# Regulating Insider Trading When Investment Matters*


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**Abstract**

We analyze the effects of insider trading on real investment and welfare and the consequences of different regulatory policies in a model in which all traders are rational expected-utility maximizers and aware of their position in the market. We find that with costly information acquisition an abstain-or-disclose rule tends to be optimal while with free information acquisition laissez faire is better. This suggests enforcing an abstain-or-disclose rule with a high standard of proof for inside information. Our approach uncovers also the pitfalls of welfare analysis in the noise trader model.



**JEL Classification:** D82, G12, G14

**Keywords:** insider trading, selective disclosure, disclose-or abstain rule, real investment, welfare, hedging, speculation, noise traders.


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# 1 Introduction

More and more countries are regulating insider trading and there is evidence that enforcement of insider trading laws reduces the cost of equity in a country (Bhattacharya and Daouk (1999)). At the same time there is evidence that insiders do trade in advance of information release and earn excess returns (see Seyhun (1992 or 1986), Damodaran and Liu (1993) and Aboody and Lev (1999) for evidence in high-tech companies).[1] Insider trading is perceived as being "unfair" and many commentators think that insider profits should be curbed.[2] Others believe in contrast that private and social incentives are aligned and therefore firms should determine themselves the restrictions to impose (Carlton and Fischel (1983)).[3] Leading regulations of insider trading include an "abstain or disclose rule" in the US and the prohibition to trade on inside (precise) information in the EU. Recently, both in the US and in some European countries tougher disclosure requirements have been imposed to avoid early selective disclosure of material information (to large investors, for example).[4]

Despite the concern about insider trading, somewhat surprisingly, the welfare consequences of regulating (or not) insider trading are less well understood. Indeed, despite an accumulation of work on the effects of insider trading further progress in its welfare consequences has been prevented by the use of noise trader models and other methodological problems related to the modelling of market power and information.

The aim of the paper is to contribute to fill this gap examining the trade-offs associated with insider trading in a production economy in which all traders are rational expected utility maximizers (doing away with noise traders) and aware of their position in the economy.

[1] The authors find that insider gains in R&D-intensive firms is larger than in other firms. The rationale for the result is traced to the uniqueness of R&D capital to the firm, non-tradability in organized markets, and poor disclosure (because of the accounting convention of expensing R&D).

[2] See, for example, Fried (1998).

[3] In fact, the authors argued that since there is no evidence that organizers of firms tried to restrict insider trading either where there was no IT regulation or when it was not enforced, this meant that IT restrictions were not necessary to enhance firm value and, indeed, could be distortionary.

[4] The Fair Disclosure rule of the SEC states that "when an issuer, or person on its behalf, discloses material nonpublic information to certain enumerated persons (in general, securities market professionals and holders of the issuer's securities who may well trade on the basis of the information), it must make public disclosure of that information." See the SEC's home page at http://www.sec.gov/rules/final/33-7881.htm.

Our analysis helps to shed light about the appropriate regulation of insider trading:

- When is laissez-faire a sensible policy?
- When is a good idea to enforce an abstain-or-disclose rule like in the US?
- Does information need to be "precise" to be considered inside information as in the EU Directive on insider dealing?
- Do high-tech highly volatile industries need a special treatment?
- What are the effects of early selective disclosure?

As a by product of our modelling we put on solid ground the welfare analysis of the noise trader model, being a limiting case of our model. In particular, we can see when the welfare implications derived from the noise trader model hold and when they are misleading.

Much progress has been done on the analysis of insider trading understanding its effects in terms of creating adverse selection, advancing the resolution of uncertainty, and modifying insurance and hedging opportunities (Manne (1966, 1980), Demsetz (1986), Manove (1989), Fishman and Hagerty (1989), Ausubel (1990), Leland (1992), Dennert(1992, 1993), Bernhardt et al (1995), Repullo (1999), Dow and Rahi (2001), and Bhattacharya and Nicodano (1999)).

However, further progress in the analysis of the effects of insider trading is hampered by one or more of the following:

- Consideration of exogenous noise traders.
- Assumption of competitive behavior on the part of agents (insider, entrepreneur) with a position of market power.
- Ill-defined incentives to float the firm/project (e.g., risk neutral entrepreneur sells firm when the expected price is lower than the expected return).
- "Inside" information actually emanating from outside the firm or with no productive value.

