Insider Trading Regulation and Market Quality Tradeoffs*

Antonio Mele

USI Lugano, Swiss Finance Institute and CEPR

Francesco Sangiorgi

Frankfurt School of Finance and Management

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Abstract

Insider trading discourages outside investors' information acquisition. Does this property imply that insider trading should be banned for the purposes of better market efficiency and liquidity? This paper provides a systematic analysis of three regulatory regimes with (i) insider trading bans, (ii) post-trade transparency, and (iii) unrestricted insider activities. When the cost to collect and process information is small and uncertainty is high, information crowding-out is so severe that bans are beneficial to market efficiency. Otherwise, information crowding-out is limited and post-trade transparency delivers the most efficient market. Markets are always the most liquid with a complete insider trading ban.

Keywords: Insider trading; post-trade transparency; ex ante corporate disclosure; information crowding-out.

JEL: D82; G14; G18.

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1. Introduction

Insider trading has been an outstanding issue in the regulatory agenda for almost a century. The Securities Exchange Act of 1934 requires corporate insiders (directors, officers and owners of at least five percent of equity securities) to disclose their trades to the SEC within days; following the Sarbanes-Oxley Act of 2002, disclosure should now occur within two business days following the transaction. The rationale behind this type of transparency is to achieve market integrity and, then, better investor protection, price discovery and liquidity conditions. This paper builds up a framework to gauge how alternative forms of insider trading regulation affect information efficiency and other attributes of market quality when investors have the ability to acquire information. We study information efficiency and market liquidity across three alternative regulatory regimes that include (i) insider trading bans, (ii) post-trade transparency, and (iii) unrestricted insider activities.

Insider trading regulation may seem to be irrelevant to market efficiency or liquidity in the current information age. Current information technology enables investors to estimate asset values faster and, arguably, more accurately than at the time of the Securities Exchange Act and its amendments. Due to data abundance, information processing techniques based on machine learning and artificial intelligence are increasingly used to forecast trends in firms' profitability and price a wide range of securities as a result. If information has become so easier to process, wouldn't insiders' informational advantage be so reduced to render regulation practically irrelevant? This paper argues that it is far from being the case. Market efficiency and liquidity both improve while properly regulating insider trading in a world with more parsimonious and efficient information search and computational costs.

So *how* should insider trading be regulated within the frameworks covered by this paper? Our main conclusions are that how to regulate depends on both uncertainty around market fundamentals (i.e., the insider's likely informational advantage) and the efficiency of information technology *and* the market quality attribute that regulation tries to target at. If regulation aims at improving price efficiency, and information technology is expensive, or uncertainty on fundamentals is low, our analysis suggests that the best option is mandatory disclosure of insider trades. However, in the presence of more efficient information technologies, or higher uncertainty, the best regulatory regime is a complete ban on insider trading. Finally, our analysis suggests that the regulatory regime that ensures the most liquid market *always* relies on a complete ban on insider trading. Our analysis yields novel insights into existing regulation, reviewed and re-assessed in light of our conclusions. We explain that, in markets with high uncertainty, policy models based on ex ante corporate disclosure of price-sensitive information (the main model in the E.U. and the U.K.) may actually be complements to mandatory disclosures of insider trades (the reference in the U.S.). In these markets, trading bans are still the best option in the absence of legislative provisions of ex ante corporate disclosure.

To help provide intuition on the main mechanisms behind our analysis, consider the rationale for insider trading regulation in the presence of improving information technologies. Acquiring information pays, provided the assets' fundamental uncertainty is sufficiently large. Now, as the costs to collect and process information drop (through, say, web crawling and parallel computing), so does the uncertainty needed to incentivize information acquisition. To illustrate, consider a stylized example, a market with relatively low uncertainty in which, prior to an information technology "shock," investors cannot bear the costs of collecting information. After the shock, however, the same investors may afford collecting information. In general, while information costs lower, information acquisition activities become more pervasive, to the entire benefit of market efficiency. Insider trading (with or without disclosure) would discourage these processes of information production, a property known as information crowding-out. Obviously, information crowding-out does not need to be strong. However, in our model it is so strong to dominate the positive, direct effects on price discovery that is exerted by allowing the insider to trade. Similar effects underlie other conclusions of our analysis, which we now illustrate in more detail. First, we describe how uncertainty affects information activities, efficiency and liquidity in our model (Section 1.1); second, we provide more details on our claims regarding the effects of information technology on market efficiency (Section 1.2). Sections 1.3 and 1.4 provide a discussion of related work and the paper outline.

1.1. Uncertainty and information activities

The inference that the effects of a policy decision are independent of the behavior of forward looking market participants seems suspicious, at least in light of the general principles underlying the Lucas' Critique. To illustrate, a "reform" that introduces mandatory disclosure is likely to alter the traders' decision space. Huddart, Hughes, and Levine (2001) (HHL, henceforth) show that mandatory disclosure does actually lead to improved market quality. The authors do show that the insiders garble their trades with the purpose of dissimulating their information; however, the dissimulation effects are weak, and the disclosure requirements lead to improved market efficiency. In this paper, we consider a market in which non-insiders, but professional, investors also trade. These investors, the "speculators," acquire information, and their trading decisions vary according to the regulatory regime.

The effects of trading disclosure requirements on market efficiency can be quite complex. We find that, in a Kyle's (1985) type market with multiple periods and a large number of speculators, a given disclosure regime is actually irrelevant to price discovery, provided asset volatility is sufficiently high: market efficiency is the same regardless of whether insider trading is subject or not to disclosure requirements. This irrelevance result is due to the speculators' information acquisition activity. When the asset payoffs are sufficiently uncertain, speculators are incentivized to purchase information. As it turns out, price discovery is, then, even independent of the asset volatility. Figure 1, based on Theorem 1 in Section 4, illustrates this conclusion. Speculators do not acquire information when the asset volatility, σ_d^2, is small. In this case, a regime with disclosure requirements leads to better price discovery (the inverse of $\sigma_{d|\mathrm{F}_2}^2$ in the picture) than one without—the prediction of the HHL model. However, as σ_d^2 increases, speculators acquire information. If insider trading is subject to disclosure, it takes higher values of σ_d^2 to incentivize information acquisition: disclosure requirements result into information crowding-out, that is, greater public disclosure about fundamentals discourages private information acquisition. However, our model predicts that these effects are not strong enough and a market with disclosure requirements is more efficient than without. But when σ_d^2 is sufficiently high, the model predicts that a reform on post-trade transparency does *not* affect market efficiency: markets subject to disclosure are as informationally efficient as markets that are not (Region R1 in Figure 1). In other words, when many speculators trade based on the information they acquire, market (in-)efficiency is "capped" at a level that is independent of post-trade transparency.

Does market efficiency or liquidity improve by banning insider trading in the first place? In a market where insider trading is prohibited, speculators *always* purchase information in equilibrium, and prices may, then, indeed, be informationally more efficient than in markets with insider trading (with or without disclosure requirements). The reason relates, again, to information crowding-out: information held by an insider is incorporated in the asset price, which discourages information acquisition.

Banning insider trading obviously eliminates the undesirable effects of information crowding-out: provided uncertainty on the asset fundamentals σ_d^2 is high enough, market efficiency then improves when insider trading is banned, just as in Regions R1 and R2 of Figure 1. When σ_d^2 is low, however, price efficiency is better when insiders are allowed to trade. The reason is that, with σ_d^2 low, speculators are only incentivized to acquire limited amounts of information and prices, then, are not very informative about the asset fundamentals: the order flow is mostly noise. By contrast, insiders, if allowed to participate, would trade on their information anyway even when σ_d^2 is low, making markets more efficient.

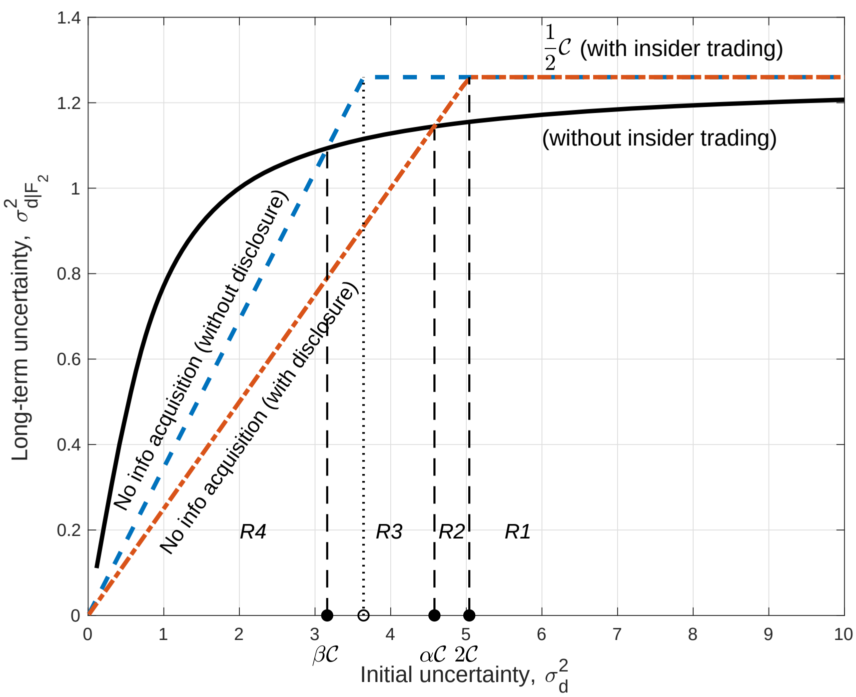

FIGURE 1. Informational efficiency and regulatory regimes. This picture depicts the asset payoff uncertainty as a function of the uncertainty of fundamentals in three regulatory regimes: (i) without insider trading (black line), (ii) with insider trading but mandatory disclosure (red, dot-dashed line), and (iii) with insider trading and without mandatory disclosure (blue, dashed line). In all markets, there is a large pool of investors that engage in costly information acquisition, and the marginal cost of acquiring the first bit of information is 50 cents per unit of noise (that is, $\kappa = \frac{1}{2}$ in Eq. (3)). Remaining notation is defined in the main text and in Section 4.

To these properties correspond others regarding market liquidity. In markets with a large number of speculators, market liquidity *always* improves by banning insider trading. The intuition on this property is the following. When σ_d^2 is low, the order flow is almost noise in a market without insiders, as explained, and liquidity conditions are, then, better than in markets where insiders are allowed to trade. When σ_d^2 is high, investors tend to purchase more information and trade more aggressively, but insider trading would discourage this behavior: markets are now more liquid without insider trading, due to information crowding-out (see Theorem 2 and Figure 4 in Section 4).

Note that the previous properties on market efficiency and liquidity result due to two effects. On the one hand, markets with insiders are always more efficient than without, for a given amount of information (see Proposition 1 in Section 4). On the other hand, when information is endogenous, markets may be inefficiently under-crowded (compared to a market without insider trading). These effects, information crowding-out, are quite strong in our model, although may become weaker in markets with a small pool of speculators.

1.2. Information technology and market efficiency

How do these conclusions link to information technology? In our model, there is a fixed number of speculators, the "potential industry size," who have access to information acquisition technologies subject to standard conditions (weak convexity), and trade in imperfect competition, with or without the presence of an insider trader. With insider trading, we find that these investors all acquire information, provided they face sufficient uncertainty regarding the asset payoff. Precisely, we find that there is a bound, $\mathcal{C}$, such that speculators always enter the market when the asset payoff uncertainty they face whilst trading is higher than $\mathcal{C}$.

Now, and remarkably, this bound, $\mathcal{C}$, is independent of σ_d^2. It is interpreted as the marginal cost that the speculators need to face whilst acquiring the first bit of information (see Eq. (3)). The lower this cost, the lower $\mathcal{C}$ and, then, the lower the uncertainty needed to trigger market participation. Ultimately, the effects of information crowding-out become more severe as these marginal costs decrease. In terms of Figure 1, Regions R1 and R2 shift to the left as information costs decrease.[1] That is, for any given value of σ_d^2, more efficient information technologies (i.e., lower values of $\mathcal{C}$) imply that

[1] Figure 3 in Section 4 provides a precise location map for all these regions and for varying levels of the variance σ_d^2 and the marginal costs of information.

increasingly stricter regulatory regimes ensure the informationally most efficient markets. When, say, information search and processing are expensive, investors acquire limited information, and insider traders help achieve price discovery. In this case, insider trading should be regulated with mandatory disclosure. However, as information costs decrease, insider traders would crowd-out investors, and a complete ban on insider trading improves market efficiency. We now explain how our conclusions relate to the existing literature.

1.3. Discussion of related work

The literature has investigated several instances of markets that lead to information crowding-out. Examples include Diamond (1985) and Gao and Liang (2013), who study firms' information disclosure when competitive investors can acquire information, or Colombo, Femminis, and Pavan (2014), who study the welfare effects of public information in competitive economies with information acquisition and payoff complementarities. Goldstein and Yang (2017) review the literature on information disclosure in financial markets.

Information crowding-out in financial markets was studied by Fishman and Hagerty (1992). They provide examples of markets with and without insider trading, and show that insider trading may discourage private information acquisition by non-insiders and, in some cases, result in lower price efficiency.[2] Our analysis provides a much stronger case for regulation: our model suggests that insider trading should *always* be regulated, independent of parameter values. Furthermore, and in contrast to the previous literature on insider trading, we suggest *how* it should be regulated: we offer a detailed analysis of the regulatory regime that is the most appropriate, depending on the insider's informational advantage and the outside investors' information technology, as anticipated in Sections 1.1-1.2. We also explain how this analysis helps assess alternative regulatory models and justify the adoption of complementary policy measures, based on ex ante corporate disclosure of price-sensitive information (see Section 5). We provide a thorough assessment of the modern and alternative regulatory models available in light of existing regulation in the U.S., the E.U., and in other legislations such as that in the U.K. or Switzerland. The literature has certainly dealt with some mitigated forms of restrictions on insider trading; to illustrate, HHL study markets in

[2] Leland (1992) analyzes insider trading in a model without endogenous information acquisition.

which insiders are subject to post-trade disclosure requirements, consistent with existing regulation in the U.S.. However, it is far from clear whether these requirements are the best option available to regulate insider trading, especially in markets with endogenous information acquisition. In these markets, insiders may have more or less informational advantage, and outside investors may have access to more or less efficient information processing technology. Finally, information acquisition arguably operates in an opaque way, which calls for new ways to model information acquisition in these markets. We provide a systematic analysis of the benefits of alternative forms of insider trading regulation, which take into account these aspects. Our analysis is confined to the most primitive forms of insider trading regulation: insider trading bans, ex post disclosure requirements, ex ante corporate disclosure, and unrestricted markets. These forms are all grounded into current real world restrictions on insider trading. Lenkey (2017) considers a more subtle restriction, the short-swing rule, which requires insiders to return any profits made from trading within six months. His model predicts that this rule lowers price efficiency because it imposes an implicit transaction cost and, hence, leads to a less aggressive insider trading. However, Lenkey's setup takes information as exogenously given. It is an open question whether our conclusions on information crowding-out would also extend to a market subject to the short-swing rule.

