1}|I_{i,t}\right)$.

Inserting (13) into the market-clearing condition (3) and solving for the (unique) equilibrium price yields:

$$p_t = \underbrace{\int E\left(p_{t+1}|I_{i,t}\right) di}_{\text{expected payoff}} - \underbrace{\frac{\xi_t}{\tau} V_t\left(p_{t+1}|I_{i,t}\right)}_{\text{risk premium}}, \tag{14}$$

Written in this general form, the equilibrium price in the integrated market setting seems quite similar to the average price in the island economy, as expressed in equation (7). In fact, however, there are important differences. Alternative modelling specifications lead to different information sets, $I_{i,t}$, on the basis of which traders arrive at market prices. As we formally show below, traders in an integrated-market setting enrich their information sets by extracting information from the equilibrium price. This is impossible in the island economy, where the average price is unobservable.

In the remainder of this section, we analyze two types of policy signals in the integrated-market setting. First, we consider a *direct* policy signal about the fundamentals. This is analogous to the policy authority releasing y in Section 3. Second, we analyze a policy signal about the non-fundamental shocks (i.e. ξ_t, or the net supply of the asset), from which traders infer an *indirect* signal about the fundamentals.

4.1 Direct policy signal

As in the island-economy setting, each trader observes two exogenous signals, $x_{i,t}$ and y. The former is again a private signal, whereas the latter now is a *direct public policy signal* about the fundamentals:

$$x_{i,t} = \theta + \varepsilon_{i,t}, \text{ where } \varepsilon_{i,t} \sim N\left(0, \frac{1}{\beta}\right) \text{ is i.i.d. across } i \text{ and } t \tag{15}$$

$$y = \theta + \eta, \text{ where } \eta \sim N\left(0, \frac{1}{\gamma}\right) \text{ is independent of all } \varepsilon_{i,t} \tag{16}$$

where β and γ denote again the precision of the respective signal. In addition to these two signals, the integrated market generates endogenously a *price-based public signal* on each trading date: $\hat{p}_t$ for $t \in \{T-2, T-1\}$. This is what distinguishes the current setting from the island economy.

Thus, the information set of investor i comprises three *types* of signals:

$$\begin{aligned} I_{i,T-2} &= \left\{x_{i,T-2}, y, \hat{p}^{DI}_{T-2}\right\} \\ I_{i,T-1} &= \left\{x_{i,T-1}, y, \hat{p}^{DI}_{T-2}, \hat{p}^{DI}_{T-1}\right\} \end{aligned}$$

where the superscript DI flags the context: a *direct policy signal* in an *integrated* market. Indeed, as stated earlier, these information sets are richer than those in the island economy (recall Section 3).

We derive the precision of the price-based public signals by first writing the market clearing prices, equation (14), in an explicit form:[10]

$$
\begin{aligned}
p_{T-2}^{DI} &= \underbrace{\omega_x^{DI}\theta + \omega_y^{DI}y + \left(1-\omega_x^{DI}-\omega_y^{DI}\right)\hat{p}_{T-2}^{DI}}_{\text{expected payoff}} - \underbrace{\frac{V_{T-2}^{DI}\left(p_{T-1}^{DI}\right)}{\tau}\xi_{T-2}}_{\text{risk premium}} \\
p_{T-1}^{DI} &= \underbrace{\varphi_x^{DI}\theta + \varphi_y^{DI}y + \varphi_p^{DI}\hat{p}_{T-2}^{DI} + \left(1-\varphi_x^{DI}-\varphi_y^{DI}-\varphi_p^{DI}\right)\hat{p}_{T-1}^{DI}}_{\text{expected payoff}} - \underbrace{\frac{V_{T-1}^{DI}\left(\theta\right)}{\tau}\xi_{T-1}}_{\text{risk premium}}
\end{aligned}
\tag{17}
$$

The weights on the different signals, denoted by ω for date $T-2$ and φ for $T-1$, are all positive and increase in the precision of the respective signal. As in the island economy, the aggregation of unbiased private signals implies that the equilibrium price depends *inter alia* on the product of the weights on these signals, ω_x^{DI} or φ_x^{DI}, and the actual (unobserved) fundamentals, θ. Finally, $V_{T-2}\left(p_{T-1}\right)$ and $V_{T-1}\left(\theta\right)$ denote the variances of tomorrow's price, as perceived by date $T-2$ and date $T-1$ traders, respectively.[11]

The second line of equation (17) effectively provides the price-based signal about θ observed on date $T-1$. For notational simplicity, we write this signal after stripping out all the variables known at that date:

$$\hat{p}_{T-1}^{DI} = \theta - \frac{V_{T-1}^{DI}\left(\theta\right)}{\tau\varphi_x^{DI}}\xi_{T-1} \tag{18}$$

with precision (i.e. inverse of the noise variance):

$$\alpha_{T-1}^{DI} = \left(\frac{\tau\varphi_x^{DI}}{V_{T-1}^{DI}\left(\theta\right)}\right)^2 \frac{1}{\sigma_\xi^2} = \frac{\beta^2\tau^2}{\sigma_\xi^2} \tag{19}$$

Similarly, the price-based signal in $T-2$ is:

$$\hat{p}_{T-2}^{DI} = \theta - \frac{V_{T-2}^{DI}\left(p_{T-1}^{DI}\right)}{\tau\omega_x^{DI}}\xi_{T-2} \tag{20}$$

[10] Note that the equilibrium price on each date, p_t, depends on a signal that is extracted from the same price, $\hat{p}_t$. The rational expectations literature provides a useful way of thinking about the formation of prices in such a context (see Grossman (1989)). Namely, each trader submits (to a market-maker) the quantity of the asset she would demand at *each* possible price, provided that the price clears the market and, thus, generates the public signal specified in equations (18) or (20) below. In equilibrium, the resulting trader-specific demand schedules accommodate the exogenous supply of the asset.

[11] All of these parameters are defined in *Appendix C*.

with precision:

$$\alpha_{T-2}^{DI} = \left(\frac{\tau\omega_x^{DI}}{V_{T-2}^{DI}\left(p_{T-1}^{DI}\right)}\right)^2 \frac{1}{\sigma_\xi^2} = \left(\frac{\alpha_{T-1}^{DI}}{\beta + \alpha_{T-1}^{DI}}\right)^2 \alpha_{T-1}^{DI} \tag{21}$$

Equation (19) has a straightforward interpretation. First, the precision of the price-based public signal at $T-1$, α_{T-1}^{DI}, increases in the precision of private signals, β. This reflects the intuition that the price of the asset is more informative when it aggregates more informative private signals. Second, since non-fundamental shocks drive a wedge between the market-clearing price and the fundamentals, the precision of the price as a signal of the fundamentals decreases in the volatility of non-fundamental shocks, σ_ξ^2. Finally, the higher is risk appetite, τ, the more forcefully traders step in to arbitrage away what they see as a distortion in the market-clearing price caused by non-fundamental shocks. This reduces the sensitivity of the price to non-fundamental shocks, implying that the precision of the price-based signal increases in τ.