In this paper we set out to build a model of the impact of trading by insiders on investment and welfare of market participants when all agents are rational and aware of their position in the market. Our emphasis on real investment makes our paper close to Ausubel (1990), Leland (1992), Bernhardt et al (1995), Repullo (1999) and Bhattacharya and Nicodano (1999). Perhaps the closest paper is Leland (1992) (and the extensions in Repullo (1999)). However we depart from them in that our entrepreneur is the insider, is risk averse and has market power. This avoids a troublesome feature of the Leland model (namely, the assumption that the risk neutral entrepreneur is forced to sell the whole firm in the asset market; indeed, given that the expected price is lower than the expected asset return, the entrepreneur has no motive to float his firm). In our model the entrepreneur issues the asset to obtain insurance. Other papers have also done away with noise traders: Ausubel (1990), Bernhardt et al (1995), and Dow and Rahi (2001), as well as Qi(1996) and Bhattacharya and Nicodano (1999); the latter two modelling noise traders as agents that suffer an interim preference shock as in Diamond and Dybvig (1983)).[5] However, they all stay within the competitive paradigm with the exception of the overlapping generations model of Bernhardt et al (1995).

Imagine the following scenario. An entrepreneur (or a coalition of insiders, the initial owners of the firm) has a project which needs investment and, because he is risk averse, wants to hedge it partially by selling shares of the firm in the stock market. In the market there are risk averse competitive speculators/market makers and hedgers who have a random endowment of an asset correlated with the project of the firm. The entrepreneur/insider obtains information about the value of the project in the course of production once investment is made. For example, a corporate insider in a high-tech company learns valuable information about the effectiveness of a new drug being developed by the firm that shortly will be released to the market. (Or perhaps the manager provides information, an early warning, to the major shareholders -the initial owners- in exchange of a promise of non intervention (Maug(1999).) The stock market opens after investment is made. Neither the stock price nor private information have a chance to affect investment.[6]

[5] Diamond and Verrecchia (1981), Battacharya and Spiegel (1991) and Spiegel and Subrahmanyam (1992) consider also traders suffering endowment shocks to rationalize noise trading in different contexts.

[6] The project can not be floated at the investment stage because of agency problems (manager has to keep shares to lessen moral hazard). Alternatively, information disclosure associated to the flotation would tip competitors that could move and try to copy the product (this may be particularly relevant in high-tech industries (Campbell (1979), Yosha (1995)). At the same time in high-tech industries outside investors would be reluctant to invest in a new project because they face very high risk with no information. Venture capital may come to the rescue then. More traditional scenarios may fit the model also. For example, consider an agricultural producer that wants to hedge in

We consider a model of the CARA-normal variety and characterize linear equilibria with and without insider trading. The insider is risk averse, has market power and receives a noisy signal about the liquidation value of the firm. The rest of the agents are also risk averse and are competitive. It is found that adverse selection may prevent the existence of a linear equilibrium. In our market when the insider has private information hedgers have also an informational advantage with respect to uninformed speculators. This is so because a hedger can recover from the price some of the information of the insider using the correlation between his endowment shock and the aggregate endowment shock. However, an equilibrium always exists when the combined risk-weighted informational advantage of the insider and the hedgers is not very high (in particular, when insurance is the main motive for trade for hedgers). We find that the level of investment is increasing in the hedging effectiveness of the asset market from the point of view of the entrepreneur.

An interesting by-product of the analysis is that we can ascertain exactly when hedgers have in the aggregate demands of the noise trader form. That is, when noise trader demands provide a good approximation to the demands with rational hedgers. This happens precisely when the risk-weighted informational advantage of a hedger is very low (in particular, when hedgers are very risk averse). At the same time this allows to check whether the implicit welfare analysis in the noise trader model is correct.

In our market if the signal is public knowledge, equilibrium always exists (except if the signal is perfect), and as the precision of the signal increases, market depth, price volatility and the average stock price increase, investment decreases as well as the expected utility of the insider and the speculators, and, for reasonable parameter values, of the hedgers. Hedgers are hurt despite the increase in market depth because of the increase in volatility and decrease of the risk premium. We see thus that a deeper market may be accompanied by a worsening of the situation of all the traders, including the hedgers. This can not happen in a noise trader model, where the losses of noise traders are proportional to the inverse of market depth. In this situation the noise trader model would be misleading.