In our setting, information choices are not observed (although they are correctly anticipated in equilibrium): in practice, hedge funds and family offices alike typically maintain their research activities quite secret. Thus, our paper belongs to a very recent strand of the literature in which information choices by strategic agents are not observed: see, e.g., Banerjee and Breon-Drish (2020), Rüdiger and Vigier (2020), and Xiong and Yang (2020).[3] In particular, Banerjee and Breon-Drish consider, amongst other things, a market with one investor in a dynamic market; Rüdiger and Vigier consider endogenous information acquisition in dealer markets; Xiong and Yang consider a market with multiple investors. These papers do not analyze markets where outside investors may co-exist with an insider trader. In comparison, we study two-period markets with multiple outside investors and an insider. We contribute to this literature by providing a systematic analysis of insider trading within this framework across three regulatory regimes: the unregulated regime, the regime that bans

[3]For a review of the standard literature on information acquisition started by Grossman and Stiglitz (1980), see Veldkamp (2011) and, amongst others, the additional contributions and references in the previous three papers, Mele and Sangiorgi (2015) and Benhabib, Liu and Wang (2019).

insider trading and, finally, the post-trade transparency regulation framework of HHL, reviewed in more detail below. Moreover, we consider intensive costs of research (as in Banerjee & Breon-Drish and Xiong & Yang), such that, then, the amount of precision of the information collected is determined in equilibrium. Finally, we also study market liquidity across regulatory regimes.

Edmans, Jayaraman, and Schneemeier (2017) show that corporate investment sensitivity to Tobin's q increases after the enforcement of regulations that deter insider trading. Their results are relevant to our paper in two ways. First, they provide empirical evidence consistent with information crowding-out: stock prices become a more informative signal about firms' investment opportunities because outside investors gather more information after insider trading bans. Second, the feedback channel from prices to real investment suggests that outsiders' information acquisition can improve firm value. Hence, the benefits of regulating insider trading may even exceed those uncovered in our paper, thereby providing an even stronger case for regulation.

Our work is related to the literature on financial markets with imperfect competition, especially to those pieces that study market quality implications of post-trading disclosure. HHL show that an equilibrium with mandatory disclosure of insider trades only exists when the insider plays a mixed strategy: the insider adds noise to his market orders to prevent perfect inference on his information by the market maker and maintain profits in future periods. In their model, mandatory public disclosure improves price discovery and liquidity, as explained earlier. We show that in markets with endogenous information acquisition and a large number of investors, mandatory disclosure results in information crowding-out, and that this effect makes mandatory disclosure irrelevant to market quality, provided the uncertainty on fundamentals is sufficiently large (see Figure 1, and Figure 4 in Section 4); in this case, a complete ban on insider trading improves market quality, as explained. Buffa (2013) studies a market with a risk-averse insider; he shows that, in a regime with mandatory disclosure, a risk-averse insider trades less aggressively, which results in less efficient prices. In contrast to these papers, we study properties of information crowding-out of trading disclosure regulation on information acquisition made by non-insiders. Yang and Zhu (2020) consider the effect of "back-running," that is, the observation of a noisy signal of the informed trader's order flow by other traders. When back-running is sufficiently precise, the informed trader hides his information with a mixed strategy—just as the insider who is subject to post-trade disclosure in HHL—and back-running reduces the amount of fundamental information that is acquired in equilibrium. As in our paper, Yang and Zhu (2020) consider a two-period extension of Kyle (1985) and the strategic interactions are across periods. Our paper has a different focus, namely the effects of insider trading regulation on the incentives left to non-insiders (the speculators) to acquire information.

1.4. Outline

The paper is organized as follows. The next section contains a description of our main assumptions. Section 3 develops a framework of analysis of endogenous information acquisition in markets with and without insider trading. The model relies on the assumption that there exists a pool of $\bar{N}$ speculators. Section 4 applies this framework while focussing on the limiting case with large $\bar{N}$, and contains our conclusions on information efficiency and liquidity across markets with alternative disclosure regimes; this section also reviews our findings in markets with finite pools of speculators. Section 5 discusses the policy implications of our analysis in light of existing legislation in the U.S., the E.U. and other markets with reference to post-trade transparency, ex ante transparency, and insider trading bans. Section 6 concludes. Three appendixes contain all technical details not included in the main text.

2. Market and regulatory regimes

We consider a market for a risky asset that pays off a random dividend $\tilde{d} \sim N\left(\bar{d}, \sigma_d^2\right)$ at time $t = 3$ and is traded at $t = 1$ and $t = 2$. The trading protocol is as in Kyle (1985): investors submit market orders to a risk-neutral market maker who sets the price p_t according to the standard semi-strong efficiency rule, $p_t = E(\tilde{d}|\mathbb{F}_t)$, where $\mathbb{F}_t$ denotes the information available to him at time-t. A risk-neutral insider has perfect knowledge of the realization of $\tilde{d}$, and trades, when possible, x_t asset units at time $t = 1, 2$. We consider three regulation regimes. One, in which the insider is not allowed to trade; a second, in which the insider is allowed to trade, but is required to disclose his trade at $t = 1$ (see Figure 2);[4] a third, in which there are no disclosure requirements. We assume noise trading is $z_t \sim N\left(0, \sigma_z^2\right)$ in each trading period $t = 1, 2$.

At time-2, a number $\bar{N}$ of risk-neutral "speculators" may trade in Cournot competition, based

[4]That is, disclosure is ex post: x_1 becomes public information only after p_1 is set. This assumption is consistent with existing regulation on insider trading.

on the first period price, the information reported by the insider (if any), and additional information that they may acquire: a signal on the asset value,[5] $s_i = \tilde{d} + \varepsilon_i$, where ε_i is independent across speculators, and normally distributed with mean zero and variance $\sigma^2_{\varepsilon_i}$. Speculator i trades v_i asset units. We assume that, independent of the regulatory regime, it costs $c(\tau_i)$ to observe a realization of one signal that is drawn with precision $\tau_i \equiv 1/\sigma^2_{\varepsilon_i}$. We assume that $c(\tau_i)$ is positive, increasing, twice differentiable, weakly convex, and satisfies $c(0) = 0$. A speculator's information acquisition decision is not observed by other players. We refer to a speculator i as "active" if he acquires information (i.e., $\tau_i > 0$), and "inactive" otherwise. We denote with $\mathcal{N}$ the index set of active speculators and let $N = |\mathcal{N}|$ (i.e., $N \leq \bar{N}$ is the number of active speculators).

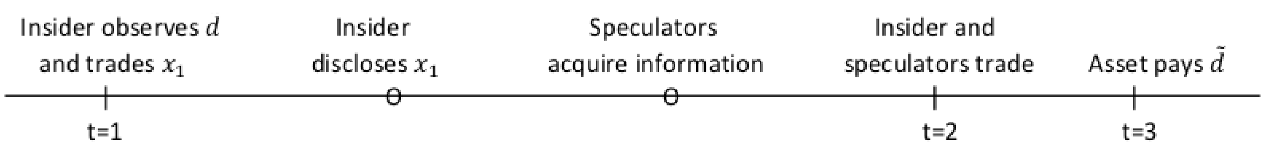

FIGURE 2. Timeline on trading and reporting in the market with mandatory disclosure.

Our equilibrium concept is Perfect Bayesian Equilibrium. The insider and each speculator's actions maximize their respective expected profits conditional on the information available to them, and prices are semi-strong efficient conditional on the information available to the market maker. We focus on linear equilibria in which all active speculators acquire signals with the same precision, i.e., $\tau_i = \tau_\varepsilon$ for all $i \in \mathcal{N}$. In the next section, we solve for the equilibrium in two steps. First, we solve for information acquisition and trading decisions in $t = 2$ taking as given the insider's trading strategy in $t = 1$, and, therefore, taking as given the information set $\mathbb{F}_1$. Second, we endogenize the insider's trading strategy in $t = 1$ and compare informational efficiency and market liquidity across regulation regimes.

[5] The model may be extended in a way that the speculators receive signals on the asset value at time-0, which they may then trade upon since time-1. We find it more plausible to focus on a market where speculators are able to observe signals on asset values only after the insider observes $\tilde{d}$.

3. Equilibrium

We initially assume that, conditional on $\mathbb{F}_1$, the dividend is normally distributed, $\tilde{d}|\mathbb{F}_1 \sim N(m_{d|h}, \sigma^2_{d|h})$, where $m_{d|h}$ and $\sigma^2_{d|h}$ are mean and variance conditional on the information available at $t = 1$ (and, as usual, we set $\tau_{d|h} = 1/\sigma^2_{d|h}$). Specifically, $h = y_1 = x_1 + z_1$ (the time-1 order flow) in the market without disclosure and $h = x_1$ in the market with disclosure.

We determine, first, the equilibrium trading strategies and price function for a given information structure. That is, let us momentarily fix N and τ_ε. Inactive speculators optimally do not trade the asset. The insider (when allowed to trade) and active speculator-i submit market orders at $t = 2$ that are equal to

$$x_2(d,h) \equiv \arg\max_{x_2} E\left((\tilde{d} - p_2)x_2 \middle| \tilde{d} = d, h\right) \quad \text{and} \quad v(s_i,h) = \arg\max_{v_i} E\left((\tilde{d} - p_2)v_i \middle| s_i, h\right). \quad (1)$$

We search for a linear equilibrium in which the price is

$$p_2 = m_{d|h} + \lambda_2 y_2,$$

where y_2 denotes the time-2 order flow, $y_2 = x_2(d,h) + \sum_{i\in\mathcal{N}} v(s_i,h) + z_2$. We conjecture and verify that $x_2(d,h) = \beta_2(d - m_{d|h})$ and $v(s_i,h) = \beta_s(s_i - m_{d|h})$. Appendix A provides expressions for the equilibrium coefficients, conditional fundamental variances and the traders' expected profits.

Next, we endogenize the number of active speculators N and their chosen precision τ_ε. Information acquisition decisions are *not* observable. Each player has beliefs about N and τ_ε, and in equilibrium these beliefs must be correct. Consider the expected profits of an active speculator *net* of information costs ("net profits," from now on),

$$\Pi(N,\tau_\varepsilon;h) \equiv E\left((\tilde{d} - p_2)\beta_s(s_i - m_{d|h})|h\right) - c(\tau_\varepsilon).$$

In an equilibrium, the pair $(N,\tau_\varepsilon) \in \mathbb{Z}_0^+ \times \mathbb{R}^+$ must be such that: (i) Active speculators have no incentives to acquire a different amount of information τ'_ε; (ii) Inactive speculators have no incentives to enter the market. Note that this notion of equilibrium takes into due account the number of players' discrete nature.

Section 3.1 deals with information acquisition in markets with and without the insider. Section 3.2 describes market behavior at time-1. Section 4 contains our main analytical results, obtained in the liming case as the number of potential entrants, $\bar{N}$, is large.

3.1. *Endogenous information acquisition*

We first analyze a market in which speculators compete with the insider trader (in Section 3.1.1). We ask: what is the size of this market when speculators are allowed to acquire information? It turns out that the answer is quite neat: all speculators have incentive to enter the market, provided the marginal cost of acquiring a *small amount of information* is sufficiently small. Section 3.1.2 deals with the market without insider traders.

3.1.1. *Insider trading*

We identify necessary conditions under which no active speculator finds it optimal to deviate to a different signal precision. Let τ_ε be an equilibrium precision. When all other traders choose τ_ε and expect others to choose the same precision, the net expected profits of an active speculator who chooses precision τ_i equal

$$\bar{\Pi}\left(N, \tau_\varepsilon, \tau_i; h\right) = \frac{\tau_i \left(\tau_{d|h} + \tau_\varepsilon\right)^2}{(\tau_{d|h} + \tau_i)\tau_{d|h}\lambda_2 \left(4\tau_{d|h} + \tau_\varepsilon(N+2)\right)^2} - c\left(\tau_i\right). \tag{2}$$

The net profits, $\bar{\Pi}\left(N, \tau_\varepsilon, \tau_i; h\right)$, are a concave function of τ_i. Therefore, the best response to τ_ε, say $\tau_i = \mathcal{T}\left(\tau_\varepsilon\right)$, is uniquely pinned down by the value of the precision τ_i that satisfies the first order condition $\frac{\partial}{\partial \tau_i}\bar{\Pi}\left(N, \tau_\varepsilon, \mathcal{T}\left(\tau_\varepsilon\right); h\right) = 0$. The equilibrium precision satisfies the fixed point, $\tau_\varepsilon = \mathcal{T}\left(\tau_\varepsilon\right)$. Lemma A.1 in Appendix A shows that a necessary condition for information acquisition to occur in equilibrium ($\tau_\varepsilon > 0$) is

$$\sigma_{d|h}^2 > \mathcal{C} \equiv 4\kappa^{2/3}, \quad \kappa \equiv \frac{c'(0)}{\sigma_z}. \tag{3}$$

That is, in equilibrium, a speculator has incentives to purchase information, provided the marginal cost of purchasing the first bit of information (in noise units, κ) is low enough, compared to the conditional variance of the fundamentals. The constant, $\mathcal{C}$ in (3) (or, equivalently, κ), plays a key role in the paper. Furthermore, note that $\mathcal{C}$ is independent of N. As explained, inequality (3) is, then, a necessary condition for information acquisition to occur in equilibrium. When it holds, the equilibrium precision given N is uniquely pinned down by the first order conditions evaluated in equilibrium (see Eq. (A.5) in Appendix A).

Next, we need to ascertain that there are no *inactive* traders left with an incentive to deviate from an equilibrium with N active traders. In the Appendix, we determine the expected profits for an inactive trader who deviates by acquiring information with precision τ_i and, then, by trading the asset, $\bar{\Pi}'(N, \tau_\varepsilon, \tau_i; h)$, say (see Eq. (A.6)). We find that it is always optimal for an inactive speculator to enter the market, i.e., $\max_{\tau_i} \bar{\Pi}'(N, \tau_\varepsilon, \tau_i; h) > 0$ independent of N, provided (3) holds. Therefore, $N = \bar{N}$ if (3) holds. If, instead, (3) does not hold, no speculators would purchase information. Lemma A.2 in Appendix A formalizes these conclusions. We now analyze markets without insider trading.