In addition, the price-based signal at $T-1$ is independent of the policy signal. This surfaces as α_{T-1}^{DI}, the precision of the former signal, being independent of γ, the precision of the latter.[12] To understand why, note that the release of a policy signal triggers two effects that exactly offset each other in our setting. First, it induces traders to shift some of the weight they place on their private signals towards the policy signal: i.e. φ_x^{DI} declines and φ_y^{DI} rises. By equation (19), this lowers the precision of the price-based public signal. Second, the release of a policy signal brings in more information, which lowers the uncertainty about the fundamentals, i.e. $V_{T-1}^{DI}(\theta)$ declines. By equation (19), this boosts the precision of the price-based signal.

Similar reasoning applies to the signal generated by p_{T-2}^{DI}. By equation (21), α_{T-2}^{DI} increases in α_{T-1}^{DI} and the properties of the two price-based signals are tightly linked. And just like α_{T-1}^{DI}, α_{T-2}^{DI} is also independent of γ.

It is instructive to note that $\alpha_{T-2}^{DI} < \alpha_{T-1}^{DI}$, as long as $\beta > 0$ and $\alpha_{T-1}^{DI} \in (0, \infty)$. Intuitively, the further the trading date is from the maturity date, the smaller is the role of the fundamentals in tomorrow's price. Thus, date $T-2$ traders pay less attention to their private signals about the fundamentals than do date $T-1$ traders. This means that p_{T-2}^{DI} is less reflective of private information than p_{T-1}^{DI}. And since private information is what underpins the precision of a price-based public signal, the precision of $\hat{p}_{T-2}^{DI}$ is smaller than that of $\hat{p}_{T-1}^{DI}$.

[12] Even though the existence of a policy signal does not affect the *information content* of the price, i.e. $d\alpha_t^{DI}/dy = d\alpha_t^{DI}/d\gamma = 0$, equation (17) reveals that the policy signal does affect the price *level*, i.e. $dp_t^{DI}/dy > 0$ and $dp_t^{DI}/d\gamma \neq 0$.

4.2 Indirect policy signal

In this section, we consider a more realistic case, in which the policy authority does not have direct information about the fundamentals, θ, but releases a signal about the net supply of the asset, ξ_t. Note that such a signal would be inconsequential in our island economy setting, where traders observe ξ_t directly. By contrast, a policy signal about ξ_t influences the outcomes in an integrated-market setting, where it refines the price-based signals about the fundamentals.

Suppose that ξ_{T-2} can be decomposed into two orthogonal components:

$$\begin{aligned}
\xi_{T-2} &= \xi^s_{T-2} + \xi^n_{T-2}, \text{ where} \\
\xi^s_{T-2} &\sim N\left(0, \delta\sigma^2_\xi\right), \xi^n_{T-2} \sim N\left(0, (1-\delta)\,\sigma^2_\xi\right), \text{and } E(\xi^s_{T-2}\xi^n_{T-2}) = 0
\end{aligned} \tag{22}$$

and that the authority observes ξ^s_{T-2} but not ξ^n_{T-2}. Thus, the higher is δ the more informed is the public authority. Suppose further that, instead of releasing a direct policy signal about fundamentals (i.e. y in previous sections), the authority reveals ξ^s_{T-2} at the *beginning* of date $T-2$. The information set of trader i then is:

$$\begin{aligned}
I_{i,T-2} &= \left\{x_{i,T-2}, \hat{p}^{II}_{T-2}\right\} \\
I_{i,T-1} &= \left\{x_{i,T-1}, \hat{p}^{II}_{T-2}, \hat{p}^{II}_{T-1}\right\}
\end{aligned}$$

where $\hat{p}^{II}_{T-2}$ incorporates the policy signal about ξ_t, $x_{i,t}$ is as defined in Subsection 4.1, and the superscript II flags the context: an *indirect policy signal* in an *integrated* market. The expressions for the market-clearing prices on the two trading dates are similar to those obtained under a direct policy signal and have an analogous interpretation:[13]

$$\begin{aligned}
p^{II}_{T-2} &= \underbrace{\omega^{II}_x\theta + \left(1-\omega^{II}_x\right)\hat{p}_{T-2}}_{\text{expected payoff}} - \underbrace{\frac{V^{II}_{T-2}\left(p^{II}_{T-1}\right)}{\tau}\xi_{T-2}}_{\text{risk premium}} \\
p^{II}_{T-1} &= \underbrace{\varphi^{II}_x\theta + \varphi^{II}_p\hat{p}_{T-2} + \left(1-\varphi^{II}_x-\varphi^{II}_p\right)\hat{p}_{T-1}}_{\text{expected payoff}} - \underbrace{\frac{V^{II}_{T-1}(\theta)}{\tau}\xi_{T-1}}_{\text{risk premium}}
\end{aligned} \tag{23}$$

The price-based signal about θ that a trader receives on date $T-1$ and its precision

[13] All of the variables below are defined in *Appendix D*.

now equal:

$$\begin{aligned}
\hat{p}^{II}_{T-1} &= \theta - \frac{V^{II}_{T-1}(\theta)}{\tau\varphi^{II}_x}\xi_{T-1} \\
\alpha^{II}_{T-1} &= \left(\frac{\tau\varphi^{II}_x}{V^{II}_{T-1}(\theta)}\right)^2 \frac{1}{\sigma^2_\xi} = \frac{\beta^2\tau^2}{\sigma^2_\xi}
\end{aligned} \tag{24}$$

and the date $T-2$ analogues are:

$$\begin{aligned}
\hat{p}^{II}_{T-2} &= \theta - \frac{V^{II}_{T-2}\left(p^{II}_{T-1}\right)}{\tau\omega^{II}_x}\xi^n_{T-2} \\
\alpha^{II}_{T-2} &= \left(\frac{\tau\omega^{II}_x}{V^{II}_{T-2}\left(p^{II}_{T-1}\right)}\right)^2 \frac{1}{(1-\delta)\,\sigma^2_\xi} = \frac{\alpha_{T-1}}{1-\delta}\left(\frac{\alpha_{T-1}}{\beta+\alpha_{T-1}}\right)^2
\end{aligned} \tag{25}$$

The precision of the price-based signal on date $T-1$ is the same as in the *direct policy signal* case in Subsection 4.1. Note that the indirect policy signal gives rise to the same opposing effects discussed above in the context of the direct policy signal. Once again, these effects cancel each other exactly, implying that the release of an indirect policy signal does not affect the precision of the endogenous price-based public signal on date $T-1$.

By contrast, the precision of the endogenous price-based signal on $T-2$, i.e. α_{T-2}, increases in the *share* of the non-fundamental shock to net supply revealed by the indirect policy signal (δ). Intuitively, the uncertainty stemming from the non-fundamental shock is what prevents prices from aggregating the information in private signals perfectly and revealing the fundamentals directly. Releasing the indirect policy signal removes a fraction of this uncertainty, thus making prices more informative.

4.3 Discussion: policy signals in an integrated market

In an integrated market, the release of a policy signal continues to have the two effects we discussed in the island economy setting of Section 3. First, there is a beneficial information effect, which brings prices closer to fundamentals by eliminating some of the uncertainty in the market. Second, there is a damaging coordination effect, which amplifies the wedge between prices and fundamentals.

In Section 3.3, we derived two necessary conditions for the effect of a public policy signal to be damaging on net. First, even after the release of a public policy signal, the overall public information should remain imprecise relative to private signals. Second, the volatility of non-fundamental shocks should be small. We also explained that the two conditions *could* be satisfied simultaneously in the island-economy setting, where the relative precision of different signals is exogenous and, thus, can be set independently of the volatility of non-fundamental shocks.