The insider trader regime (IT) is compared with two benchmarks: equilibrium with no information (NI) and equilibrium with public disclosure of the signal (PD). The strategy of the analysis

the futures market part of his production and that obtains private information about the future value of the crop once the seeds have been planted (like in Bray (1985)).

is to perform the comparison "close" to the noise trader case where the risk-adjusted informational advantage of the hedgers is small (and analytical results are possible) and extend the results with simulations to a broad region of the parameter space.

The regimes NI and PD are interesting because they arise in a context where an "disclose or abstain" rule is applied to corporate insiders (as in the US with SEC rule 10b-5 of the 1934 Act). The insider in possession of "material" nonpublic information must abstain from trading (until the information becomes public) or disclose the information to the market and then trade. This happens when the other party to the transaction is entitled to know the information because of a fiduciary duty (Chiarella v. US and Dirk v. SEC) or other similar relationship (according to the misappropriation theory adopted in US v. Newman).[7] What constitutes "material" information is left vague (Seyhun (1992)). In contrast, the EU Directive on insider dealing (1989) requires (Article 1) the information to be "precise" (similarly UK law requires inside information to be precise or specific).[8] Article 2 prohibits insider trading and defines broadly who is an insider.[9] The European procedure can be explained in part by a larger reliance on criminal prosecution (Maug (1999)). In the context of our model the entrepreneur/coalition of insiders when trading on the basis of their acquired private information would be subject to the US abstain or disclose rule or the EU prohibition of insider dealing.

The effects of a "disclose or abstain" rule will depend on whether information is acquired for free or at a cost. If the entrepreneur/insider learns the signal for free in the course of his activity,

[7]Rule 10b-5 applies to insiders but not to outside shareholders who may possess information on the company (because those do not have a fiduciary duty to other shareholders) except if the shareholder owns more than 10% of the equity of the firm. In that case it is considered an "insider". The 1934 Securities and Exchange Act defines corporate insiders as corporate officers, directors and owners of 10% or more of any equity class of securities.

[8]Article 1 states that "'inside information' shall mean information which has not been made public of a precise nature relating to one or several issuers of transferable securities or to one or several transferable securities, which, if it were made public, would be likely to have a significant effect on the price of the transferable security or securities in question".

[9]Article 2: "Each Member State shall prohibit any person who: by virtue of his membership of the administrative, management or supervisory bodies of the issuer, by virtue of his holding in the capital of the issuer, or because he has access to such information by virtue of the exercise of his employment, profession or duties, possesses inside information from taking advantage of that information with full knowledge of the facts by acquiring or disposing of for his own account or for the account of a third party, either directly or indirectly, transferable securities of the issuer or issuers to which that information relates".

then when faced with the choice or disclosing the information and trading or not disclosing and not being able to trade, he will choose to disclose because by not trading he can not hedge at all the investment risk. The relevant welfare comparison is between a disclosure regime (PD) and insider trading (IT). If to learn the signal has a cost, then the entrepreneur will never spend any effort in learning it if the information has to be disclosed before use. The relevant welfare comparison is between a regime in which the entrepreneur has no private information (NI) and insider trading (IT).

It is found that the effects of insider trading depend on whether the information of the insider is precise or not (or more in general on his risk-adjusted informational advantage).[10] However, several results emerge:

- Insider trading decreases investment except if the information of the insider is very precise and acquired at no cost (PD benchmark), in which case insider trading is Pareto superior.
- Otherwise insider trading is Pareto inferior with two exceptions:

1. If the information of the insider is very precise and acquired at a cost (NI benchmark) then insider trading benefits the insider and hurts outsiders.
2. If the information of the insider has an intermediate level of precision and acquired at no cost (PD benchmark) then insider trading hurts everyone except the hedgers.

Insider trading tends to depress market depth and investment because of adverse selection. The expected stock price tends to increase (and the risk premium is lower). The risk premium increases with the level of investment and decreases with market depth. The first effect tends to dominate the second. However, investment increases when compared with the PD regime if the signal of the insider is very precise because with public disclosure of the signal the Hirshleifer (1971) effect (insurance opportunities destroyed because of revelation of information) is very severe. When compared with the NI (PD) regime price precision and volatility is increased (decreased) with insider trading. The effect of insider trading on the expected utility of the insider depends on the trade off

[10] Bernhardt and Hughson (2000) find that in the NYSE the price impact of information is positive but small because "the quality of the information signals is quite poor, particularly in the middle of the trading day". This would suggest a low precision of the signals of informed traders.

between speculative and insurance gains and on hedgers on the combined impact on market depth, risk premium and price volatility.