3.1.2. Markets without insider trading

We still search for a linear equilibrium in which the price is $p_2 = m_{d|h} + \lambda_2 y_2$ where, now, the order flow is $y_2 = \sum_{i \in \mathcal{N}} v(s_i, h) + z_2$, and $v(s_i, h)$ is, formally, the same as in (1). For given N, τ_ε, Appendix A provides the solution for $v(s_i, h)$ and the equilibrium coefficients. Lemma A.3 in Appendix A contains our conclusions on information acquisition: all speculators *always* acquire information in markets without insider trading, that is, $N = \bar{N}$. By contrast, in markets with insider trading, speculators are incentivized to acquire information only when condition (3) holds, as explained in the previous subsection.

The intuition for these results is as follows. In a market *with* an insider, prices contain information even when the market maker expects no speculator to acquire information, i.e., $\lambda_2 > 0$ when $N = 0$. This price impact limits the profitability of a speculator who deviates and acquires information, and condition (3) summarizes speculators' incentives to participate. By contrast, in a market *without* insider trading, the market maker considers the order flow to be pure noise when he expects no speculator to acquire information, i.e., $\lambda_2 = 0$ when $N = 0$. But, this cannot be an equilibrium because a speculator who deviates faces no price impact; therefore, he can make arbitrarily large expected profits by acquiring information.

3.2. *Insider (early) trading: with and without mandatory disclosure*

Assume, first, that the insider is not allowed to trade. We are assuming that speculators only trade in the second period. Therefore, in the first period, the price is just the unconditional expectation of the fundamentals, $p_1 = \bar{d}$, such that, then, $\sigma^2_{d|h} = \sigma^2_d$. Next, we determine the equilibrium in markets with insider trading, both with and without mandatory disclosure. In both cases, the equilibrium is unique and is determined in closed form. First, we determine the insider trader's profits expected for time-2. In the Appendix, we explain that

$$\Pi_2(N, \tau_\varepsilon; d, h) \equiv E\left((\tilde{d} - p_2)x_2(\tilde{d}, h)|\tilde{d} = d\right) = (d - m_{d|h})^2 \pi_{|h}, \tag{4}$$

where the constant $\pi_{|h}$ equals

$$\pi_{|h} = \begin{cases} \dfrac{\sigma_z}{2\sigma_{d|h}}, & \text{for } \sigma^2_{d|h} \leq \mathcal{C} \\ \dfrac{4c'(0)}{\sigma^4_{d|h}}, & \text{otherwise} \end{cases} \tag{5}$$

The insider's expected profits in the second period depend on the other players' conditional beliefs $m_{d|h}, \sigma^2_{d|h}$. These beliefs are formed via Bayesian updating given the players' conjectures on the insider's strategy in the first period. In equilibrium, these conjectures are correct. The first period trade of the insider satisfies

$$x_1(d) \equiv \arg\max_{x_1} E\left((\tilde{d} - p_1)x_1 + \Pi_2(N, \tau_\varepsilon; \tilde{d}, h)\middle|\, \tilde{d} = d\right).$$

We consider a linear equilibrium, $p_1 = m + \lambda_1 y_1$, where $y_1 = x_1 + z_1$ is the time-1 order flow. We conjecture and verify that, in the model without mandatory disclosure, $x_1(d) = \beta_1(d - m)$; and in the model with mandatory disclosure, $x_1(d) = \beta_1(d - m) + \eta$, where η is a zero-mean normally distributed random variable, with variance σ^2_η determined in equilibrium (mixed strategy). Relying on the description in Section 3.1, we have that, in the market without disclosure, $h = y_1$ and therefore $m_{d|y_1} = p_1$; by contrast, in the market with disclosure requirements, $h = x_1$ such that $m_{d|x_1} = m + \gamma x_1$. Lemma A.4 in the Appendix shows that there is a unique equilibrium. The proof provides the equilibrium expressions for the coefficients $\beta_1, \lambda_1, \gamma$, and the variance σ^2_η and, finally, the conditional fundamental variances across periods for both disclosure regimes.

4. Main results: market quality tradeoffs

We are now in a position to characterize price efficiency and market liquidity across alternative regulatory regimes. We make our main conclusions based on the assumption that $\bar{N} = \infty$. Remarkably, this assumption enables us to illustrate our findings analytically, despite the complexity underlying the process of endogenous information acquisition underlying our model. We begin by analyzing a benchmark case in which investors' information is exogenous (Section 4.1). The remaining parts of this section contain the predictions of our endogenous information acquisition model against this benchmark regarding market efficiency and liquidity conditions across regulatory regimes (Section 4.2). Section 4.3 contains results that help interpret our main conclusions. Section 4.4 discusses the model predictions in markets with a finite number of speculators.

4.1. A benchmark with exogenous information

To clarify the role of information crowding-out in our model, it is instructive to consider a benchmark in which the information available to speculators is fixed. The following proposition compares price informativeness and liquidity across regulatory regimes in this benchmark. We define price informativeness as the reciprocal of conditional uncertainty in the second period, $var\left(d|\, h, y_2\right)$, and we define liquidity as the reciprocal of the price impact parameter in the second period, λ_2.

Proposition 1. (Exogenous information benchmark.) *Consider a large market, and define* $\theta \equiv \lim_{N\uparrow\infty} N\tau_{\varepsilon}$. *Then, for fixed* θ:

(i) (Price informativeness.)

(i-a) *Prices are the least informative with insider trading bans.*

(i-b) *A regulatory regime with mandatory disclosure of insider trades leads to more informative prices compared to an unregulated market.*

(ii) (Liquidity.) *Let* λ_2^p, λ_2^m *and* λ_2^u *denote the price impacts in the markets in which insider trading is, (i) prohibited, (ii) regulated with mandatory disclosure, and (iii) left unregulated. Then,*

(ii-a) $\lambda_2^u > \lambda_2^m$.

(ii-b) *There exist positive constants $s_m < s_u$, which depend on θ, such that: $\lambda_2^p > \lambda_2^m$ if and only if $\sigma_d^2 > s_m$; and $\lambda_2^p > \lambda_2^u$ if and only if $\sigma_d^2 > s_u$.*

Part (i-a) of this proposition explains that prohibiting insider trading leads to the least informative market. Intuitively, insider trading contributes directly to price discovery across both trading periods. Therefore, by fixing the amount of information held by the speculators, θ, the price becomes more informative with the presence of an insider. Part (i-b) shows, instead, that a more mitigated form of regulation (mandatory disclosure) improves price efficiency compared to the unregulated market: this conclusion generalizes the two-period version of HHL model, in which $\theta = 0$.

Part (ii) uncovers liquidity conditions across regulatory regimes. Part (ii-a) says that liquidity is better in the market with mandatory disclosure than in the unregulated market and, hence, generalizes the two-period version of the HHL model too. Part (ii-b), then, tells us that, provided uncertainty is large enough ($\sigma_d^2 > s_m$), liquidity worsens while requiring a stricter regulatory regime than mandatory disclosure. If uncertainty reaches a higher threshold ($\sigma_d^2 > s_u$), prohibiting insider trading would make liquidity conditions even worse than in the unregulated regime. Only when uncertainty is low, would liquidity be the best with a complete ban on insider trading. The intuition underlying these properties is the following. When σ_d^2 and, hence, the speculators' signal-to-noise ratio, is small, so is the price impact of the speculators' trade. By contrast, the price impact of the insider's trade is such that $\lambda_2\beta_2 \to \frac{1}{2}$ even when $\sigma_d^2 \to 0$. Thus, the market maker supplies less liquidity in the market with insider trading when the asset fundamentals is small. As σ_d^2 increases, liquidity deteriorates. However, it deteriorates faster in the market with insider trading bans (due to a lower trading aggressiveness) than in the market with the insider.

In our model, the amount of information available to speculators, θ, is endogenous, and we now show that the conclusions of Proposition 1 are largely overturned as a result.

4.2. Insider trading regulation with endogenous information

4.2.1. Price informativeness

We begin by formalizing the reasoning underlying Figure 1 in the Introduction. The next theorem provides exact details on the threshold in that figure.

Theorem 1. (Price informativeness.) *For given σ_z and $c'(0)$, we can partition the values of σ_d^2 in the following four regions:*

R1. $\sigma_d^2 \geq 2\mathcal{C}$ *(Highly uncertain markets). Prices are the most informative with insider trading bans. In a market with insider trading, price informativeness is the same with and without mandatory disclosure of insider trades.*

R2. $\sigma_d^2 \in [\alpha\mathcal{C}, 2\mathcal{C})$, $\alpha \approx 1.817120$ *(High/moderate uncertainty). Prices are still the most informative with insider trading bans. In markets with insider trading, prices are more informative with than without mandatory disclosure.*

R3. $\sigma_d^2 \in [\beta\mathcal{C}, \alpha\mathcal{C})$, $\beta \approx 1.254308$ *(Low/moderate uncertainty). Prices are the most informative when insider trading is regulated with mandatory disclosure. Prices are more informative in markets with insider trading bans than in unregulated markets.*

R4. $\sigma_d^2 \in (0, \beta\mathcal{C})$ *(Low uncertainty). Markets with insider trading bans result in the less informative prices. Prices are the most informative with mandatory disclosure of insider trading.*

As uncertainty increases, more stringent regulatory requirements ensure the most informationally efficient markets. There are two forces at play. The first force is *direct*: insider trading obviously contributes to price discovery through information incorporated in the asset price, just as in the benchmark case with exogenous information (see Proposition 1). The second force is *indirect*: insider trading discourages information acquisition by the outsiders, leading to lower informed trading by the speculators. The two forces act in opposite directions. The first effect dominates when σ_d^2 is low, whereas the second effect dominates when σ_d^2 is high.

Consider the following limiting examples. Let ϱ_u (resp. ϱ_m) denote the long-term uncertainty in Figure 1, resulting when insider trading is unregulated (resp., regulated with mandatory disclosure), relative to when is banned. We can show that $\lim_{\sigma_d^2 \to 0} \varrho_u \approx 0.35$ and $\lim_{\sigma_d^2 \to 0} \varrho_m = 0.25$. Intuitively, when σ_d^2 is very small, speculators' incentives to acquire information vanish, whereas the insider trades on perfect information. As a result, the first effect dominates. Next, consider larger values of uncertainty. Speculators' incentives to acquire information increase with uncertainty, and, crucially, they increase faster when speculators do not compete with the insider. As a result, the indirect effect eventually dominates as uncertainty increases: $\rho_u > 1$ for $\sigma_d^2 > \beta\mathcal{C}$ and $\rho_m > 1$ for $\sigma_d^2 > \alpha\mathcal{C}$ (Theorem 1). Finally, as uncertainty grows large, speculators as a whole trade more and more aggressively on their information, and, in response, the insider scales back his trading aggressiveness ($\lim_{\sigma_d^2 \to \infty} \beta_2 = 0$). As a result, the markets with and without insider trading converge in the limiting case, and irrespective of post-trade regulatory details, $\lim_{\sigma_d^2 \to \infty} \varrho_u = \lim_{\sigma_d^2 \to \infty} \varrho_m = 1$.

Thus, markets in the current U.S. regulatory regime (post-trade transparency of insiders) are the most informative when the initial uncertainty σ_d^2 is relatively small, as in Regions R4 and R3 of Figure 1. In these regions, prohibiting insider trading does not still provide speculators with incentives to purchase large enough amounts of information. Removing information crowding-out effects leads to small efficiency gains: therefore, market efficiency is the best when insider trading is regulated with post-trade transparency. However, as σ_d^2 increases (see Regions R2 and R1 of Figure 1), speculators are more incentivized to purchase information: removing information crowding-out effects by means of insider trading bans results in the most informative prices. We now connect these conclusions to the effects of a change in the information technology.

4.2.2. Information technology

Note that Figure 1 relies on the assumption that the marginal cost of the first unit of information is half noise units, $\kappa = \frac{1}{2}$ (see Eq. (3) in Section 3). Figure 3 identifies the four regimes of Theorem 1 for all combinations of σ_d^2 *and* κ. First, and consistent with previous explanations, markets that belong to Region R4 would then belong Regions R3, R2 and R1 as uncertainty increases, and for a given κ. Next, consider a given level of uncertainty, σ_d^2. When information acquisition is expensive, speculators acquire a small amount of information without insider trading. In this case, regulating insider trading through mandatory disclosure results in more efficient prices (Regions R4, R3). As information becomes less costly and κ decreases, speculators acquire a large amount of information without the insider. In this case, information crowding effects are severe, and a ban on insider trading eliminates its undesirable effects on price efficiency (Regions R2, R1).

These conclusions are at the heart of one additional policy recommendation that emanates from our analysis. With the advent of new information technologies (as, for example, with big data analytics), the marginal costs of information have obviously decreased for any level of information accuracy. In terms of Figure 3, for any given level σ_d^2, combinations of points in Region R4, say, move down to Regions R3, R2 and R1 as κ lowers, as explained. Thus, unless uncertainty on asset payoffs is really very low (to illustrate, $\sigma_d^2 = 1$ in Figure 3), and information acquisition is already very limited to start with, a vast progress in information technology calls for regulating insider trading either through disclosure (Region R3) or by a complete ban (Regions R2 and R1).

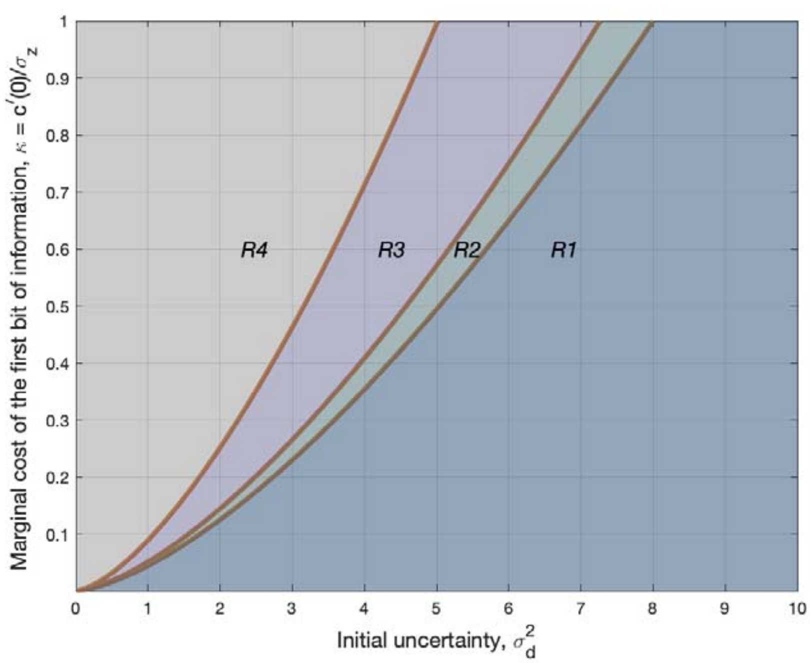

FIGURE 3. Regimes of information efficiency. This picture depicts the four regions of market efficiency of Theorem 1, obtained by varying levels of σ_d^2 and $\kappa = \frac{c'(0)}{\sigma_z}$, the normalized marginal cost of the initial bit of information (see Eq. (3)). In all markets, there is a large pool of investors that engage in costly information acquisition.