In an integrated market, there is strong tension between the two necessary conditions. The reason is that, in contrast to the island economy, an integrated market shapes *endogenously* the relationship between the precision of different signals and the volatility of non-fundamental shocks. This relationship can be seen clearly in the expressions for the precision of price-based signals: (19), (21), (24) and (25). For one, since prices aggregate private signals, an increase in the precision of these signals (a higher β) increases the precision of public price-based signals (raises the α's). In addition, only volatile non-fundamental shocks can prevent prices from aggregating private information well, i.e. only a higher σ_ε/τ can depress α for a given β. Thus, a decrease in σ_ε, which takes the model towards satisfying the second necessary condition above, raises α relative to β, which runs against the first condition. Conversely, α would be low relative to β only for a high σ_ε, which would run against the second condition.

In *Appendices C* and *D*, we take this intuition one final step by proving formally that the two necessary conditions above cannot hold *simultaneously*, and thus a policy signal is *unambiguously* beneficial, in the integrated market. Concretely, we prove that the variance of price deviations from fundamentals, across both trading dates and both policy signal types, declines unambiguously as the informational content of the policy signal increases:

$$\frac{dV\left(p^{DI}_{T-2}|\theta\right)}{d\gamma} < 0 \text{ and } \frac{dV\left(p^{DI}_{T-1}|\theta\right)}{d\gamma} < 0, \text{ for all } \gamma \in [0,\infty) \tag{26}$$

$$\frac{dV\left(p^{II}_{T-2}|\theta\right)}{d\delta} < 0 \text{ and } \frac{dV\left(p^{II}_{T-1}|\theta\right)}{d\delta} < 0, \text{ for all } \delta \in [0,1] \tag{27}$$

Importantly, the *net* effect of a policy signal is beneficial on both dates $T-2$ and $T-1$, even though strategic complementarity strengthens the coordination role of policy signals at $T-2$. In addition, the result holds irrespective of whether the authority releases a direct signal about the fundamentals or – as might be more feasible in practice – a signal about the traded quantity of the asset.

4.4 Robustness check: a delayed indirect policy signal

While the indirect policy signal in Section 4.2 is arguably more realistic than the direct signal in Section 4.1, it may seem implausible that an authority could release information about the net supply of the asset (i.e. about non-fundamental shocks) just as it materializes. In practice, the authority may need some time to collect and verify such information. A natural question then is whether an indirect policy signal would remain beneficial – in the sense that its release contributes to a closer alignment of market prices with economic fundamentals – even if it is released with a lag. In this section, we show that this is indeed the case: all of the qualitative messages from Section 4.2 remain valid even if traders observe a portion of the date $T-2$ net supply of the asset only on date $T-1$. In other words, the policy signal is beneficial even before traders observe it, i.e. when they only anticipate it.[14]

Let the market structure be as outlined in Subsection 4.2 but let the net quantity of the asset supplied on date $T-2$, i.e. ξ^s_{T-2}, be revealed one period later, at the beginning of $T-1$. The information structure now is:

$$\begin{aligned} I_{i,T-2} &= \left\{x_{i,T-2}, \hat{p}^{ILI}_{T-2}\right\} \\ I_{i,T-1} &= \left\{x_{i,T-1}, \widehat{\hat{p}}^{ILI}_{T-2}, \hat{p}^{ILI}_{T-1}\right\} \end{aligned}$$

where the double hat notation flags that $\widehat{\hat{p}}^{ILI}_{T-2}$ contains more information than $\hat{p}^{ILI}_{T-2}$ because it incorporates the delayed release of ξ^s_{T-2}. And the superscript to the endogenous public signals, ILI, flags the context: an *indirect and late policy signal* in an *integrated* market.

Paralleling Subsection 4.2, we obtain the following expressions for equilibrium prices:

$$\begin{aligned} p^{ILI}_{T-2} &= \underbrace{\omega^{ILI}_x \theta + \left(1 - \omega^{ILI}_x\right) \hat{p}^{ILI}_{T-2}}_{\text{expected payoff}} - \underbrace{\frac{V^{ILI}_{T-2}\left(p^{ILI}_{T-1}\right)}{\tau} \xi_{T-2}}_{\text{risk premium}} \\ p^{ILI}_{T-1} &= \underbrace{\varphi^{ILI}_x \theta + \varphi^{ILI}_p \widehat{\hat{p}}^{ILI}_{T-2} + \left(1 - \varphi^{ILI}_x - \varphi^{ILI}_p\right) \hat{p}^{ILI}_{T-1}}_{\text{expected payoff}} - \underbrace{\frac{V^{ILI}_{T-1}\left(\theta\right)}{\tau} \xi_{T-1}}_{\text{risk premium}} \end{aligned} \tag{28}$$

[14] Delays in the release of the direct policy signals, which we introduced in Sections 3 and 4.1, also do not affect the key messages from these sections. The straightforward (but tedious) algebra backing this statement is available upon request.

The price-based signals available on date $T-1$ then are:

$$\widehat{\widehat{p}}_{T-2}^{ILI} = \theta - \frac{V_{T-2}^{ILI}\left(p_{T-1}^{ILI}\right)}{\tau\omega_x^{ILI}}\xi_{T-2}^{n}, \text{ with precision } \frac{\alpha_{T-2}^{ILI}}{1-\delta} = \left(\frac{\tau\omega_x^{II}}{\sigma_\xi V_{T-2}^{ILI}\left(p_{T-1}^{ILI}\right)}\right)^2 \frac{1}{(1-\delta)} \tag{29}$$

$$\hat{p}_{T-1}^{ILI} = \theta - \frac{V_{T-1}^{ILI}(\theta)}{\tau\varphi_x^{ILI}}\xi_{T-1}, \text{ with precision } \alpha_{T-1}^{ILI} = \left(\frac{\tau\varphi_x^{ILI}}{\sigma_\xi V_{T-1}^{ILI}(\theta)}\right)^2 = \frac{\beta^2\tau^2}{\sigma_\xi^2}$$

In turn, the price-based signal available at $T-2$ is:

$$\hat{p}_{T-2}^{ILI} = \theta - \frac{V_{T-2}^{ILI}\left(p_{T-1}^{ILI}\right)}{\tau\omega_x^{II}}\xi_{T-2}, \text{ with precision } \alpha_{T-2}^{ILI} = \left(\frac{\tau\omega_x^{ILI}}{\sigma_\xi V_{T-2}^{ILI}\left(p_{T-1}^{ILI}\right)}\right)^2 \tag{30}$$

We derive the precision parameter α_{T-2}^{ILI} in *Appendix E.*

Even *before* its release, a policy signal improves the information content of the market price. The reason is that the *anticipation* of a policy signal at $T-1$ induces date $T-2$ traders to rely more heavily on their private signals in setting p_{T-2}^{ILI}. This allows p_{T-2}^{ILI} to aggregate the private signals in a more precise endogenous signal.