There is a large range of cases where the welfare analysis of the noise trader model is misleading *qualitatively*, even in the case that hedgers' risk aversion is high and the demands of traders approach those of the noise trading model. For example, for a high precision of the information of the insider hedgers improve with insider trading (compared with a PD regime) despite the fact that market depth decreases, contradicting the implicit welfare criterion of noise trader models. Indeed, hedgers care about the risk premium and price volatility also.

Our modeling of insider trading puts emphasis on the effects on ex ante investment in line with the analysis of Ausubel (1990) and Bhattacharya and Nicodano (1999). This is in contrast with the work of Leland (1992), Dow and Rahi (2001) as well as Medrano and Vives (2002), who analyze the effect of insider information on interim investment. The issues raised in our paper have also a parallel in the literature on security design (Demange and Laroque (1995) and Rahi (1996)).

Ausubel (1990) considers an exchange economy with rational traders and a unique REE, in which private information is received after investment by both the (competitive) insider and outsiders. Abolition of insider trading increases the expected return of outsiders, outsiders invest more and this may benefit insiders. The result is that a ban on insider trading may be Pareto improving. However, in his model inside information has no productive value (and is unrelated to investment). Bhattacharya and Nicodano (1999) model liquidity traders as early diers in a Diamond-Dybvig frame, there is a risk neutral insider with an endowent of the risky asset, potentially multiple equilibria, and the insider is not one of the entrepreneurs. They find, using simulations, that inside information may be beneficial by making the price more informative and improving risk sharing (making short term traders better off). Adverse selection drive the results above.

The presence of insiders tends to make prices more informative.[11] Leland (1992) shows that the average investment level may be higher with insider trading because risk averse outsiders increase the demand for the risky asset associated to investment. Expected stock prices will tend to increase decreasing the risk premium (decreasing the conditional volatility of returns and increasing the ex

[11] However, Fishman and Hagerty (1992) show that the presence of insiders may discourage information collection by outside investors/analysts, leading perhaps to less informative prices. In their model stock prices guide the entry decisions of potential entrants. A related result is obtained by Khana et al (1994). There is also a literature on how information in stock prices help managerial incentives (Holmstom and Tirole(1993)).

ante volatility of prices). Liquidity traders and outside investors are hurt, insiders and owners of firms issuing shares benefit (because of a higher issuing price). The net effect is ambiguous (positive if investment is very sensitive to the current price, risk aversion of investors low and liquidity trading has low volatility). In the model of Leland (1992) the firm does not learn anything from the stock price. Repullo (1999) shows that Leland's results are not robust to the introduction of noise in the information of the insider and analyzes some variations of the model with investment prior to trading.

Bernhardt et al (1995) examine the trade-offs associated to the adverse selection and price information effects of insider trading in an overlapping generations model. They show that when investment is sufficiently information elastic insider trading may be welfare enhancing. In principle the net effect on outsiders is ambiguous. They prefer informative prices (due to past insider trading) but they dislike to trade with insiders in the future. With persistence in production shocks the first effect dominates.

It is well-known from the work of Hirshleifer (1971) that early revelation of information (before being able to put hedging position) may destroy insurance possibilities. Insider trading will tend to hurt then uninformed hedgers. However, early revelation of information may also help insurance possibilities. If uncertainty about risk factors not correlated with the endowment of the hedger is resolved early then the stock is more correlated with the hedgers' endowment and hedging opportunities are improved (Dow and Rahi (2001)).

We develop the implications for regulation of insider trading in the final section of the paper.

The plan of the paper is the following. In Section 2 we present the model. Section 3 deals with equilibrium with insider trading and Section 4 with equilibrium with public disclosure. Section 5 analyzes the effects of insider trading taking as benchmarks the NI and PD regimes. The final section contains the implications for the regulation of insider trading and proofs are collected in the Appendix.