4.2.3. Liquidity

How do regulatory regimes affect liquidity conditions? The next theorem contains our model predictions resulting under alternative regulatory regimes:

Theorem 2. (Liquidity.) *Let λ_2^p, λ_2^m and λ_2^u be as in Proposition 1. We have $\lambda_2^p \leq \lambda_2^m < \lambda_2^u$. Moreover, there exists only one value of initial uncertainty, $\sigma_d^2 = \delta \mathcal{C}$, $\delta \approx 0.793701$, for which the market with mandatory disclosure is as liquid as the market without insider trading, $\lambda_2^p = \lambda_2^m$.*

A market without insider trading is always the most liquid. Figure 4 depicts the price impacts across all regulatory regimes. Consider the following limiting cases. When insider trading is prohibited, and σ_d^2 is small, speculators collect limited amounts of information and the order flow is not very informative as a result. In the limit as $\sigma_d^2 \to 0$, the order flow becomes pure noise without the insider. By contrast, the order flow is more informative when the insider trades, even for small values of σ_d^2. Using the expressions of the price impacts provided in the proof of Theorem 2, we can show that, in the limit, $\lim_{\sigma_d^2 \to 0} \lambda_2^p/\lambda_2^u = \lim_{\sigma_d^2 \to 0} \lambda_2^p/\lambda_2^m = 0$. As σ_d^2 increases, speculators as a whole acquire more information and trade more aggressively on it. Their information acquisition and trading aggressiveness increase faster without the insider, and the market maker reacts by scaling down λ_2 compared to the market with the insider.

Thus, when σ_d^2 is low, the order flow is more informative in the market with insider; however, as σ_d^2 increases, speculators collect more information and trade more aggressively without the insider. As it turns out, there exists a level of uncertainty (i.e., $\sigma_d^2 = \delta \mathcal{C}$) such that these two forces compensate and market liquidity is the same in the market without insider and with insider trading subject to disclosure. In the limiting case, $\lim_{\sigma_d^2 \to \infty} \lambda_2^p/\lambda_2^u = \lim_{\sigma_d^2 \to \infty} \lambda_2^p/\lambda_2^m = 1$: the insider's trading aggressiveness vanishes as $\sigma_d^2 \to \infty$, and liquidity conditions becomes the same in the markets with and without insider trading. Note that, when information is exogenously fixed, liquidity deteriorates in markets without insider trading for large σ_d^2 (see Proposition 1). Our model predicts liquidity is better in markets without insiders even for large σ_d^2, as speculators trade very aggressively in this case.

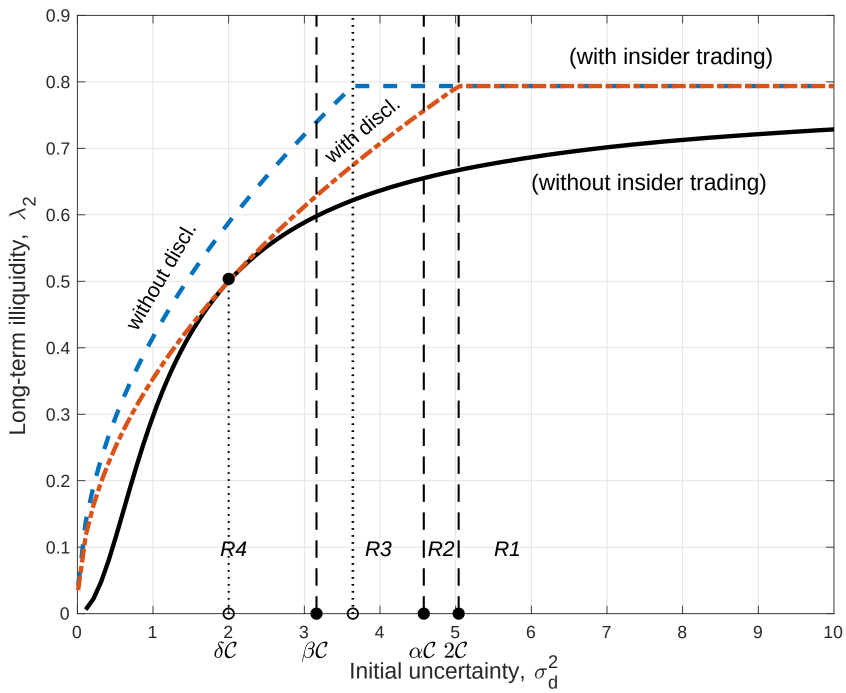

FIGURE 4. Long-term liquidity across regulatory regimes. This picture depicts market liquidity at time-2, λ_2, as a function of the uncertainty of fundamentals in three regulatory regimes: (i) without insider trading (black line), (ii) with insider trading but mandatory disclosure (red, dot-dashed line), and (iii) with insider trading and without mandatory disclosure (blue, dashed line). In all markets, there is a large pool of investors that engage in costly information acquisition, and parameter values are as in the legend of Figure 1.

4.3. Inspecting the mechanism: information acquisition in large markets

We provide intuition on our main conclusions. The next proposition provides results on information acquisition, price discovery, and price impacts with and without the insider while taking as given the information set $\mathbb{F}_1$ (and, hence, the conditional price uncertainty, $\sigma^2_{d|h}$ at the beginning of time-2 in Figure 2). Note, however, that this subsection contains results of independent interest, as $\mathbb{F}_1$ may be given alternative content than that in this paper.

We show that the precision acquired by each speculator vanishes in the limit, $\lim_{\bar{N}\to\infty} \tau_\varepsilon = 0$. However, the total amount of acquired information, $\bar{N}\tau_\varepsilon$, the price impact parameter, λ_2, and conditional uncertainty, $var\left(d|\, h, y_2\right)$, all have finite limits when the marginal cost of the first bit of information is strictly positive, $c'(0) > 0$. We have:

Proposition 2. (Limiting markets and irrelevance.) *Assume that $c'(0) > 0$. Then:*

(i) *In the market with insider trading:*

(a) *If condition (3) does not hold, then no speculator acquires information, and*

$$\lambda_2 = \frac{1}{2}\frac{\sigma_{d|h}}{\sigma_z}, \quad var\left(d|\, h, y_2\right) = \frac{1}{2}\sigma^2_{d|h};$$

(b) *If condition (3) holds, then all $\bar{N}$ speculators become informed. As $\bar{N} \to \infty$,*

$$\lim_{\bar{N}\to\infty} \bar{N}\tau_\varepsilon = 4\left(\mathcal{C}^{-1} - \sigma^{-2}_{d|h}\right), \quad \lim_{\bar{N}\to\infty} \lambda_2 = \frac{1}{2}\frac{\sqrt{\mathcal{C}}}{\sigma_z}, \quad \lim_{\bar{N}\to\infty} var\left(d|\, h, y_2\right) = \frac{1}{2}\mathcal{C};$$

(ii) *In the market without insider trading, all $\bar{N}$ speculators become informed. As $\bar{N} \to \infty$,*

$$\lim_{\bar{N}\to\infty} \bar{N}\tau_\varepsilon = \phi, \quad \lim_{\bar{N}\to\infty} \lambda_2 = \frac{1}{8}\frac{\phi\sqrt{\mathcal{C}}^3}{\sigma_z}, \quad \lim_{\bar{N}\to\infty} var\left(d|\, h, y_2\right) = \frac{1}{4}\sqrt{\phi}\sqrt{\mathcal{C}}^3,$$

where ϕ is solution to

$$\left(2\sigma^{-2}_{d|h} + \phi\right)\sqrt{\phi}\sqrt{\mathcal{C}}^3 = 8.$$

Proposition 2 provides a neat analytical framework, which we can base on and analyze a number of markets with a large pool of speculators. Theorems 1 and 2 in the previous section build precisely on this proposition while identifying the precise equilibrium values for the initial uncertainty $\sigma^2_{d|h}$ that correspond to alternative regulatory regimes with information disclosure requirements and trading bans (see Appendix B). However, it is instructive to discuss the implications of Proposition 2 for a given $\sigma^2_{d|h}$.

First, and intuitively, the limiting amount of total information acquired in both markets increases with $\sigma^2_{d|h}$ and decreases with $\mathcal{C}$, or, equivalently, with κ, the marginal cost of the first bit of information per unit of noise trading. Second, Proposition 2 contains an *irrelevance* result: when the insider is allowed to trade, as in the current regulatory requirements, the price impact, λ_2, and conditional uncertainty, $var\left(d|\, h, y_2\right)$, are independent of $\sigma^2_{d|h}$. That is, in large markets, and as long as condition

(3) holds in equilibrium, trading disclosure requirements do not affect price discovery or liquidity conditions. Figure 1 in the Introduction and Figure 4 in Section 4.2 illustrate this property. The striking conclusion is that λ_2 and $var\left(d|\, h, y_2\right)$ only depend on $\mathcal{C}$, and in an intuitive way: the higher $\mathcal{C}$, the lower the information precision acquired by the speculators, implying higher adverse selection costs and lower price discovery. We can show that, in the market without insider trading, λ_2 and $var\left(d|\, h, y_2\right)$ both increase with $\sigma^2_{d|h}$, that $var\left(d|\, h, y_2\right)$ increases with $\mathcal{C}$ and, finally, that λ_2 first increases and then decreases with $\mathcal{C}$.

Finally, note that Proposition 2 relies on the assumption that $c'(0) > 0$. This assumption can be micro-founded with discrete sampling with a constant cost per observation in the limit where the cost and the precision of each observation become small (see, e.g., Han and Sangiorgi, 2018). If, instead, the marginal cost of a small amount of information is zero, $c'(0) = 0$, it is straightforward to verify that the price becomes fully informative in the limit as $\bar{N} \to \infty$. Our analysis shows that assuming $c'(0) = 0$ has strong implications in large markets.[6]

How does the presence of the insider affect market quality in more detail? The next result follows by Proposition 2:

Corollary 1. (Crowding-out, price discovery and liquidity.) *Under the same assumptions of Proposition 2, and for a given value of* $\sigma^2_{d|h}$*, in the market with insider trading:*

(i) *Speculators acquire less information than in the market without insider trading;*

(ii) $var\left(d|\, h, y_2\right)$ *is higher than in the market without insider trading if and only if* $\sigma^2_{d|h} > 0.793701\mathcal{C}$;

(iii) λ_2 *is always higher than in the market without insider trading.*

Part (i) of this corollary tells us that competition with the insider in the second-period crowds out speculators' information acquisition. This information crowding-out leads to reduced price discovery

[6] Precisely, in this case, we have that, regardless of whether the insider trader participates in the market,

$$\lim_{\bar{N}\to\infty} \bar{N}\tau_\varepsilon = \infty, \quad \lim_{\bar{N}\to\infty} \lambda_2 = 0, \quad \lim_{\bar{N}\to\infty} var(d|h, y_2) = 0.$$

Paradoxically, this conclusion holds even though the total amount of resources spent on information acquisition converges to zero, $\lim_{\bar{N}\to\infty} \bar{N}c\left(\tau_\varepsilon\right) = 0$.

(Part (ii)), provided fundamental uncertainty is sufficiently high. This contemporaneous effect of insider trading on price efficiency contrasts with the effect of insider trading over multiple periods. Indeed, comparing Theorem 1 with Corollary 1 shows that the net effects of an early trade of the insider are positive: with one additional trading period, it takes larger values of uncertainty before insider trading begins to be detrimental to price efficiency.[7]

Finally, liquidity always improves by banning insider trading (Part (iii)). Intuitively, it does under the condition in Part (ii) precisely due to better price discovery. However, it also does when uncertainty is small because, in this case, speculators' incentives to purchase information are weak, and the order flow is very noisy as a result.

4.4. Markets with finite pools of investors

Our conclusions in this section regard markets with a large pool of investors. Appendix C contains numerical results in markets with finite pools of investors, $\bar{N} < \infty$ (see Figures A-1 and A-2). We find that in these markets, price discovery and liquidity converge to those in this section when the pool size is between $\bar{N} = 100$ and $\bar{N} = 250$. Furthermore, we find that $\bar{N}\tau_\varepsilon$ increases with $\bar{N}$ (results are available upon request). Therefore, the smaller $\bar{N}$, the smaller the total amount of information acquired by speculators. Furthermore, competition amongst speculators becomes less fierce as $\bar{N}$ decreases. Accordingly, informational efficiency benefits from insider trading bans when σ_d^2 is high, provided $\bar{N}$ is sufficiently large. In small markets, that is, where the number of potential speculators is small, regulating insider trading with mandatory disclosure leads to the most informative prices. However, and except for very small values of $\bar{N}$, our conclusions regarding market liquidity remain largely unaffected in markets with a finite pool of speculators.

5. Discussion

Regulating insider trading is an old and still quite active topic of debate. For example, insider trading is simply prohibited in countries such as Switzerland, where it has long been debated (see, e.g.,

[7] The threshold values are, approximately: $0.793701\mathcal{C}$, with only one trading round (Corollary 1-(ii)); $1.254308\mathcal{C}$, with two trading rounds in the unregulated case (Theorem 1-R3); and $1.817120\mathcal{C}$, with two trading rounds and mandatory disclosure (Theorem 1-R2).

Alexander, 2013) and is currently treated both as a criminal offence and a violation of public administrative law (Arts. 154 and 142 of Financial Market Infrastructure Act, respectively). This debate does not uniquely involve insiders of a firm. It may also regard outside investors, brokers or individuals, who might gain access to material nonpublic information (MNPI) of corporations and governments. Only in December 2019, the House of Representatives passed a bill (the "Insider Trading Prohibition Act") that would have reinforced rules on insider trading based on MNPI. The bill, however, was never passed by the Senate. Likewise, in the wake of the global financial crisis of the 2007-2009, it became known that Congressmen were trading on MNPI on risks of the global financial system, which they had garnered through confidential meetings. In 2012, U.S. legislation incorporated the STOCK (Stop Trading on Congressional Knowledge) Act, which was designed to prohibit members and employees of the Congress to trade on information gathered by means of their business. Yet, in 2013, the STOCK Act was partially lifted by loosening some of the financial disclosure requirements regarding some officials.