More concretely, the release of a policy signal drives a wedge between the price-based public signal available to traders on $T-2$, i.e. $\hat{p}_{T-2}^{ILI}$, and the refined version of this signal available to traders on $T-1$, i.e. $\widehat{\widehat{p}}_{T-2}^{ILI}$. And the more precise is the policy signal, i.e. the higher is δ, the bigger is this wedge. By expression (28), this weakens the information content of $\hat{p}_{T-2}^{ILI}$ as a signal about tomorrow's price, p_{T-1}^{ILI}, giving rise to two effects on date $T-2$. First, all else equal, there is greater uncertainty about p_{T-1}^{ILI}, i.e. $V_{T-2}^{ILI}\left(p_{T-1}^{ILI}\right)$ rises. Second, since traders are rational, they start paying more attention on date $T-2$ to their private signals, i.e. ω_x^{DLI} rises. In *Appendix E*, we show that the second effect always dominates and, through equation (30), leads to:

$$d\alpha_{T-2}^{ILI}/d\delta > 0 \text{ for } \delta \geq 0 \tag{31}$$

Finally, we also show in *Appendix E* that, even when the indirect policy signal is delayed, it improves the alignment of market prices with fundamentals:

$$\frac{dV\left(p_{T-1}^{ILI}|\theta\right)}{d\delta} < 0 \text{ and } \frac{dV\left(p_{T-2}^{ILI}|\theta\right)}{d\delta} < 0 \text{ for all } \delta \in [0,1] \tag{32}$$

The intuition is as follows. When a policy signal reveals a part of the non-fundamental shock, i.e. ξ_{T-2}^{s}, with a one-period delay, it cannot have a damaging coordination function on date $T-2$. However, by expression (31), the policy signal plays a beneficial information function even *before* it is observed. This makes the policy signal unambiguously beneficial, as stated in (32).

5 Information deficiencies in real-world financial markets

In this section, we relate our model to two real-world examples. First, we examine the rapid rise and subsequent abrupt collapse of the market prices of structured finance products. Second, we analyze the cross-currency funding of investments in such products, focusing on its contribution to the evaporation of US-dollar liquidity in 2008.

5.1 Example 1: The CDO market prior to the global financial crisis

During the run-up to the global financial crisis, investment in collateralized debt obligations (CDOs) soared. At end-2007, the global amount of these instruments stood at approximately $1.4 trillion, almost twice the level in 2005.[15] There were two factors that contributed to this outcome. On the one hand, regulated entities and institutional investors – such as banks, insurance companies, pension and mutual funds – were in search of yield but also needed to meet certain criteria on the types of assets they could hold. On the other hand, highly rated CDO tranches satisfied nominally these criteria while offering a substantial yield pick up relative to other similarly rated instruments (see Hull (2009), Gorton (2010) and Hull and White (2012)). And regulated entities and institutional investors purchased these tranches in large amounts, neglecting some of the underlying risks that the associated ratings failed to reflect (Gennaioli et al (2012), Manconi et al (2012)). Thus, they acted as the *information insensitive* (or noise) traders in our model, bidding up the price of a poorly understood asset class.

Our model provides a stylized explanation of why more sophisticated, *information sensitive*, investors (such as hedge funds and securities firms) were not able to take advantage of overpriced CDO tranches. Even when such an investor observes market prices growing out of line with what her private signal suggests, she faces two competing explanations. First, the high price may reflect demand from information insensitive investors. All else the same, this would lead the sophisticated investor to revise her expectation of the fundamentals downwards. Alternatively, the high price may indicate that the sophisticated investor's private signal is overly pessimistic, thus prompting her to revise her expectation upwards. In equilibrium, the two forces balance each other, leaving the asset overpriced. This point is captured by equations (17) and (23), where

[15] This information is provided by the Securities Industry and Financial Markets Association (SIFMA) at http://www.sifma.org/research/statistics.aspx

greater demand from information insensitive investors corresponds to a higher absolute value of a negative ξ.

What might a policy authority have done to mitigate the mispricing? Our model indicates that a policy signal about the relative size of investments by information insensitive agents would have allowed sophisticated investors to disentangle the two competing interpretations of the price level. In effect, such a policy signal would have allowed the asset price itself to be a better signal about the underlying fundamentals. This would have strengthened arbitrage forces at the marketplace, thus driving the price closer to its fundamental value.

Importantly, a policy signal would have been, in principle, beneficial under quite weak conditions. In the particular CDO example, it would have sufficed that the signal revealed the volume held by regulated institutional investors. In order to protect the confidentiality of individual institutions, this information could have been published only at an aggregate level. Furthermore, the discussion in Section 4.4 suggests that even delayed dissemination of such information – reflecting the time an authority would need to collect and process data on trading positions – would have been useful. Simply the anticipation of an upcoming policy signal would have brought prices closer to fundamental values early on.

5.2 Example 2: Shortage of US dollar funding in 2008

Heavy investment in US dollar structured-finance products (e.g. CDOs) in the run-up to the crisis was mirrored by investors' demand for US dollar funding. While our model abstracts from the mechanics of cross-currency funding, it does help to illustrate how lack of knowledge about overall investment positioning could lead to mispricing in currency markets as well. Thus, this indirect example highlights the usefulness of the types of policy signals discussed in Sections 3 and 4.

For non-US dollar based investors, purchases of US dollar structured finance products involved cross-currency funding. That is, while the bulk of these products was denominated in US dollars, the readily available funding for many of the investors was in euros, Swiss Francs or other currencies. To hedge open currency positions on their balance sheets, such investors often relied on currency derivatives, such as foreign-exchange (FX) swaps. However, FX swaps are generally short term and thus amplify the maturity mismatches on balance sheets.

What went unnoticed prior to the crisis was the build-up of common US dollar funding positions in FX swaps across many non-US dollar based (primarily, European) institutions. McGuire and von Peter (2009) use data covering internationally active banks to sketch out the size of the aggregate funding needs of non-US dollar based institutions. Since these data do not cover the balance sheet positions of non-banks and were not designed to cast light on currency funding mismatches, they permit only a partial analysis. Nevertheless, rough estimates based on these data suggest that, by mid-2007, European banks demanded more than half a trillion in US dollars from the FX swap market in order to fund their US dollar assets (Graph 2, left-hand panel).

– Graph 2 –

As the crisis unfolded, many providers of short-term funding withdrew from the market and others, faced with a swollen share of banks' funding needs, were willing to step in only if compensated substantially for counterparty credit risk. One of the manifestations of these tight conditions was a spike in euro-dollar swap spreads, i.e. the premium paid for US dollars over and above that paid for euros (Graph 2, middle panel). In addition, these conditions contributed to a massive appreciation of the US dollar over the five months following the collapse of Lehman Brothers in September 2008. Behind this appreciation were non-US dollar based investors, which were no longer able to roll over their FX swap funding positions and thus had to close them out by purchasing *en masse* US dollars in the spot market. Calming markets required central bank swap lines and an official commitment to provide *unlimited* liquidity (Graph 2, right-hand panel).[16]

Lacking a bird's eye view, individual investors relied on short-term US-dollar funding to an extent that turned out to be imprudently high. Without knowledge of the size of common funding positions at a system level, these investors were unaware that their funding roll-over risks grew as others entered into similar positions. Thus, they were unable to properly price these risks, whose magnitude became known only once the supply of short-term US-dollar credit disappeared. The resulting appreciation of the US-dollar exchange rate was commensurate with the extent of cross-currency financing embedded in the system as a whole at that point in time.