## 2 The model

Consider an economy where a single risky asset, with random (ex post) liquidation value $v$, and a riskless asset, with unitary return, are traded among a continuum of risk-averse competitive uninformed speculators, a continuum of risk-averse competitive hedgers and a large informed trader (the insider). The risky asset is traded at a price $p$ and thus generates a return $v - p$.

*Insider.* The insider is an entrepreneur who undertakes a risky business. Let $q$ denote the level of investment (and also the number of shares issued). The stochastic return per unit of investment (and the liquidation value per share) is given by $v$. The technology is represented by a deterministic quadratic cost function of the form $C(q) = c_1 q + c_2 q^2/2$ where $c_1 \geq 0$ and $c_2 \geq 0$. The insider is risk averse and has CARA utility: $U(W_i) = -exp\{-\rho_i W_i\}$, where $\rho_i > 0$ is the coefficient of constant absolute risk aversion and $W_i$ is the insider's final wealth. By virtue of his position, the entrepreneur has some privileged (inside) information $s$ on the likely realization of production return $v$. We assume that $s$ is observed after choosing $q$, but before trading in the security market, and that it is a noisy version of $v$: $s = v + \epsilon$, where $v$ and $\epsilon$ are independent, and $E[\epsilon] = 0$. [12] The final wealth of the insider, choosing a level of investment $q$ and buying $x_i$ shares, is given by $W_i = vq - C(q) + (v - p)x_i$. The position of the entrepreneur in the market is therefore $q + x_i$.[13]

The insider has two motives to trade in the security market. First, he is interested in trading in order to hedge part of the risk coming from real investment $q$ ($vq - C(q)$ is the random value of the entrepreneur's endowment before trading in the security market). Secondly, he may trade for speculative reasons, in order to exploit his private information about $v$. The insider acts strategically, that is, takes into account the effect his demand has on prices and submits a demand schedule $X_i(s, p)$, contingent on the private information $s$ he observes. If $x_i$ is positive, the entrepreneur is a net buyer of shares while he is a net supplier if $x_i$ is negative ( $-x_i$ will be the entrepreneur's net supply of the risky asset). In equilibrium we will see that $Ex_i < 0$ and the entrepreneur will sell shares on average.

*Speculators.* There is a continuum of competitive uninformed speculators (or market makers) indexed in the interval [0, 1] (endowed with the Lebesgue measure). The final wealth of speculator

[12]We will use $\overline{x}$ , $Ex$ or $E[x]$ to denote the expected value of a random variable $x$, and $\sigma_x^2$ and $\sigma_{xy}$ to denote the variance of $x$ and the covariance between $x$ and $y$, respectively.

[13]Production and share issuing is modeled as in Leland (1992). See also Bray (1985) for a related model of futures markets where $p$ would correspond to the price in the futures market and $v$ to the future random spot price. Note also that our formulation is equivalent to letting the entrepreneur choose a fraction $k_i$ of the project to sell. Then, letting $-x_i = qk_i$ , we have that $W_i = vq - C(q) + (v - p/q)k_i$, which is equivalent to our formulation once the price of the asset is normalized according to the size of the project.

$k$ buying $x_{sk}$ shares at price $p$ is given by $W_{sk} = (v - p)x_{sk}$, where his initial non-random wealth is normalized to zero[14]. Speculators trade in order to obtain some profits by taking some of the risks that the entrepreneur and hedgers try to hedge (but their trades are not motivated by any informational advantage or any need of hedging).They do not bear any risk before trading in the security market. Speculators are risk averse and have CARA utilities: $U(W_{sk}) = -exp\{-\rho_s W_{sk}\}$, where $\rho_s > 0$. Speculator $k$ submits a demand schedule $X_{sk}(p)$. Since they have rational expectations, they use their observation of the price to update their beliefs about $v$.