Therefore, insider trading regulation is very fluid, and subject to new legislative initiatives, amendments and vivid policy discussions. Our analysis focusses on uncertainty around a single asset, but is suggestive of a clear message. When uncertainty around asset markets is very high, as during periods of financial distress, insider trading should be banned: in these markets, information acquisition is particularly strong, but it could be discouraged by the presence of insider traders. Instead, regulating insider trading through mandatory disclosure should help improve price discovery in markets with lower uncertainty: when uncertainty is low, information acquisition is plausibly very limited, and so should be the damage made by information crowding-out effects.

These effects seem to be particularly relevant in the information age. For example, Andrei, Friedman and Ozel (2020) provide strong empirical evidence that periods of higher uncertainty lead investors to intensify their searches for information, as measured by queries through the SEC EDGAR (Electronic Data Gathering, Analysis, and Retrieval) system: uncertainty crowds-in investors' search for information. In terms of our model, lower information costs decrease the threshold $\mathcal{C}$ in (3) that triggers information crowding-out. More generally, the progress in information technology seems to have affected many areas of signal generation, such as the history of trades by politicians.[8]

[8]For example, "Smart Insider Ltd" (`https://www.smartinsider.com`), a U.K. company that specializes in data provision, delivers granular information regarding firms' events (such as directors' changes) but also details on trades

Insider trading can be regulated throughout other models, in addition to those explicitly discussed so far. For example, insiders may be required to disclose all price-sensitive information they acquire within their corporation, as per E.U. law: Art. 17 of the Market Abuse Regulation (also "onshored" into U.K. law on December 31, 2020) requires listed corporations to inform the public as soon as possible of inside information, that is, information that has the potential to affect asset prices (Art. 7), or material information. While U.S. legislation focusses on mandatory disclosure of insider trades (see the Introduction), many stock exchanges include timely disclosure of material information (see, e.g., Section 202.05 of NYSE Listed Company Manual: "Timely Disclosure of Material News Developments").[9] In terms of our model, these rules would act as if the insider were required to provide the market with a signal on his private information (i.e., the dividend in this paper), which would reduce the initial uncertainty on the asset payoff. Our analysis suggests that this type of corporate transparency has strong effects on price efficiency when uncertainty is low, but that these effects are less obvious when uncertainty is high (see Figure 1). The mechanism is the following: we have shown that information acquisition is particularly strong when uncertainty is high; thus, reducing uncertainty does not lead to sizeable efficiency improvements in this case. However, our analysis suggests that certain "policy-mix" initiatives may lead to such improvements. In particular, when uncertainty is elevated, and markets fall in Region R1 (say), trading bans lead to the most informative markets. Now, requiring the insider to ex ante disclosure of his information may cause markets to fall in Region R3, where the most efficient regime is achieved throughout mandatory disclosure. Therefore, ex ante disclosure of information and mandatory disclosure of insider trades may well be complementary policy actions. Note, however, that these actions may worsen market liquidity.

Finally, quite often do debates list pros and cons regarding the presence of insider trading. Insider trading advocates explain that it allows for nonpublic information to be impounded in asset prices, thereby making markets more efficient. However, this paper shows that this line of reasoning is incomplete: when the information of the price system is determined endogenously, market behave quite differently according to whether insider trading is banned or not. More precisely, market efficiency benefits from insider trading when information is fixed (see Proposition 1), but it may deteriorate when investors do proactively collect information, unless insider trading is not properly

made by U.S. politicians.

[9] Ventoruzzo (2015) provides a comparison of the U.S. and E.U. insider trading regulations.

regulated (see Theorem 1). Finally, too often do these debates mention that insider trading is "unfair," as it allows better informed individuals to make profits to the expense of non-informed investors. Our paper does indeed point to one related potential difficulty: liquidity. Liquidity would always improve by banning insider trading (See Theorem 2), thereby avoiding losses to investors who trade based on diversification motives.

6. Conclusion

How should insider trading be regulated? The main conclusion of this paper is that a "one-size-fits-all" regulation is not a suitable approach. We have explained that different legislations have adopted different regulatory models, from mandatory disclosure (the current approach in the U.S.) to ex ante corporate disclosure of price-sensitive information (in the E.U. and the U.K.), or a straight ban (in Switzerland). Why do these approaches differ? Historical reasons do undoubtedly underlie the emergence of such models. The focus of our paper is to provide the economic rationale for the most appropriate regulatory model amongst the most primitive ones, in light of the main features of the market under scrutiny *and* the objectives of the regulator.

Our model suggests that regulatory treatments should be particularly strict when market uncertainty (i.e., the insider's informational advantage) is high or information technology is efficient. In these cases, banning insider trading would encourage outside investors to purchase information and render the market informationally more efficient. When uncertainty is low, or information technology is more expensive, more mitigated forms of regulation (mandatory disclosure of insider trades) seem more suitable for the purpose of enhancing informational efficiency. Interestingly, a complete ban on insider trading always leads to the most liquid market. Finally, regulatory models can be complements. Most notably, in markets with elevated uncertainty, regulating insider trading through ex ante corporate disclosure and post-trade transparency proves to be a "policy mix" for the purpose of improving informational efficiency, although this mix may lead to deteriorated market liquidity.

Appendix

This appendix is organized as follows. Appendix A provides all proofs regarding the equilibrium with endogenous information acquisition in markets with insider trading (with and without trading disclosure requirements) and without. Appendix B contains the proofs of the core results in the paper. Appendix C provides numerical results on market efficiency and liquidity in the case of a finite number of speculators.

A. Proofs for Section 3

First, we consider the market with insider trading of Section 3.1.1. We derive equilibrium coefficients, conditions for an equilibrium with endogenous information acquisition (Lemma A.1) and, finally, a statement that summarizes the properties of the equilibrium in this market (Lemma A.2).

Equilibrium coefficients. By standard derivations, we find that the equilibrium coefficients for a given information structure are

$$\begin{cases} \beta_2 &= \dfrac{1}{\lambda_2}\dfrac{2\tau_{d|h}+\tau_\varepsilon}{4\tau_{d|h}+\tau_\varepsilon(N+2)} \\ \beta_s &= \dfrac{1}{\lambda_2}\dfrac{\tau_\varepsilon}{4\tau_{d|h}+\tau_\varepsilon(N+2)} \\ \lambda_2 &= \dfrac{\sigma_{d|h}}{\sigma_z}\dfrac{\sqrt{(2\tau_{d|h}+\tau_\varepsilon)^2+\tau_\varepsilon N(\tau_{d|h}+\tau_\varepsilon)}}{4\tau_{d|h}+\tau_\varepsilon(N+2)} \end{cases} \tag{A.1}$$

and the variance of the fundamental conditional on y_2 is

$$var(d|y_2,h)=\sigma^2_{d|h}\frac{2\tau_{d|h}+\tau_\varepsilon}{4\tau_{d|h}+(2+N)\tau_\varepsilon}. \tag{A.2}$$

Finally, the insider trader's expected profits equal

$$\Pi_2(N,\tau_\varepsilon;d,h)\equiv E\left(\beta_2(\tilde{d}-m_{d|h})(\tilde{d}-p_2)|\tilde{d}=d,h\right)=\frac{(d-m_{d|h})^2}{\lambda_2}\left(\frac{2\tau_{d|h}+\tau_\varepsilon}{4\tau_{d|h}+\tau_\varepsilon(N+2)}\right)^2, \tag{A.3}$$

and the speculator's (gross) expected profits are

$$\Pi(N,\tau_\varepsilon;h)\equiv E\left(\beta_s\left(s_i-m_{d|h}\right)(\tilde{d}-p_2)|h\right)=\frac{\tau_\varepsilon}{\tau_{d|h}\lambda_2}\frac{\left(\tau_{d|h}+\tau_\varepsilon\right)}{\left(4\tau_{d|h}+\tau_\varepsilon(N+2)\right)^2}.$$

Lemma A.1. (Information acquisition.) *There exists an equilibrium with information acquisition only if inequality (3) holds.*

Proof. Consider the first order conditions for any speculator's information acquisition problem, $\frac{\partial}{\partial\tau_i}\bar{\Pi}\left(N,\tau_\varepsilon,\mathcal{T}\left(\tau_\varepsilon\right);h\right)=0$. The solution, $\tau_i=\mathcal{T}\left(\tau_\varepsilon\right)$, satisfies

$$\frac{\left(\tau_{d|h}+\tau_\varepsilon\right)^2}{\left(\tau_{d|h}+\mathcal{T}\left(\tau_\varepsilon\right)\right)^2\lambda_2\left(4\tau_{d|h}+\tau_\varepsilon(N+2)\right)^2}=c'\left(\mathcal{T}\left(\tau_\varepsilon\right)\right).$$

In equilibrium, $\tau_\varepsilon = \mathcal{T}(\tau_\varepsilon)$, leaving

$$\frac{1}{\lambda_2 \left(4\tau_{d|h} + \tau_\varepsilon (N+2)\right)^2} = c'(\tau_\varepsilon). \tag{A.4}$$

By replacing the expression of λ_2 in (A.1), the equilibrium precision satisfies

$$\frac{\sigma_z}{\sigma_{d|h}\sqrt{(2\tau_{d|h}+\tau_\varepsilon)^2 + \tau_\varepsilon N(\tau_{d|h}+\tau_\varepsilon)}\left(4\tau_{d|h}+\tau_\varepsilon(N+2)\right)} = c'(\tau_\varepsilon). \tag{A.5}$$

Because the L.H.S. of Eq. (A.5) is strictly decreasing in τ_ε, whereas the R.H.S. is increasing, (3) is a necessary condition that ensures that $\tau_\varepsilon > 0$. ■

The next lemma summarizes the properties of the equilibrium with information acquisition and insider trading.

Lemma A.2. (Equilibrium with insider trading.) *Assume that, conditional on public information at the information acquisition stage, the dividend is normally distributed with variance $\sigma^2_{d|h}$. Then: either $\sigma^2_{d|h} \leq \mathcal{C}$, and no speculator acquires information; or $\sigma^2_{d|h} > \mathcal{C}$, and all $\bar{N}$ speculators acquire information. In the latter case, the equilibrium signal precision acquired by speculators, τ_ε, is the unique solution to Eq. (A.5).*

Note that Lemma A.2 applies to the one-period Kyle (1985) model in which one informed insider competes with $\bar{N}$ speculators who can acquire information and $\sigma^2_{d|h}$ is the dividend prior uncertainty. In our paper, $\sigma^2_{d|h}$ depends on the insider's trading strategy in first period, and is determined in equilibrium.

Proof. Consider the expected net profits for an idle but would-be active speculator who deviates by acquiring information with precision τ_i and, then, trades the asset. They are

$$\bar{\Pi}'(N, \tau_\varepsilon, \tau_i; h) = \frac{\tau_i \left(2\tau_{d|h}+\tau_\varepsilon\right)^2}{4(\tau_{d|h}+\tau_i)\tau_{d|h}\lambda_2\left(4\tau_{d|h}+\tau_\varepsilon(N+2)\right)^2} - c(\tau_i), \tag{A.6}$$

a concave function of τ_i. The first order conditions for this trader, $\frac{\partial}{\partial \tau_i}\bar{\Pi}'(N, \tau_\varepsilon, \tau_i; h) = 0$, lead to

$$c'(\tau_i) = \frac{\left(2\tau_{d|h}+\tau_\varepsilon\right)^2}{\left(2\tau_{d|h}+2\tau_i\right)^2}\frac{1}{\lambda_2\left(4\tau_{d|h}+\tau_\varepsilon(N+2)\right)^2} = \frac{\left(2\tau_{d|h}+\tau_\varepsilon\right)^2}{\left(2\tau_{d|h}+2\tau_i\right)^2}c'(\tau_\varepsilon), \tag{A.7}$$

where the second equality follows by (A.4). Because $c(0) = 0$, this inactive trader has no incentives to enter if he optimally chooses $\tau_i = 0$, which he does under the following condition

$$\frac{\left(2\tau_{d|h}+\tau_\varepsilon\right)^2}{(2\tau_{d|h})^2}c'(\tau_\varepsilon) \leq c'(0). \tag{A.8}$$

Since the cost function is weakly convex, this inequality cannot hold for $\tau_\varepsilon > 0$. Therefore, all speculators, $\bar{N}$, enter, under the condition in Lemma A.1, $\sigma^2_{d|h} > \mathcal{C}$. Furthermore, note that by replacing for $N = 0$ into (A.4), the inequality in (A.8) reduces to $\sigma^2_{d|h} \leq \mathcal{C}$. That is, if the inequality in (3) is violated, $N = 0$ is indeed an equilibrium. ■

Next, we analyze the market without insider trading of Section 3.1.2. We derive equilibrium coefficients and, then, summarize the equilibrium properties in this market (Lemma A.3).