This example illustrates that there is scope for policymakers to collect and disseminate data on aggregate balance sheet positioning. To be sure, national authorities already have such data for certain regulated industries in their jurisdictions (e.g. banks). However, these data are not always published at the national level or aggregated at the international level. In the context of the above example, such aggregation would not have necessarily provided information about the "fundamental value" of the underlying US-dollar assets themselves but would have generated useful policy signals about the

[16] See Board of Governors of the Federal Reserve System (2008).

build-up of gross funding positions. Alerting investors to the magnitude of the price adjustments from a sudden contraction in the supply of US-dollar funding and the associated risks for non-US dollar based investors, such signals would have allowed the system to more effectively govern itself.

6 Conclusion

In this paper, we ask whether public policy signals are beneficial in the sense of aligning market outcomes with economic fundamentals. In order to answer this question, we employ a model in which public signals, a special case of which are policy signals, play both a beneficial information role and a damaging coordination role. This theoretical framework has underpinned arguments that authorities should abstain from speaking up, unless they bring substantial new information to the marketplace. These arguments, however, are derived from models with a rather restrictive information structure. Specifically, they hinge on the assumption of segregated markets, in which all signals are exogenous.

We argue that, if the market is integrated and optimizing traders observe a common market-clearing price, public policy signals refine endogenous price-based public signals and improve *unambiguously* the alignment between fundamentals and market outcomes. In an integrated market, the overall information environment falls in one of two general categories. First, the price-based signal is precise, in which case a policy signal improves on an already close alignment between prices and fundamentals. Second, volatile non-fundamental shocks render the price-based signal imprecise, in which case the policy signal helps market players arbitrage away the effect of these shocks on market prices. In either case, the beneficial information role of the policy signal dominates its damaging coordination role.

In addition, we contend that, in an integrated market setting, a policy signal about economic fundamentals would have a beneficial impact on market outcomes even if it is indirect, i.e. deduced from information about market volumes, and comes with a time lag. This suggests that public authorities could contribute to financial stability by collecting and disseminating data on aggregate market positions. In order to illustrate this point, we refer to the overheating of the CDO market in the run-up to the recent global financial crisis and the concurrent experience of non-US dollar based investors in the market for short-term US-dollar funding.

Appendix A: Island-specific equilibrium

In this appendix we derive the equilibrium island-specific price in equation (7) on the basis of the optimization problem in expression (6).

We start with two assumptions. First, there is a positive net supply of the asset, $\xi_t > 0$. Second, there exists a price $p_{j,t} > 0$ at which each trader would like to accommodate this supply. By expression (6), the second assumption is equivalent to $E_{j,t}(p_{t+1}) - \frac{\xi_t}{2\tau} V_t(p_{t+1}) > 0$.

Under these two assumptions, there *exists* an equilibrium in which both traders announce $p^*_{j,t} = E_{j,t}(p_{t+1}) - \frac{\xi_t}{2\tau} V_t(p_{t+1})$. By expression (6), $p^*_{j,t}$ renders each trader indifferent between: (i) buying ξ_t of the asset and (ii) not investing at all. If one trader deviates with a price above $p^*_{j,t}$, she gets the asset for sure but, given expression (6), would have had a higher expected utility had she abstained from trading altogether. Conversely, if a trader deviates with a price below $p^*_{j,t}$, she does not get the asset for sure and her expected utility is the same as when she announces $p^*_{j,t}$.

We now show that $p^*_{j,t}$ is the *only Nash* equilibrium. First, suppose that the two traders announce different prices and the higher price is above $p^*_{j,t}$. The trader announcing this price buys the asset for sure and faces an expected utility that is lower than what it would have been had the trader announced a price equal to or smaller than $p^*_{j,t}$. Thus, the conjectured price configuration could not be a Nash equilibrium. Second, suppose that one of the traders announces $p^*_{j,t}$, while the other announces a lower price. Then, the former trader could increase her expected utility by announcing a price that is between $p^*_{j,t}$ and the price announced by the latter trader. Again, the conjectured price configuration cannot be an equilibrium. Third, both traders announcing prices below $p^*_{j,t}$ is not an equilibrium either. In this case, each trader could improve her expected utility by outbidding the other trader by an infinitesimal amount, which would result in a certain purchase of the asset at a positive expected utility. The three price configurations that we just ruled out constitute all the possible price configurations other than both traders announcing $p^*_{j,t}$.

A similar reasoning, applied to the remaining three configurations of the signs of ξ_t and $E_{j,t}(p_{t+1}) - \frac{\xi_t}{2\tau} V_t(p_{t+1})$, completes the proof.

Appendix B: Island economy

In this appendix, we prove expressions (10) and (11), which relate to expression (9).

The proof is in three parts. First, note that, for any $\beta > 0$ and $\gamma > 0$, $\frac{\beta}{\beta+\gamma} \in (0,1)$ and thus the expected payoff term of $V(p_{T-2}|\theta)$ is larger than that of $V(p_{T-1}|\theta)$, i.e.

$\left(1-\left(\frac{\beta}{\beta+\gamma}\right)^2\right)^2\frac{1}{\gamma} > \left(1-\frac{\beta}{\beta+\gamma}\right)^2\frac{1}{\gamma}$. In addition, as σ_ξ/τ decreases towards zero, the risk premium terms of both $V\left(p_{T-1}|\theta\right)$ and $V\left(p_{T-2}|\theta\right)$ decrease continuously towards zero. This implies the existence of $\Sigma_1^L > 0$ such that $V\left(p_{T-2}|\theta\right) > V\left(p_{T-1}|\theta\right)$ for $\sigma_\varepsilon/\tau \in \left(0,\Sigma_1^L\right)$.

Second, considering again the expected payoff terms, straightforward algebra reveals that $d\left(1-\frac{\beta}{\beta+\gamma}\right)^2\frac{1}{\gamma}/d\gamma > 0$ for $\gamma \in (0,\beta)$, $d\left(1-\left(\frac{\beta}{\beta+\gamma}\right)^2\right)^2\frac{1}{\gamma}/d\gamma > 0$ for $\gamma \in \left(0,\beta\left(\sqrt{17}-3\right)/2\right)$, and $d\left(1-\left(\frac{\beta}{\beta+\gamma}\right)^2\right)^2\frac{1}{\gamma}/d\gamma > d\left(1-\frac{\beta}{\beta+\gamma}\right)^2\frac{1}{\gamma}/d\gamma$ for $\gamma \in \left(0,\beta\left(\sqrt{73}-5\right)/8\right)$. Define $\Gamma \equiv \beta\left(\sqrt{73}-5\right)/8$. By the above-noted dependence of the risk premium terms on σ_ξ/τ, it then follows that there exists $\Sigma_2^L > 0$ such that $dV\left(p_{T-2}|\theta\right)/d\gamma > dV\left(p_{T-1}|\theta\right)/d\gamma > 0$ for $\gamma \in (0,\Gamma)$ and $\sigma_\varepsilon/\tau \in \left(0,\Sigma_2^L\right)$. Defining $\Sigma^L \equiv \min\left\{\Sigma_1^L,\Sigma_2^L\right\}$ leads to expression (10).