*Hedgers.* There is a continuum of competitive hedgers indexed in the interval (1, 2] (endowed with the Lebesgue measure). Hedger $j$ has an initial endowment $u_j$ of an asset with future (random) value $z$ correlated with $v$. For example, suppose the firm is in the telecommunications sector and the hedger has participation on a nontraded firm in the same sector with liquidation value $z$; or, alternatively, $u_j$ is linked to the human capital of worker of the firm. The final wealth of hedger $j$ buying $x_{hj}$ shares at price $p$ is given by $W_{hj} = u_j z + (v - p)x_{hj}$. Hedgers are risk averse and have CARA utilities: $U(W_{hj}) = -exp\{-\rho_h W_{hj}\}$, where $\rho_h > 0$. Hedger $j$ privately observes $u_j$ and places a demand schedule $X_{hj}(p, u_j)$, contingent on his private information $u_j$. We assume that $u_j$ may be written as $u_j = u + \eta_j$, where $u$ and $\eta_j$ are independent (and $\eta_j$ is independent of $\eta_l$ for all $j \neq l$.). The usual convention that errors cancel out in the aggregate, $\int_1^2 \eta_j dj = 0 \quad a.s.$, will be used. As a result, $\int_1^2 u_j dj = \int_1^2 (u + \eta_j) dj = u + \int_1^2 \eta_j dj = u \quad a.s.$, so that $u$ is the aggregate risky endowment of the hedgers. A hedger uses the observation of the price to update his beliefs about $v$. Hedgers' main motive to trade is to reduce risks. However, the endowment shock to hedger $j$ is his private information and each hedger places a demand schedule. Therefore their demand has also a speculative component.

*Timing.* The timing of events in the model is as follows. At $t = 0$, the entrepreneur chooses the level of real investment $q$ and also the number of shares issued (at this time he has no private information). The level of investment $q$ is public information. At $t = 1$, the entrepreneur receives a private signal $s$ about $v$ and hedger $j$ gets an endowment shock $u_j$. At $t = 2$, the entrepreneur, speculators, and hedgers submit their demand schedules, the market clearing price is set and trade

[14] As is well-known, with constant absolute risk aversion, a trader's demand for a risky asset does not depend on his initial non-random wealth, so that we can assume (without loss of generality) that speculators have zero initial wealth.

occurs. Finally, at $t = 3$, the terminal values $z$ and $v$ are realized and agents consume. It may be useful to think about the insider as a coalition of the initial owners of the firm who face an investment opportunity. They (or their manager) decide the level of investment knowing that the next round of trade will incorporate the expectations about the value of the project and that the coalition of insiders will have by then privileged information. Risk aversion provides the incentive to float the project.

*Distributional assumptions.* All random variables are assumed to be normally distributed: $v \sim N(\overline{v}, \sigma_v^2)$, $z \sim N(\overline{z}, \sigma_z^2)$, $u \sim N(0, \sigma_u^2)$, $\epsilon \sim N(0, \sigma_\epsilon^2)$, and $\eta_j \sim N(0, \sigma_\eta^2)$ for all $j$. Without loss of generality, we assume that $z$ may be written as $z = \sigma_z[(\frac{r_{vz}}{\sigma_v})v + \sqrt{1 - r_{vz}^2}\xi]$ , where $r_{vz}$ is the correlation coefficient between $z$ and $v$, and $\xi \sim N(0, 1)$. Moreover, we assume that $\xi$ is independent of any other variable in the model and that $\text{cov}(v, u) = \text{cov}(s, u) = \text{cov}(v, u_j) = \text{cov}(s, u_j) = \text{cov}(v, \epsilon) = \text{cov}(v, \eta_j) = \text{cov}(u, \eta_j) = \text{cov}(s, \eta_j) = \text{cov}(\epsilon, u) = \text{cov}(\epsilon, \eta_j) = 0$ for all $j$ and $\text{cov}(\eta_j, \eta_l) = 0$ for all $j \neq l$.

Let $R_{sv}$ denote the square of the correlation coefficient between $s$ and $v$, $R_{sv} = \frac{\sigma_v^2}{\sigma_v^2 + \sigma_\epsilon^2}$, and let $R_u$ denote the square of the correlation coefficient between $u$ and $u_j$, $R_u = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_\eta^2}$.

Throughout this paper the subscript $i$ will refer to the insider; the subscript $s$ will refer to the speculators, and the subscript $h$ will refer to the hedgers.

*Linear equilibria and pricing.* We will restrict attention to perfect Bayesian linear (affine) equilibria. At these equilibria, agents' strategies at the market stage will be linear in the signals they observe:

- The insider's strategy will be a linear function of his private information $s$, the price $p$ (since he submits a limit order) and $q$. The strategy may be written (without loss of generality)[15] as

$$X_i(s, p) = \alpha_i(s - \overline{v}) + \beta_i(\overline{v} - p) - \gamma_i q$$

  where $\alpha_i$, $\beta_i$,and $\gamma_i$ are endogenous non-random parameters.