Equilibrium coefficients. We conjecture that the strategy of any speculator-i is linear in the signal, $v(s_i, h) = \beta_s\left(s_i - m_{d|h}\right)$. By standard derivations, we find that the equilibrium coefficients are

$$\beta_s = \frac{1}{\lambda_2}\left(\frac{\tau_\varepsilon}{2\tau_{d|h} + \tau_\varepsilon(N+1)}\right), \quad \lambda_2 = \frac{\sigma_{d|h}}{\sigma_z}\frac{\sqrt{\tau_\varepsilon N(\tau_{d|h}+\tau_\varepsilon)}}{2\tau_{d|h} + \tau_\varepsilon(N+1)}. \tag{A.9}$$

Furthermore, the variance of the fundamental conditional on second period order flow equals

$$var(d|h, y_2) = \sigma^2_{d|h}\frac{2\tau_{d|h} + \tau_\varepsilon}{2\tau_{d|h} + \tau_\varepsilon(N+1)}, \tag{A.10}$$

and the traders' gross expected profits equal

$$\Pi(N, \tau_\varepsilon; h) \equiv E\left[\beta_s(s_i - m_{d|h})(\tilde{d} - p_2)|h\right] = \frac{\tau_\varepsilon}{\tau_{d|h}\lambda_2}\frac{\left(\tau_{d|h} + \tau_\varepsilon\right)}{\left(2\tau_{d|h} + \tau_\varepsilon(N+1)\right)^2}.$$

The next lemma records the properties of the equilibrium with information acquisition when only speculators can trade:

Lemma A.3. (Equilibrium without insider trading.) *Assume that insider traders do not trade. Then, the equilibrium with endogenous information acquisition is unique: all* $\bar{N}$ *speculators become informed, and the equilibrium signal precision,* τ_ε*, satisfies Eq. (A.12) provided in the proof.*

Proof. When all other traders choose τ_ε, and expect others to choose the same precision, the net expected profits of an active speculator who chooses precision τ_i are

$$\bar{\Pi}(N, \tau_\varepsilon, \tau_i; h) = \frac{\tau_i\left(\tau_{d|h} + \tau_\varepsilon\right)^2}{\tau_{d|h}\left(\tau_{d|h} + \tau_i\right)\lambda_2\left(2\tau_{d|h} + \tau_\varepsilon(N+1)\right)^2} - c(\tau_i),$$

a concave function of τ_i. The best response is, then, unique, and is the function $\tau_i = \mathcal{T}(\tau_\varepsilon)$ that satisfies the first order conditions $\frac{\partial}{\partial\tau_i}\bar{\Pi}(N, \tau_\varepsilon, \mathcal{T}(\tau_\varepsilon); h) = 0$, that is,

$$\frac{\left(\tau_{d|h} + \tau_\varepsilon\right)^2}{\left(\tau_{d|h} + \mathcal{T}(\tau_\varepsilon)\right)^2\lambda_2\left(2\tau_{d|h} + \tau_\varepsilon(N+1)\right)^2} = c'(\mathcal{T}(\tau_\varepsilon)).$$

Thus, the equilibrium precision, $\tau_\varepsilon = \mathcal{T}(\tau_\varepsilon)$, is solution to

$$\frac{1}{\lambda_2\left(2\tau_{d|h} + \tau_\varepsilon(N+1)\right)^2} = c'(\tau_\varepsilon). \tag{A.11}$$

By plugging in the expression of λ_2 in Eq. (A.9), we find that the equilibrium precision, τ_ε, satisfies

$$\frac{\sigma_z}{\sigma_{d|h}\sqrt{\tau_\varepsilon N(\tau_{d|h}+\tau_\varepsilon)}\left(2\tau_{d|h} + \tau_\varepsilon(N+1)\right)} = c'(\tau_\varepsilon). \tag{A.12}$$

The L.H.S. of Eq. (A.12) is strictly decreasing in τ_ε and approaches infinity as τ_ε approaches zero; the R.H.S. is increasing in τ_ε and $c'(0) < \infty$. Thus, there always exists a unique $\tau_\varepsilon > 0$ that solves Eq. (A.12).

Next, we determine the expected profits for an inactive trader who deviates by acquiring a signal with a precision equal to τ_i and, then, participating in the asset market. Assume, first, that the number of active traders is $N = 0$. In this case, the price is obviously insensitive to the order flow, and it is immediate to show that any inactive trader may achieve to arbitrarily large expected profits with any positive, but limited, amount of precision. Therefore, $N = 0$ cannot be an equilibrium as long as the signal precision could be acquired at a finite cost.

Assume, now, that $N \geq 1$. The expected profits of the would-be active, but currently idle, trader, who acquires a signal with precision τ_i, are

$$\bar{\Pi}'(N, \tau_\varepsilon, \tau_i; h) = \frac{\tau_i \left(2\tau_{d|h} + \tau_\varepsilon\right)^2}{4(\tau_{d|h} + \tau_i)\tau_{d|h}\lambda_2 \left(2\tau_{d|h} + \tau_\varepsilon(N+1)\right)^2} - c(\tau_i). \tag{A.13}$$

We proceed similarly as in the proof of Lemma A.2. First, the trader solves the problem $\max_{\tau_i} \bar{\Pi}'(N, \tau_\varepsilon, \tau_i; h)$; the first order conditions for this problem are

$$\frac{\left(2\tau_{d|h} + \tau_\varepsilon\right)^2}{(2\tau_{d|h} + 2\tau_i)^2} \frac{1}{\lambda_2 \left(2\tau_{d|h} + \tau_\varepsilon(N+1)\right)^2} = c'(\tau_i). \tag{A.14}$$

Since $c(0) = 0$, this trader does not participate, provided he chooses $\tau_i = 0$, which is the case if

$$\begin{aligned} c'(0) &\geq \frac{\left(2\tau_{d|h} + \tau_\varepsilon\right)^2}{(2\tau_{d|h})^2} \frac{1}{\lambda_2 \left(2\tau_{d|h} + \tau_\varepsilon(N+1)\right)^2} \\ &= \frac{\left(2\tau_{d|h} + \tau_\varepsilon\right)^2}{(2\tau_{d|h})^2} c'(\tau_\varepsilon), \end{aligned}$$

where the last line follows by Eq. (A.11). The inequality is impossible, due to the convexity of the cost function. Hence, $N = \bar{N}$, and the equilibrium precision is the unique $\tau_\varepsilon > 0$ that solves Eq. (A.12). ■

Finally, we provide the source for the proof of the insider trading profits in Section 3.2.

Proof of Eqs. (4)-(5). Eq. (4) follows by standard derivations, and (5) follows by replacing the expressions for the limiting variances in Part (i) of Proposition 2 in Section 4 (proven in Appendix B) into Eq. (4). ■

Next, we state a preliminary result mentioned in Section 3, which we rely upon while proving the main results in Section 4. We have:

Lemma A.4. *There exists a unique linear equilibrium. Moreover, assume that $\bar{N} \to \infty$. We have:*

(i) *In the market without mandatory disclosure, there exists a constant $x_0 \approx 0.307979$ such that:*

(i-a) *For $\sigma_d^2 \leq (1 - x_0)^{-1}\mathcal{C}$,*

$$\sigma_{d|y_1}^2 = \sigma_d^2(1 - x_0), \quad \sigma_{d|y_1,y_2}^2 = \frac{1}{2}(1 - x_0)\sigma_d^2, \quad \phi = 0.$$

(i-b) *For $\sigma_d^2 > (1 - x_0)^{-1}\mathcal{C}$, $\sigma_{d|y_1}^2$ is the unique solution in $(\frac{1}{2}\sigma_d^2, \sigma_d^2)$ to*

$$\sigma_{d|y_1}^2 \left(1 + \sigma_d^2 \mathcal{C}^{-3}(2\sigma_{d|y_1}^2 - \sigma_d^2)^2\right) = \sigma_d^2; \quad \textit{and } \sigma_{d|y_1,y_2}^2 = \frac{1}{2}\mathcal{C}, \quad \phi = 4\left(\mathcal{C}^{-1} - \sigma_{d|y_1}^{-2}\right).$$

(ii) *In the market with mandatory disclosure:*

(ii-a) *For* $\sigma_d^2 \leq 2\mathcal{C}$,

$$\sigma^2_{d|x_1} = \frac{1}{2}\sigma_d^2, \quad \sigma^2_{d|x_1,y_2} = \frac{1}{4}\sigma_d^2, \quad \phi = 0.$$

(ii-b) *For* $\sigma_d^2 > 2\mathcal{C}$, $\sigma^2_{d|x_1}$ *is the unique solution to*

$$\sigma^2_{d|x_1}\left(1 + \mathcal{C}^{-3}\sigma^6_{d|x_1}\right) = \sigma_d^2; \quad \text{and} \quad \sigma^2_{d|x_1,y_2} = \frac{1}{2}\mathcal{C}, \quad \phi = 4\left(\mathcal{C}^{-1} - \sigma^{-2}_{d|x_1}\right).$$

Proof. Part (i) First, we determine equilibrium coefficients. By standard derivations, we find that

$$\beta_1 = \frac{1 - 2\lambda_1\pi_{|y_1}}{2\lambda_1(1 - \lambda_1\pi_{|y_1})}, \quad \lambda_1 = \frac{\sigma_d^2\beta_1}{\sigma_d^2\beta_1^2 + \sigma_z^2}, \quad \sigma^2_{d|y_1} = \sigma_d^2(1 - \beta_1\lambda_1). \tag{A.15}$$

This system can be reduced to the following equation

$$\sigma_d^2 = 2\sigma^2_{d|y_1}\left(1 - \pi_{|y_1}\frac{\sigma_{d|y_1}}{\sigma_d\sigma_z}\sqrt{\sigma_d^2 - \sigma^2_{d|y_1}}\right). \tag{A.16}$$

We prove Part (i-a). We conjecture that $\sigma^2_{d|y_1} \leq \mathcal{C}$, which implies $\pi_{|y_1} = \frac{\sigma_z}{2\sigma_{d|y_1}}$ by Eq. (5). Define $x \equiv \lambda_1\beta_1$, such that $\sigma^2_{d|y_1} = (1-x)\sigma_d^2$. Eq. (A.16) simplifies to

$$1 = (1 - x)(2 - \sqrt{x}). \tag{A.17}$$

The system (A.15) implies $x \in (0, \frac{1}{2})$, so Eq. (A.17) has a unique solution, equal to $x_0 \approx 0.307979$. Therefore, the initial conjecture $\sigma^2_{d|y_1} \leq \mathcal{C}$ is verified for $(1-x_0)\sigma_d^2 \leq \mathcal{C}$ or, equivalently, $\sigma_d^2 \leq (1-x_0)^{-1}\mathcal{C}$. By Lemma A.2, no speculator acquires information for $\sigma^2_{d|y_1} \leq \mathcal{C}$. Hence, $\phi = 0$. Finally, the result that $\sigma^2_{d|y_1,y_2} = \frac{1}{2}(1-x_0)\sigma_d^2$ follows by noting that, in this case, the model can be interpreted as the standard one-period Kyle (1985) model with beginning of period variance equal to

$$\sigma^2_{d|y_1} = (1 - x_0)\,\sigma_d^2, \tag{A.18}$$

which proves Part (i-a).

To prove Part (i-b), we conjecture, instead, that $\sigma^2_{d|y_1} > \mathcal{C}$, in which case $\pi_{|y_1} = 4\frac{c'(0)}{\sigma^4_{d|y_1}}$ by Eq. (5). Then, Eq. (A.16) can be rearranged as

$$\sigma_d^2 = \sigma^2_{d|y_1}\left(1 + \sigma_d^2\mathcal{C}^{-3}(2\sigma^2_{d|y_1} - \sigma_d^2)^2\right). \tag{A.19}$$

Because, again, $x \equiv \lambda_1\beta_1 \in (0, \frac{1}{2})$, then, $\sigma^2_{d|y_1} \in (\frac{1}{2}\sigma_d^2, \sigma_d^2)$. Therefore, the R.H.S. of Eq. (A.19) is strictly increasing in $\sigma^2_{d|y_1}$ and has a unique solution for $\sigma^2_{d|y_1}$ in $(\frac{1}{2}\sigma_d^2, \sigma_d^2)$. Eq. (A.19) also implies that this solution is increasing in σ_d^2. Letting $\sigma_d^2 = (1-x_0)^{-1}\mathcal{C}$, where x_0 is defined above as the solution to Eq. (A.17), it is immediate to verify that Eq. (A.19) is solved by $\sigma^2_{d|y_1} = \mathcal{C}$. Hence, $\sigma^2_{d|y_1} > \mathcal{C}$ if and only if $\sigma_d^2 > (1-x_0)^{-1}\mathcal{C}$. The expressions in the proposition for $\sigma^2_{d|y_1,y_2}$ and ϕ follow from Proposition 2 in Section 4.3 (proven in Appendix B).

Part (ii). The equilibrium coefficients are determined as follows. First, define γ as the slope coefficient of the expected dividend conditional upon x_1,

$$m_{d|x_1} = m + \gamma x_1.$$

Standard derivations lead to the following system

$$1 = 2\gamma\pi_{|x_1},\ \lambda_1 = \gamma_1^2\pi_{|x_1},\ \lambda_1 = \frac{\sigma_d^2\beta_1}{\sigma_d^2\beta_1^2 + \sigma_\eta^2 + \sigma_z^2},\ \gamma = \frac{\sigma_d^2\beta_1}{\sigma_d^2\beta_1^2 + \sigma_\eta^2},\ \sigma_{d|x_1}^2 = \sigma_d^2(1 - \beta_1\gamma). \tag{A.20}$$

The system (A.20) can be reduced to

$$\sigma_{d|x_1}^2 = \sigma_d^2 - \frac{\sigma_z^2}{4\pi_{|x_1}^2}. \tag{A.21}$$

Next, we prove Part (ii-a). We conjecture that $\sigma_{d|x_1}^2 \leq \mathcal{C}$, such that $\pi_{|x_1} = \frac{\sigma_z}{2\sigma_{d|x_1}}$ by Eq. (5). We still have that $\sigma_{d|x_1}^2 = (1 - x)\sigma_d^2$, for $x \equiv \gamma\beta_1$. Eq. (A.21) simplifies to

$$\sigma_{d|x_1}^2 = \frac{1}{2}\sigma_d^2. \tag{A.22}$$

Since we assumed $\sigma_{d|x_1}^2 \leq \mathcal{C}$, it must be $\sigma_d^2 \leq 2\mathcal{C}$. By Lemma A.2, for $\sigma_{d|x_1}^2 \leq \mathcal{C}$, no speculator acquires information. Hence, $\phi = 0$. Finally, $\sigma_{d|x_1,y_2}^2 = \frac{1}{4}\sigma_d^2$ follows because, and similarly as in Part (i-a), the model can be interpreted as the one-period Kyle (1985) model with beginning of period variance equal to $\sigma_{d|x_1}^2 = \frac{1}{2}\sigma_d^2$. This proves part (ii-a).

To prove Part (ii-b), we conjecture $\sigma_{d|x_1}^2 > \mathcal{C}$, so that $\pi_{|x_1} = 4\frac{c'(0)}{\sigma_{d|x_1}^4}$ by Eq. (5). In this case, Eq. (A.21) can be rearranged as

$$\sigma_d^2 = \sigma_{d|x_1}^2 + \mathcal{C}^{-3}\sigma_{d|x_1}^8. \tag{A.23}$$

Eq. (A.23) has a unique solution for $\sigma_{d|x_1}^2$, which is increasing in σ_d^2. Letting $\sigma_d^2 = 2\mathcal{C}$, Eq. (A.23) is solved by $\sigma_{d|x_1}^2 = \mathcal{C}$. Hence, $\sigma_{d|x_1}^2 > \mathcal{C}$ if and only if $\sigma_d^2 > 2\mathcal{C}$. The expressions in the proposition for $\sigma_{d|x_1,y_2}^2$ and ϕ follow from Proposition 2 in Section 4.3 (proven in Appendix B). ■

B. Proofs for Section 4

This appendix contains the proofs of the main results of the paper. First, we provide the proof of Proposition 1 in Section 4.1.