Third, it is straightforward to see that the risk premium terms of $V\left(p_{T-1}|\theta\right)$ and $V\left(p_{T-2}|\theta\right)$ decreases in γ. Expression (11) then follows from the dependence of these terms on σ_ξ/τ.

Appendix C: Integrated market, direct policy signal

In this appendix, we substantiate statements made in Sections 4.1 and 4.3. First, we derive the signal weights $\left\{\omega_x^{DI},\omega_y^{DI},\varphi_x^{DI},\varphi_y^{DI},\varphi_p^{DI}\right\}$ and the perceptions of payoff risk, $V_{T-2}^{DI}\left(p_{T-1}^{DI}\right)$ and $V_{T-1}^{DI}(\theta)$, which enter the equilibrium prices in expression (17). Finally, we prove expression (26). We lighten the notation by suppressing the DI superscript for the rest of this appendix.

Signal weights are proportional to the respective precision and uncertainty decreases in each signal's precision. Since date $T-1$ traders forecast θ on the basis of signals that have mutually independent and normally distributed noise terms, then:

$$\varphi_x = \beta V_{T-1}(\theta)\,,\ \varphi_y = \gamma V_{T-1}(\theta)\,,\ \varphi_p = \alpha_{T-2}V_{T-1}(\theta)\ \text{ and } V_{T-1}(\theta) = \frac{1}{\beta+\gamma+\alpha_{T-2}+\alpha_{T-1}}$$

Making use of the solution for φ_x and $V_{T-1}(\theta)$, we confirm (19). Switching to date $T-2$ traders, we note that the risk they perceive in p_{T-1} stems from θ and the unforecastable ξ_{T-1}. We thus approach date $T-2$ signals in the same way as date $T-1$ signals and then derive the following expressions for the parameters in p_{T-2}:

$$
\begin{aligned}
\omega_x &= \frac{\beta\left(\beta+\alpha_{T-1}\right)}{\left(\beta+\gamma+\alpha_{T-2}\right)\left(\beta+\gamma+\alpha_{T-2}+\alpha_{T-1}\right)} \\
\omega_y &= \frac{\gamma\left(2\beta+\gamma+\alpha_{T-1}+\alpha_{T-2}\right)}{\left(\beta+\gamma+\alpha_{T-2}\right)\left(\beta+\gamma+\alpha_{T-1}+\alpha_{T-2}\right)} \\
V_{T-2}\left(p_{T-1}\right) &= \frac{\left(\beta+\alpha_{T-1}\right)^2}{\alpha_{T-1}\left(\beta+\gamma+\alpha_{T-2}\right)\left(\beta+\gamma+\alpha_{T-2}+\alpha_{T-1}\right)}
\end{aligned}
$$

Making use of the solution for ω_x and $V_{T-2}\left(p_{T-1}\right)$, we confirm (21).

Expressions (15), (16), (17), (19) and the above explicit expressions for date $T-1$ parameters imply that

$$
\begin{aligned}
V\left(p_{T-1}|\theta\right) &= \frac{\gamma+\alpha_{T-2}}{\left(\beta+\gamma+\alpha_{T-2}+\alpha_{T-1}\right)^2}+\frac{\left(\frac{\alpha_{T-1}}{\tau\beta}+\frac{1}{\tau}\right)^2\sigma_\xi^2}{\left(\beta+\gamma+\alpha_{T-2}+\alpha_{T-1}\right)^2} \\
&= \frac{\alpha_{T-2}+\gamma+\frac{\left(\beta+\alpha_{T-1}\right)^2}{\alpha_{T-1}}}{\left(\beta+\gamma+\alpha_{T-2}+\alpha_{T-1}\right)^2}
\end{aligned}
$$

where we use the fact that the noise in $\hat{p}_{T-1}$ and the risk premium term are driven by the same random variable, ξ_{T-1}. Then, the derivative of the last expression confirms that $dV\left(p_{T-1}|\theta\right)/d\gamma<0$ for all $\gamma\geq 0$, as stated by the second expression in (26).

Similarly, making use of expressions (15), (16), (17), and (21) we derive:

$$
\begin{aligned}
V\left(p_{T-2}|\theta\right) = &\frac{\gamma\left(2\beta+\gamma+\alpha_{T-1}+\alpha_{T-2}\right)^2}{\left(\beta+\gamma+\alpha_{T-2}\right)^2\left(\beta+\gamma+\alpha_{T-1}+\alpha_{T-2}\right)^2} \\
&+\frac{\left(\alpha_{T-2}^2+\alpha_{T-1}\alpha_{T-2}+\beta^2+\beta\alpha_{T-1}+2\beta\alpha_{T-2}+\gamma\alpha_{T-2}\right)^2}{\alpha_{T-2}\left(\beta+\gamma+\alpha_{T-2}\right)^2\left(\beta+\gamma+\alpha_{T-1}+\alpha_{T-2}\right)^2}
\end{aligned}
$$

and confirm directly that $dV\left(p_{T-2}|\theta\right)/d\gamma<0$ for all $\gamma\geq 0$, as stated by the first expression in (26).

Appendix D: Integrated market, indirect policy signal

In this appendix, we substantiate statements we made in Sections 4.2 and 4.3. First, we derive the signal weights $\left\{\omega_x^{II},\varphi_x^{II},\varphi_p^{II}\right\}$ and the perceptions of payoff risk, $V_{T-2}^{II}\left(p_{T-1}^{II}\right)$ and $V_{T-1}^{II}\left(\theta\right)$, which enter the equilibrium prices in expression (23). Finally, we prove expression (27). We lighten the notation by suppressing the II superscript for the rest of this appendix.

Paralleling the analysis in *Appendix C*, we obtain

$$\varphi_x = \beta V_{T-1}(\theta), \; \varphi_p = \alpha_{T-2} V_{T-1}(\theta) \; \text{ and } V_{T-1}(\theta) = \frac{1}{\beta + \alpha_{T-2} + \alpha_{T-1}} \tag{D.1}$$

which immediately confirms (24). And as regards date $T-2$:

$$\begin{aligned} \omega_x &= \frac{\beta(\beta+\alpha_{T-1})}{(\beta+\alpha_{T-2})(\beta+\alpha_{T-2}+\alpha_{T-1})} \text{ and} \\ V_{T-2}(p_{T-1}) &= \frac{(\beta+\alpha_{T-1})^2}{\alpha_{T-1}(\beta+\alpha_{T-2})(\beta+\alpha_{T-2}+\alpha_{T-1})} \end{aligned} \tag{D.2}$$

which confirms (25).

Using expression (23) together with (D.1) and (D.2) leads to:

$$\begin{aligned} V(p_{T-2}|\theta) &= \frac{1}{\alpha_{T-2}} \\ V(p_{T-1}|\theta) &= \frac{\alpha_{T-2} + \frac{(\beta+\alpha_{T-1})^2}{\alpha_{T-1}}}{(\beta+\alpha_{T-2}+\alpha_{T-1})^2} \end{aligned}$$

Since δ enters these expression only through α_{T-2}, $d\alpha_{T-2}/d\delta > 0$ by expression (25), and $dV(p_{T-2}|\theta)/d\alpha_{T-2} < 0$ and $dV(p_{T-1}|\theta)/d\alpha_{T-2} < 0$, we can confirm the second line in expression (27).