Proof of Proposition 1. Part (i-a). For a fixed $\sigma_{d|h}^2$, N, and τ_ε, it is immediate to verify that $var(d|y_2, h)$ with the insider in Eq. (A.2) is strictly lower than $var(d|y_2, h)$ in Eq. (A.10) without the insider. Since $var(d|y_2, h)$ is increasing in $\sigma_{d|h}^2$ and, with the insider, $\sigma_{d|h}^2 \leq \sigma_d^2$, it follows that the market without the insider has the highest $var(d|y_2, h)$ for all N, τ_ε.

Part (i-b). Next, we prove that the market with mandatory disclosure has more informative prices than the unregulated market. Using Eqs. (A.1)-(A.3), and fixing $\theta \equiv \lim_{N\uparrow\infty} N\tau_\varepsilon$, the expression for the insider's expected profits in the second period satisfies

$$\lim_{N\uparrow\infty} \Pi_2(N, \tau_\varepsilon; d, h) = (d - m_{d|h})^2\bar{\pi}_{|h},$$

where

$$\bar{\pi}_{|h} = \frac{4\sigma_z}{\sigma_{d|h}\left(4 + \theta\sigma_{d|h}^2\right)^{\frac{3}{2}}}. \tag{A.24}$$

In the unregulated regime we have $h = y_1$. Using the expressions (A.15)-(A.16) in the proof of Lemma A.4

together with Eq. (A.24) we have that, in the unregulated regime,

$$\sigma^2_{d|y_1} = \sigma^2_d (1 - x_u)$$

where $x_u \in (0,1)$ solves $g_1(x_u) = 0$, and

$$g_1(x) = 2(1-x)\left(1 - \frac{4\sqrt{x}}{(4+\theta\sigma^2_d(1-x))^{\frac{3}{2}}}\right) - 1.$$

Note that g_1 is decreasing in x and such that $g_1(0) = 1$, $g_1(1) = -1$. Since $g_1(1/2) < 0$ for all $\theta \geq 0$, we conclude that $x_u < 1/2$.

With mandatory disclosure, we have $h = x_1$. Using the expression (A.20)-(A.21) in the proof of Lemma A.4 together with (A.24) we have that, in the mandatory disclosure regime,

$$\sigma^2_{d|x_1} = \sigma^2_d (1 - x_m)$$

where $x_m \in (0,1)$ solves $g_2(x_m) = 0$, and

$$g_2(x) = 64x - (1-x)\left(4+\theta\sigma^2_d(1-x)\right)^3.$$

Now, g_2 is increasing in x and such that $g_2(0) = -\left(4+\theta\sigma^2_d\right)^3$, $g_2(1) = 64$. Since $g_2(1/2) = 32 - \frac{\left(8+\theta\sigma^2_d\right)^3}{16} < 0$ for all $\theta \geq 0$, we conclude that $x_m > 1/2$. Therefore, $\sigma^2_{d|h}$ is greater in the unregulated regime than in the mandatory disclosure regime.

Part (ii). By Eq. (A.9) we have that, without the insider,

$$\lim_{\bar{N}\to\infty} \lambda^p_2 = \frac{\sqrt{\theta}}{\sigma_z(2\tau_d + \theta)}.$$

By Eq. (A.1) and by the proof of Part (i) of this proposition we have that, in the market with the insider,

$$\lim_{\bar{N}\to\infty} \lambda^j_2 = \frac{1}{\sigma_z\sqrt{4\tau_d\alpha^j + \theta}} \quad \text{for } j \in \{d, u\},$$

where $\alpha_m = \frac{1}{1-x_m}$, in the mandatory disclosure regime and $\alpha_u = \frac{1}{1-x_u}$, in the unregulated regime. Since $0 < x_u < x_m < 1$, then $\alpha_m > \alpha_u > 1$. Therefore, it is immediate that $\lambda^u_2 > \lambda^m_2$. This proves Part (ii-a) of the proposition.

For the proof of Part (ii-b), we directly compare λ^p_2 with λ^u_2. First, we find that

$$\lim_{\tau_d\to 0} \lambda^p_2 = \lim_{\tau_d\to 0} \lambda^u_2 = \frac{1}{\sigma_z\sqrt{\theta}}. \tag{A.25}$$

Second, we find that

$$\left.\frac{\partial}{\partial\tau_d}\lambda^p_2\right|_{\tau_d=0} = -\frac{2}{\theta^{3/2}} > -\frac{2\alpha_u}{\theta^{3/2}} = \left.\frac{\partial}{\partial\tau_d}\lambda^u_2\right|_{\tau_d=0}. \tag{A.26}$$

Third, we have that

$$\lim_{\tau_d\to\infty} \frac{\lambda^p_2}{\lambda^u_2} = 0. \tag{A.27}$$

Finally, straightforward calculations show that

$$\lambda^p_2 = \lambda^u_2 \Leftrightarrow \tau_d = (\alpha_u - 1)\theta. \tag{A.28}$$

Eqs. (A.25)-(A.28) imply that $\lambda_2^p > \lambda_2^u \Leftrightarrow \tau_d < \theta(\alpha_u - 1)$. Since $\tau_d = \sigma_d^{-2}$, setting $s_u = \frac{1}{\theta(\alpha_u - 1)}$ yields the statement in the proposition. The derivation for λ_2^m is identical and is omitted. Since $\alpha_m > \alpha_u$, then $s_u > s_m$. ■

Next, we prove Theorems 1 and 2 in Section 4.2.

Proof of Theorem 1. First, we determine price informativeness in markets with insider trading across alternative disclosure regimes. For $\sigma_d^2 \geq 2\mathcal{C}$, Proposition 2 (Part (i)) implies that, regardless of the disclosure regime, price informativeness in the second period is $\frac{1}{\sigma^2_{d|h,y_2}} = 2\mathcal{C}^{-1}$. For $(1-x_0)^{-1}\mathcal{C} < \sigma_d^2 < 2\mathcal{C}$, where $(1-x_0)^{-1} \approx 1.445043$, Lemma A.4 (Part (i-b) and Part (ii-a)) implies that price informativeness equals $2\mathcal{C}^{-2}$ without mandatory disclosure and $4\sigma_d^{-2}$ with mandatory disclosure. Since $\sigma_d^2 < 2\mathcal{C}$, prices are more informative in a regime with mandatory disclosure than without. Finally, consider the case $\sigma_d^2 < (1-x_0)^{-1}\mathcal{C}$. Lemma A.4 (Part (i-a) and Part (ii-a)) now implies that price informativeness is $2(1-x_0)^{-1}\sigma_d^{-2} \approx 2.890086\sigma_d^{-2}$ in a market without mandatory disclosure and $4\sigma_d^{-2}$ in a market with mandatory disclosure. Therefore, prices are more informative in the market with disclosure than without.

Next, we compare price informativeness in the market with insider with that in the market without. In a market without insider trading, Proposition 2 (Part (ii)) implies that

$$\frac{1}{var(d|y_2)} = \left(\frac{1}{4}\sqrt{\phi}\sqrt{\mathcal{C}}^3\right)^{-1} = \sigma_d^{-2} + \frac{1}{2}\phi, \tag{A.29}$$

where ϕ is solution to

$$f(\phi) \equiv \left(2\sigma_d^{-2} + \phi\right)\sqrt{\phi}\sqrt{\mathcal{C}}^3 = 8. \tag{A.30}$$

Define $\bar{\phi} \equiv 4\mathcal{C}^{-1} - 2\sigma_d^{-2}$, and note that $f(\bar{\phi}) \equiv 4\mathcal{C}^{-1}\sqrt{4\mathcal{C}^{-1} - 2\sigma_d^{-2}}\sqrt{\mathcal{C}}^3 < 8$. Since $f(\cdot)$ is strictly increasing, then, $\phi > \bar{\phi}$, such that, by Eq. (A.29), price efficiency in the market without insider trading is

$$\frac{1}{var(d|y_2)} > \sigma_d^{-2} + \frac{1}{2}\bar{\phi} = 2\mathcal{C}^{-1}.$$

Lemma A.4 (Part (i-b) and Part (ii-b)) now implies that price efficiency without insider trading is better than with insider trading when $\sigma_d^2 > (1-x_0)^{-1}\mathcal{C}$ (in a regime without mandatory disclosure) and when $\sigma_d^2 > 2\mathcal{C}$ (in a regime without mandatory disclosure).

Next, we identify the threshold values of σ_d^2 such that price informativeness is the same without and with insider trading (with and without mandatory disclosure). We search for values of σ_d^2 such that price efficiency in a market without insider trading is the same as price efficiency with insider trading in the regime with mandatory disclosure (Case 1) and without (Case 2). We have already established that speculators never buy information in both cases in the market with insider trading. Therefore, in the market with insiders, we determine price informativeness based on Lemma A.4 (Part (ii-a)) for Case 1, and based on Lemma A.4 (Part (i-a)) for Case 2. Instead, we rely on Eq. (A.29).

Case 1 The value of σ_d^2 that equates price efficiency in the markets with and without insider trading is

$$\sigma_d^2 : \sigma_d^{-2} + \frac{1}{2}\phi = 4\sigma_d^{-2},$$

where the L.H.S. of the equality follows by Eq. (A.29) and the R.H.S. by Lemma A.4 (Part (ii-a)). That is, $\phi = 6\sigma_d^{-2}$. Replacing this value of ϕ into (A.30) leaves a unique solution, $\sigma_d^2 = 1.817120\mathcal{C}$.

Case 2 The threshold value of σ_d^2 now is

$$\sigma_d^2 : \sigma_d^{-2} + \frac{1}{2}\phi = 2\left(1 - x_0\right)^{-1}\sigma_d^{-2},$$

where $x_0 \approx 0.307979$. Proceeding similarly as in Case 1 leaves the following unique solution: $\sigma_d^2 = \frac{1}{1-x_0}\sqrt[3]{\frac{1}{2}\left(1+x_0\right)\mathcal{C}} \approx 1.254308\mathcal{C}$.

The proof is complete as price informativeness is continuous in σ_d^2: price informativeness is higher in the market without insider than in the market with insider and mandatory disclosure (resp., without mandatory disclosure) if and only if $\sigma_d^2 > 1.817120\mathcal{C}$ (resp., $\sigma_d^2 > 1.254308\mathcal{C}$). ■

Proof of Theorem 2. In the market with insider trading,

$$\lambda_2 = \begin{cases} \frac{1}{2}\frac{\sigma_{d|h}}{\sigma_z} & \sigma_{d|h}^2 < \mathcal{C} \\ \frac{1}{2}\frac{\sqrt{\mathcal{C}}}{\sigma_z}, & \sigma_{d|h}^2 > \mathcal{C} \end{cases} \tag{A.31}$$

where the first equality follows by standard results and the second follows by Proposition 2. In the market with mandatory disclosure, $\sigma_{d|h}^2 = \frac{1}{2}\sigma_d^2$ (see (A.22)) whereas, in the market without mandatory disclosure, $\sigma_{d|h}^2 = (1 - x_0)\,\sigma_d^2$, where $x_0 \approx 0.307979$ (see (A.18)). Replacing these values into (A.31) leads to the conclusion that the price impact in the market without mandatory disclosure is higher than in the market with mandatory disclosure:

$$\lambda_2^u = \frac{\sqrt{1-x_0}}{2}\frac{\sigma_d}{\sigma_z} \text{ for } \sigma_d^2 < (1-x_0)^{-1}\mathcal{C}, \quad \text{and} \quad \lambda_2^u = \frac{1}{2}\frac{\sqrt{\mathcal{C}}}{\sigma_z}, \text{ otherwise,}$$

in the market without mandatory disclosure, and

$$\lambda_2^m = \frac{1}{2\sqrt{2}}\frac{\sigma_d}{\sigma_z}, \text{ for } \sigma_d^2 < 2\mathcal{C}, \quad \text{and} \quad \lambda_2^m = \frac{1}{2}\frac{\sqrt{\mathcal{C}}}{\sigma_z}, \text{ otherwise,}$$

in the market with mandatory disclosure. Therefore, we are left to show that the market without insider trading is more liquid than the market with insider trading and mandatory disclosure.

Note, then, that, by Proposition 2 (Part (ii)),

$$\lambda_2^p = \frac{1}{8}\frac{\phi\sqrt{\mathcal{C}}^3}{\sigma_z},$$

where $\sigma_{d|h}^2 = \sigma_d^2$ and, hence, $\phi : f(\phi) = 8$, with the function f defined as in (A.30). We claim that $\lambda_2^p < \lambda_2^m$ for all values of σ_d^2 in Region R1 of Theorem 1, i.e., where speculators purchase information in the market with mandatory disclosure. Indeed, define $\hat{\phi} = 4\mathcal{C}^{-1}$, such that $f(\hat{\phi}) = \left(2\sigma_d^{-2} + 4\mathcal{C}^{-1}\right)2\mathcal{C} > 8$. Therefore, since f is increasing, $\phi < \hat{\phi}$, such that

$$\lambda_2^p = \frac{1}{8}\phi\mathcal{C}\frac{\sqrt{\mathcal{C}}}{\sigma_z} < \frac{1}{8}\hat{\phi}\mathcal{C}\frac{\sqrt{\mathcal{C}}}{\sigma_z} = \frac{1}{2}\frac{\sqrt{\mathcal{C}}}{\sigma_z} = \lambda_2^m.$$

Therefore, λ_2^p and λ_2^m may have some values in common only in Regions R2 through R4. Let, then, $\phi_*(\sigma_d^2)$ denote the values of ϕ such that $\lambda_2^p = \frac{1}{8}\phi\frac{\mathcal{C}^{3/2}}{\sigma_z} = \frac{1}{2\sqrt{2}}\frac{\sigma_d}{\sigma_z} = \lambda_2^m$, i.e., $\phi_*(\sigma_d^2) = 2\sqrt{2}\sigma_d\mathcal{C}^{-3/2}$. Define $\varphi(\sigma_d^2, \phi) \equiv f(\phi)$ and

$$\bar{\varphi}(\phi_*) \equiv \varphi(s^{-1}(\phi_*), \phi_*) = \left(a\phi_*^{-3/2} + \phi_*^{3/2}\right)\mathcal{C}^{3/2}, \quad a \equiv 16\mathcal{C}^{-3},$$

where $s^{-1}(\cdot)$ denotes the inverse function of $\phi_*(\cdot)$. Note that $\bar{\varphi}$ achieves a minimum at $\hat{\phi}_* = a^{1/3}$ and that $\bar{\varphi}(\hat{\phi}_*) = 8$. That is,

$$\varphi(\sigma_d^2, \phi_*(\sigma_d^2)) \geq \bar{\varphi}(\hat{\phi}_*) = 8 = \varphi\left(\sigma_d^2, \phi\right),$$

where the last equality follows by the definition of ϕ. Now, for fixed σ_d^2, the function $\varphi\left(\sigma_d^2, \phi\right)$ is increasing in ϕ. Therefore, $\phi \leq \phi_*(\sigma_d^2)$, with an equality for $\phi_*(\sigma_d^2) = \hat{\phi}_*$. Hence $\lambda_2^p \leq \lambda_2^m$ with an equality when $\hat{\phi}_* = a^{1/3}$, i.e., for $\sigma_d^2 = \delta\mathcal{C}$, and $\delta \approx 0.793701$, the constant appearing in the theorem. ■

Finally, we provide proofs of results in Section 4.3.

Proof of Proposition 2. Consider, first, the market with insider trading. In this case, Eq. (A.5) implies that $\lim_{\bar{N}\to\infty} \tau_\varepsilon = 0$, and that $\bar{N}\tau_\varepsilon$ converges to the limit in Part (i) of the proposition. The limiting expressions for λ_2 and $var(d|y_2, h)$ are obtained by taking the limits of the expression for λ_2 and $var(d|y_2, h)$ in (A.1) and (A.2), respectively, and using the limiting expression for τ_ε and $\bar{N}\tau_\varepsilon$, and the definition of $\mathcal{C}$ in (3).

In the market without insider, Eq. (A.12) implies that $\lim_{\bar{N}\to\infty} \tau_\varepsilon = 0$. Then, by taking the limits in Eqs. (A.9) and (A.12), we find that $\bar{N}\tau_\varepsilon$ converges to a constant ϕ that is the solution to the equation provided in Part (ii) of the proposition. Finally, the limiting expressions for λ_2 and $var(d|y_2, h)$ follow by calculating the limits in (A.9) and (A.10). ■

Proof of Corollary 1. Part (i) Denote $\phi_1 \equiv \lim_{\bar{N}\to\infty} \bar{N}\tau_\varepsilon =$ (respectively, $\phi_2 \equiv \lim_{\bar{N}\to\infty} \bar{N}\tau_\varepsilon$) the limiting amount of information acquired by speculators with the insider (respectively, without the insider). By Proposition 2, we have $\phi_1 = \max\left\{0, 4\left(\mathcal{C}^{-1} - \sigma_{d|h}^{-2}\right)\right\}$ and ϕ_2 is the unique real solution to $G\left(\phi_2\right) = 0$, where $G\left(x\right) = \left(2\sigma_{d|h}^{-2} + x\right)\sqrt{x}\sqrt{\mathcal{C}^3} - 8$. We will prove that $\phi_2 > \phi_1$. Clearly, for $\sigma_{d|h}^2 \leq \mathcal{C}$, we have $\phi_2 > \phi_1 = 0$. For $\sigma_{d|h}^2 > \mathcal{C}$, we have that

$$G\left(\phi_1\right) = \left(4\mathcal{C}^{-1} - 2\sigma_{d|h}^{-2}\right)\sqrt{4\left(\mathcal{C}^{-1} - \sigma_{d|h}^{-2}\right)}\sqrt{\mathcal{C}^3} - 8.$$

Since the R.H.S. is increasing in $\sigma_{d|h}^2$ and $\lim_{\sigma_{d|h}^2\uparrow\infty} G\left(\phi_1\right) = 0$, we have $G\left(\phi_1\right) < 0$ for all $\sigma_{d|h}^2 < \infty$. Since G is strictly increasing, then, it must be $\phi_2 > \phi_1$.

Part (ii) By Eq. (A.2) we have that, with the insider, $\lim_{N\uparrow\infty} var(d|y_2, h)^{-1} = 2\sigma_{d|h}^{-2} + \phi_1/2$; by Eq. (A.10) we have that, without the insider, $\lim_{N\uparrow\infty} var(d|y_2, h)^{-1} = \sigma_{d|h}^{-2} + \phi_2/2$. Hence, Corollary 1-(ii) is equivalent to the claim that $2\sigma_{d|h}^{-2} + \phi_1 < \phi_2$ if and only if $\sigma_{d|h}^2 > \frac{\mathcal{C}}{\sqrt[3]{2}}$. First, consider the case $\sigma_{d|h}^2 \leq \frac{\mathcal{C}}{\sqrt[3]{2}}$. Since, in this case, $\phi_1 = 0$, then it is sufficient to show that $2\sigma_{d|h}^{-2} > \phi_2$. We have

$$G\left(2\sigma_{d|h}^{-2}\right) = 2^{5/2}\left(\sigma_{d|h}^{-2}\mathcal{C}\right)^{3/2} - 8.$$

The R.H.S. is decreasing in $\sigma_{d|h}^2$ and is therefore minimized at $G\left(2\sigma_{d|h}^{-2}\right)\Big|_{\sigma_{d|h}^2 = \frac{\mathcal{C}}{\sqrt[3]{2}}} = 0$. Since G is increasing, it follows that $2\sigma_{d|h}^{-2} > \phi_2$. Next, consider $\sigma_{d|h}^2 > \frac{\mathcal{C}}{\sqrt[3]{2}}$, in which case we must show that $4\mathcal{C}^{-1} - 2\sigma_{d|h}^{-2} < \phi_2$. We have

$$G\left(4\mathcal{C}^{-1} - 2\sigma_{d|h}^{-2}\right) = 2^{3/2}\sqrt{2 - \sigma_{d|h}^{-2}\mathcal{C}} - 8.$$

Since the R.H.S. is increasing in $\sigma_{d|h}^2$ and $\lim_{\sigma_{d|h}^2\uparrow\infty} G\left(4\mathcal{C}^{-1} - 2\sigma_{d|h}^{-2}\right) = 0$, we have $G\left(4\mathcal{C}^{-1} - 2\sigma_{d|h}^{-2}\right) < 0$ for all $\sigma_{d|h}^2 < \infty$. Since G is strictly increasing, then, it must be $\phi_2 > 4\mathcal{C}^{-1} - 2\sigma_{d|h}^{-2}$.

Part (iii) Consider first, the case $\sigma_{d|h}^2 \geq \mathcal{C}$. The expressions for λ_2 in Proposition 1 imply that λ_2 is higher with the insider than without if $\phi_2 < 4/\mathcal{C}$. Implicit differentiation of $G(\phi_2) = 0$ shows that ϕ_2 is increasing in σ_d^2 and that $\lim_{\sigma^2_{d|h}\uparrow\infty} \phi_2 = 4/\mathcal{C}$. Therefore, $\phi_2 < 4/\mathcal{C}$ for all finite values of $\sigma^2_{d|h}$. Next, consider the case $\sigma^2_{d|h} < \mathcal{C}$. For this case, λ_2 is higher with the insider than without if $\phi_2 < \frac{4\sigma_{d|h}}{\sqrt{\mathcal{C}^3}}$. Straightforward simplifications show that

$$G\left(\frac{4\sigma_{d|h}}{\sqrt{\mathcal{C}^3}}\right) < 0 \Leftrightarrow \left(\frac{\mathcal{C}}{\sigma_{d|h}}\right)^{\frac{3}{2}} + \sigma_{d|h}^{\frac{3}{2}} - 2\mathcal{C}^{\frac{3}{4}} > 0.$$

The L.H.S. in the second inequality is strictly decreasing in $\sigma_{d|h}$ for all $\sigma^2_{d|h} < \mathcal{C}$ and is equal to zero for $\sigma^2_{d|h} = \mathcal{C}$. Therefore, $G\left(\frac{4\sigma_{d|h}}{\sqrt{\mathcal{C}^3}}\right) > 0$ for all $\sigma^2_{d|h} < \mathcal{C}$. Since ϕ_2 solves $G(\phi_2) = 0$ and G is strictly increasing, it follows that $\phi_2 < \frac{4\sigma_{d|h}}{\sqrt{\mathcal{C}^3}}$. ■

C. Markets with a finite number of speculators

Figures A-1 and A.2 summarize the main numerical results in markets with a finite pool of speculators, $\bar{N} < \infty$. In both figures, the pool of speculators $\bar{N}$ equals 25 (top-left panel), 50 (top-right panel), 100 (bottom-left panel), and 250 (bottom-right panel), the cost function is $c(\tau_\varepsilon) = \frac{1}{2}\tau_\varepsilon$, and $\sigma_z = 1$.

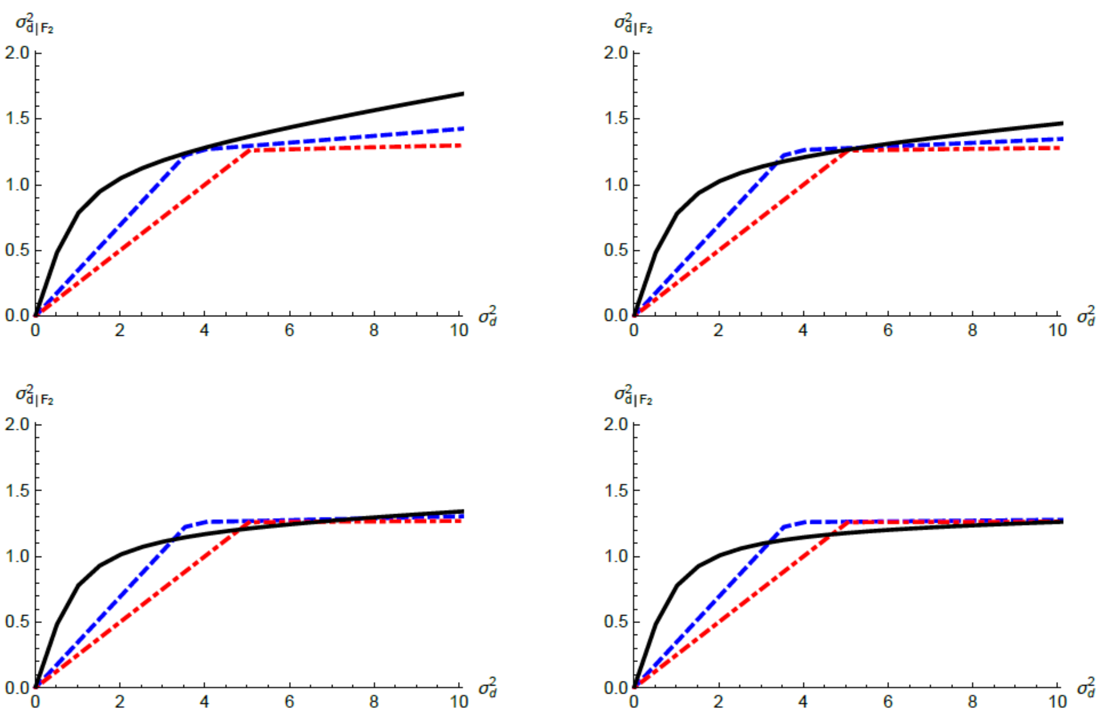

Figure A-1. Informational efficiency and regulatory regimes with finitely many speculators. This picture depicts the asset payoff uncertainty as a function of the uncertainty of fundamentals in three regulatory regimes: (i) without insider trading (black line), (ii) with insider trading but mandatory disclosure (red, dot-dashed line), and (iii) with insider trading and without mandatory disclosure (blue, dashed line).

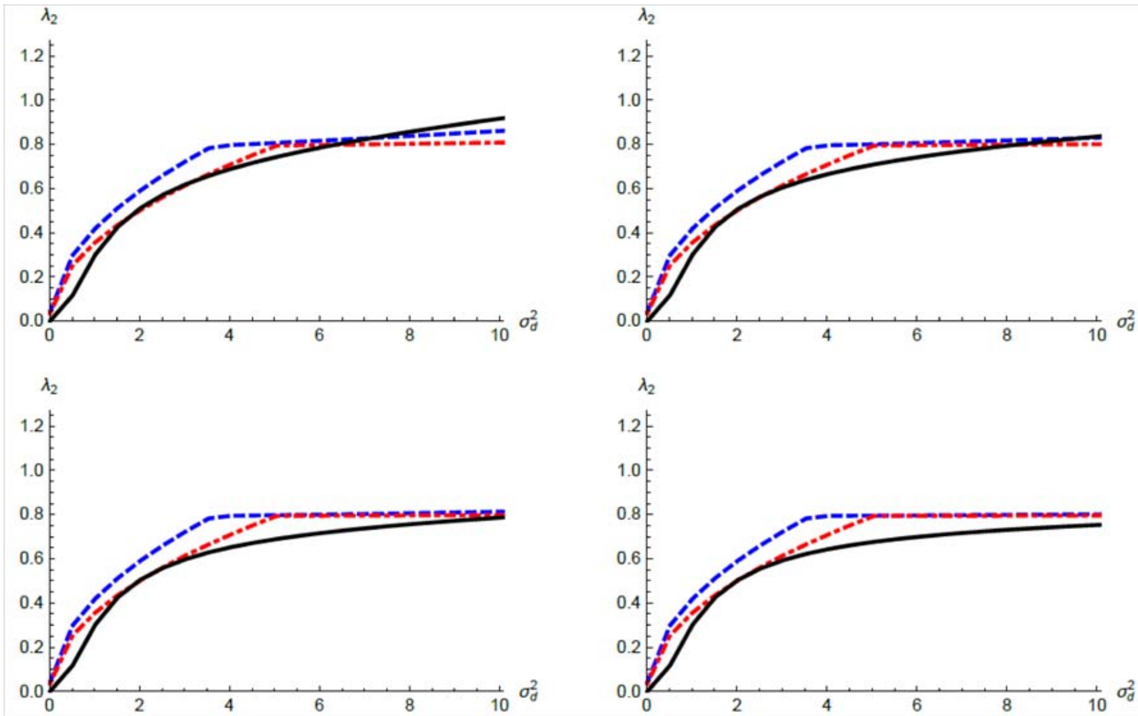

Figure A-2. Long-term liquidity across regulatory regimes. This picture depicts market liquidity at time-2, λ_2, as a function of the uncertainty of fundamentals in three regulatory regimes: (i) without insider trading (black line), (ii) with insider trading but mandatory disclosure (red, dot-dashed line), and (iii) with insider trading and without mandatory disclosure (blue, dashed line).

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