Appendix E: Integrated market, indirect late policy signal

In this appendix, we substantiate claims made in Section 4.4. First, we derive the signal weights $\{\omega_x^{ILI}, \varphi_x^{ILI}, \varphi_p^{ILI}\}$ and the perceptions of payoff risk, $V_{T-2}^{ILI}(p_{T-1}^{ILI})$ and $V_{T-1}^{ILI}(\theta)$, which enter the equilibrium prices in expression (28). Finally, we prove expression (32). We lighten the notation by suppressing the ILI superscript for the rest of this appendix.

Paralleling the analysis in *Appendices C* and *D*, we obtain

$$\varphi_x = \beta V_{T-1}(\theta), \; \varphi_p = \frac{\alpha_{T-2}}{1-\delta} V_{T-1}(\theta) \; \text{ and } V_{T-1}(\theta) = \frac{1}{\beta + \frac{\alpha_{T-2}}{1-\delta} + \alpha_{T-1}}$$

which immediately confirms the last equality in the first line of (29). Regarding date $T-2$ traders, we note that the forecastable risk they are facing stems not only from θ

but also from ξ^n_{T-2}. Incorporating this in the inference procedure, we obtain:

$$\omega_x = \frac{\beta\left(\beta+\frac{\delta}{1-\delta}\alpha_{T-2}+\alpha_{T-1}\right)}{\left(\beta+\alpha_{T-2}\right)\left(\beta+\frac{\alpha_{T-2}}{1-\delta}+\alpha_{T-1}\right)}$$

$$V_{T-2}\left(p_{T-1}\right) = \frac{\frac{\left(\beta+\frac{\alpha_{T-2}}{1-\delta}+\alpha_{T-1}\right)^2}{\beta}+\frac{\alpha_{T-2}}{1-\delta}+\frac{\left(\beta+\alpha_{T-1}\right)^2}{\alpha_{T-1}}-\frac{\alpha_{T-2}\left(2\beta+\frac{\alpha_{T-2}}{1-\delta}+\alpha_{T-1}\right)^2}{\beta\left(\beta+\alpha_{T-2}\right)}}{\left(\beta+\frac{\alpha_{T-2}}{1-\delta}+\alpha_{T-1}\right)^2}$$

which reduce to the corresponding expressions in *Appendix C* when $\gamma=\delta=0$, i.e. when the there is no exogenous public information and no policy signal. The last two expressions and expression (30) then imply the following implicit solution for α_{T-2}:

$$\begin{aligned}
\alpha_{T-2} &= \alpha_{T-1}\left(\frac{A}{B+C}\right)^2, \text{ where} \qquad \text{(E.1)}\\
A &\equiv \frac{\alpha_{T-1}}{\beta}\left(1+\frac{\delta}{1-\delta}\frac{\alpha_{T-2}}{\beta}+\frac{\alpha_{T-1}}{\beta}\right)\left(1+\frac{1}{1-\delta}\frac{\alpha_{T-2}}{\beta}+\frac{\alpha_{T-1}}{\beta}\right)\\
B &\equiv \left(\left(1+\frac{\alpha_{T-1}}{\beta}\right)^3+\frac{\alpha_{T-2}}{\beta}\right)\\
C &\equiv \frac{\alpha_{T-1}\alpha_{T-2}}{\beta^2\left(1-\delta\right)^2}\left(\left(2+\delta\right)\left(1-\delta\right)+\delta\frac{\alpha_{T-2}}{\beta}+\left(1-\delta^2\right)\frac{\alpha_{T-1}}{\beta}\right)
\end{aligned}$$

A solution for α_{T-2} exists because the right-hand side of (E.1) satisfies two conditions: (i) it equals $\alpha_{T-1}\left(\frac{\alpha_{T-1}}{\beta+\alpha_{T-1}}\right)^2>0$ at $\alpha_{T-2}=0$; and (ii) it converges to the finite α_{T-1} as $\alpha_{T-2}\to\infty$. Thus, $\alpha_{T-2}\in\left(\alpha_{T-1}\left(\frac{\alpha_{T-1}}{\beta+\alpha_{T-1}}\right)^2,\alpha_{T-1}\right)$. Numerical checks for $\alpha_{T-1}>0$ and $\delta\in[0,1]$ reveal that α_{T-2} is unique.

The variance of prices around fundamentals is then given by

$$V\left(p_{T-2}|\theta\right) = \frac{1}{\alpha_{T-2}}$$

$$V\left(p_{T-1}|\theta\right) = \frac{\frac{\alpha_{T-2}}{1-\delta}+\frac{\left(\beta+\alpha_{T-1}\right)^2}{\alpha_{T-1}}}{\left(\beta+\frac{\alpha_{T-2}}{1-\delta}+\alpha_{T-1}\right)^2}$$

It follows directly that $dV\left(p_{T-2}|\theta\right)/d\alpha_{T-2}<0$, $dV\left(p_{T-1}|\theta\right)/d\alpha_{T-2}<0$ and $dV\left(p_{T-1}|\theta\right)/d\delta<0$. A straightforward but tedious inspection of the right-hand side of (E.1) reveals that it increases in α_{T-2} and shifts upwards as δ increases. It then follows that $d\alpha_{T-2}/d\delta>0$. Putting these four derivatives together implies that $dV\left(p_{T-1}|\theta\right)/d\delta<0$

and $dV\left(p_{T-2}|\theta\right)/d\delta < 0 \;\; for \;\; \delta \in [0,1]$, as stated in expression (32).

References

Allen, F, S Morris and H Shin (2006): "Beauty Contests and Iterated Expectations in Asset Markets", *Review of Financial Studies*, 19, 719 – 752.

Angeletos, G-M, and A Pavan (2007): "Efficient Use of Information and Social Value of Information." *Econometrica*, 75(4): 1103-1142.

Avery, C and P Zemsky (1998): "Multidimensional Uncertainty and Herd Behavior in Financial Markets", *American Economic Review*, 88, 724-48.

Board of Governors of the Federal Reserve System (2008), Press release, October 13, http://www.federalreserve.gov/newsevents/press/monetary/20081013a.htm

Case, K and R Shiller (1989): "The Efficiency of the Market for Single-Family Homes", *American Economic Review*, 79, 125-137.

Case, K and R Shiller (2003): "Is There a Bubble in the Housing Market?", *Brookings Papers on Economic Activity*, 34(2), 299-362.

Colombo, L, G Femminis and A Pavan (2012): "Endogenous Information and Welfare", working paper.

DeGroot, M (1970): *Optimal Statistical Decisions*, John Wiley and Sons Inc.

Dupor (2005): "Stabilizing non-fundamental asset price movements under discretion and limited information", *Journal of Monetary Economics*, 52, 727-747.

Gennaioli, N, A Shleifer and R Vishny (2012): "Neglected Risks, Financial Innovation, and Financial Fragility", *Journal of Financial Economics*, 104, pp 452-68.

Gerardi, K, A Lehnert, S Sherlund and P Willen. 2008. "*Making Sense of the Subprime Crisis*", Brookings Papers on Economic Activity: 69-145.

Gilchrist S and J V Leahy (2002), "Monetary Policy and Asset Prices", *Journal of Monetary Economics*, 49, 75-97.

Gorton, G (2010): *Slapped by the Invisible Hand: The Panic of 2007*, Oxford University Press.

Grossman (1989), *The Informational role of prices*, MIT Press.

Hellwig, C (2005): "Heterogeneous Information and the Welfare Effects of Public Information Disclosures." http://www.econ.ucla.edu/people/papers/Hellwig/Hellwig283.pdf

Hull, J (2009): "The credit crunch of 2007: What went wrong? Why? What lessons can be learned?", *Journal of Credit Risk*, 5(2), pp 3-18.

Hull, J and A White (2012): "Ratings arbitrage and structured products", *Journal of Derivatives*, forthcoming.

James, J and P Lawler (AER, forthcoming): "Optimal Policy Intervention and the Social Value of Public Information", Working Paper, Swansea University.

Keynes, J M (1936): *General Theory of Employment, Interest, and Money.* MacMillan, London.

Kohn, D (2011): "Enhancing financial stability: the role of transparency", http://www.bankofengland.co.uk/publications/speeches/2011/speech516.pdf

Lucas, R E (1972): "Expectations and the neutrality of money", *Journal of Economic Theory*, 4, pp 103-24.

Lucas, R E (1973): "Some international evidence on output-inflation tradeoffs", *American Economic Review*, 63, pp 326-34.

Manconi A, M Massa and A Yasuda: "The Role of institutional investors in propagating the crisis of 2007-2008", *Journal of Financial Economics*, 104 (3), pp 491-518.

McGuire P and G von Peter (2009): "*The US dollar shortage in global banking and the international policy response*", BIS Working Paper 291, October.

Morris, S, and H S Shin (2002): "Social Value of Public Information." *American Economic Review*, 92(5): 1521-1534.

Phelps, E S (1970): "Introduction", *Microeconomic Foundations of Employment and Information Theory*, E S Phelps et al (eds), Norton, New York, pp 1-22.

Poterba, J (2000): "Stock Market Wealth and Consumption", *Journal of Economic Perspectives*, 14(2), 99-118.

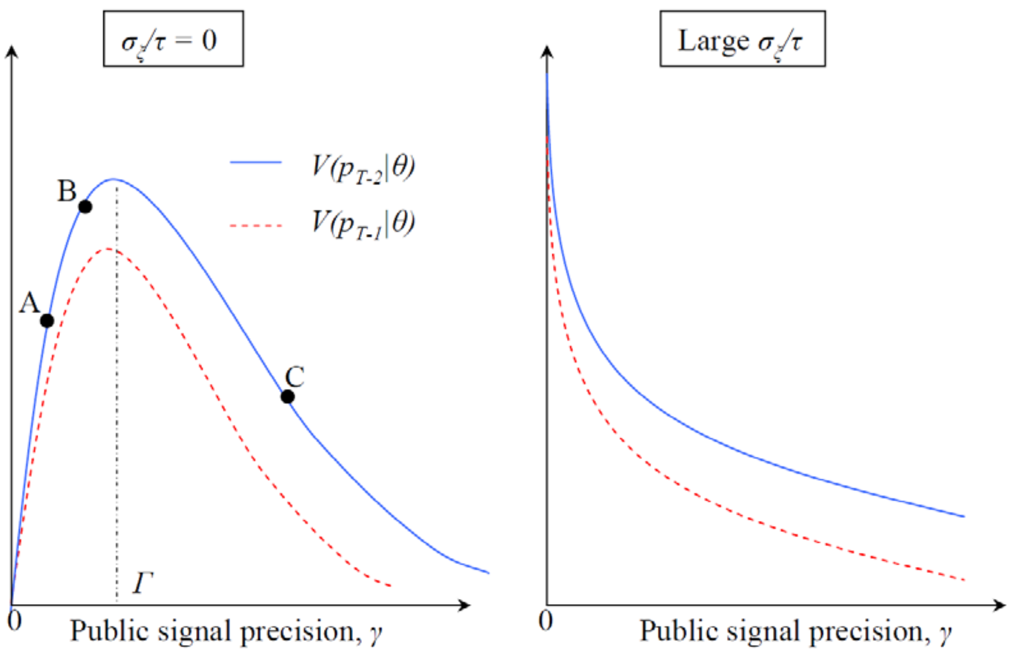
Reinhart, C and K Rogoff (2009): "*This Time Is Different: Eight Centuries of Financial Folly*", Princeton, NJ: Princeton University Press.

Shiller, R (2000): *Irrational Exuberance.* Princeton University Press.

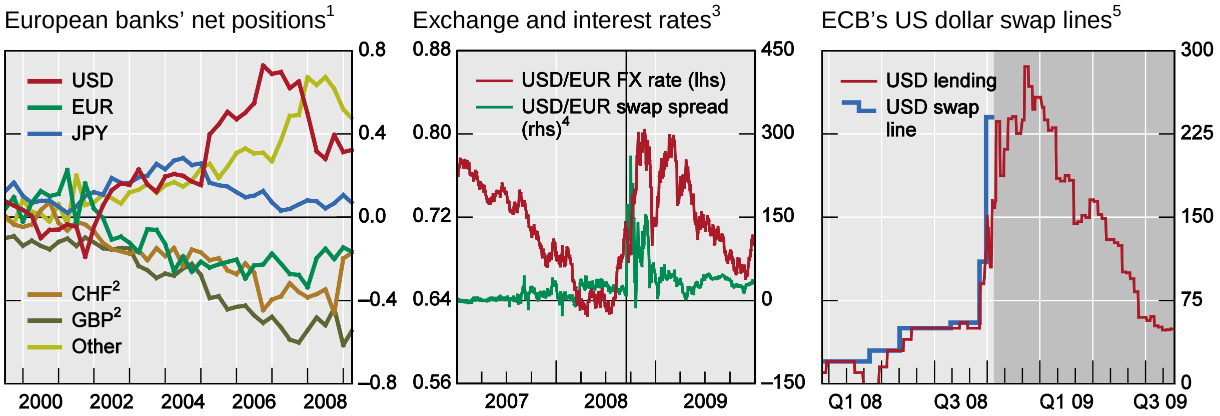
Svensson, L E O (2006): "The Social Value of Information: Morris and Shin (2002) is Actually Pro Transparency, not Con." *American Economic Review*, 96(1): 448-451.

Graph 1: Island economy

for given precision of private signals: $\beta > 0$



Graph 2: European banks' US dollar funding and market prices



[1] Estimates are constructed by aggregating the on-balance sheet cross-border and local positions reported by Belgian, Dutch, French, German, Italian, Spanish, Swiss and UK banks' offices; in trillions of US dollars. [2] Positions booked by offices located in Switzerland (for CHF) and in the United Kingdom (for GBP). CHF and GBP positions reported by offices located elsewhere are included in "Other". [3] The vertical line indicates the collapse of Lehman Brothers (15 September 2008). [4] Spread between three-month FX swap implied dollar rate and the three-month USD Libor; the FX swap implied rate is the implied cost of raising US dollars via FX swap using the euro; in basis points. [5] Amounts outstanding are constructed by cumulating US dollar auction allotments, taking into account the term to maturity. The shaded area indicates the period of unlimited swap lines (as of 13 October 2008); in billions.

Sources: Bloomberg; Central banks; BIS international banking statistics.

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