- Speculator $k$'s strategy may be written (without loss of generality) as

$$X_{sk}(p) = \beta_s(\overline{v} - p) - \gamma_s q$$

  where $\beta_s$,and $\gamma_s$ are endogenous non-random parameters.

[15] We should write $X_i(s, p) = \alpha_i s - \beta_i p - \gamma_i q + \varphi_i$ but in equilibrium we will have $\varphi_i = (-\alpha_i + \beta_i)\overline{v}$.

- Finally, hedger $j$'s strategy $x_{hj}$ will depend on his endowment shock $u_j$, the price, and $q$. We can assume that it may be written as

$$X_{hj}(p, u_j) = \beta_h(\overline{v} - p) - \delta u_j - \gamma_h q$$

where $\beta_h, \gamma_h$, and $\delta$ are endogenous non-random parameters.

The equilibrium price must satisfy the market clearing condition

$$X_s(p) + X_h(p, u) + X_i(p, s) + q = q, \tag{1}$$

where $X_s(p) = \int_0^1 X_{sk}(p)dk$ is the speculators' aggregate demand and $X_h(p, u) = \int_1^2 X_{hj}(p, u_j)dj$ is the hedgers' aggregate demand. Given the linear strategies posited above, $X_s(p) = \beta_s(\overline{v} - p) - \gamma_s q$, $X_h(p, u) = \beta_h(\overline{v} - p) - \delta u - \gamma_h q$, and equilibrium price is given by

$$p = \overline{v} + \frac{1}{\beta_i + \beta_s + \beta_h}\left[\alpha_i(s - \overline{v}) - \delta u\right] - \frac{(\gamma_i + \gamma_s + \gamma_h)}{(\beta_i + \beta_s + \beta_h)}q$$

or, equivalently,

$$p = \overline{v} - \Gamma q + \frac{\{\alpha_i(s - \overline{v}) - \delta u\}}{\Lambda}$$

where $\Gamma = \frac{(\gamma_i + \gamma_s + \gamma_h)}{(\beta_i + \beta_s + \beta_h)}$, and $\Lambda = \beta_i + \beta_s + \beta_h$. That is, the equilibrium price will be a linear function of the random inside information $s$, the hedgers' random aggregate endowment $u$ (errors $\eta_j$ cancel in the aggregate), and the level of real investment $q$.

*Reasonable parameter values.* We extend the analytical results with simulations. We take two base cases for our simulations. We postulate as central case that $\rho_h \geq \rho_i > \rho_s$ and that volatilities are not too far from market values (similar to those in Leland (1992), for example). The base case has $\rho_h = 3$, $\rho_i = 2$,and $\rho_s = 1$; volatilities are given by $\sigma_v = .2, \sigma_u = .1, \sigma_z = .2$ and covariances by $r_u = \sqrt{R_u} = .1$, $r_{vz} = \frac{\sigma_{vz}}{\sigma_v \sigma_z} = .91$, and $\overline{v} = 1$, $R_{sv}$ ranges from 0 to 1. In variation 1 (BC1) we have $c_1 = .9, c_2 = .02$ and in variation 2 (BC2), $c_1 = c_2 = 0$. We also consider variations in $\rho_h, \rho_i$, $r_u$, $\sigma_u$ and $\sigma_v$. (For example, we consider a volatility of the fundamental value of $\sigma_v = .6$, which is of the Nasdaq type in contrast with the base case of $\sigma_v = .2$, which is of the NYSE type; $\rho_h = 6$, $\rho_i \in \{.1, .2, .5, 1.5\}$ , high noise scenarios with $\sigma_u \in \{.5, .6, .7\}$ and $r_u = .4, .5$.)

# 3 Equilibrium with insider trading

In this section we characterize first equilibria in the securities market for a given investment level $q$ when the entrepreneur/insider is allowed to trade on the basis of his private information. We go on then to characterize the investment policy.

## 3.1 Equilibrium in the securities market

Speculator $k$'s objective function given his information $\{p\}$ can be written as

$$E[-\, exp\{-\rho_s W_{sk}\}|\, p] = -exp\{-\rho_s(E[W_{sk}|\, p] - \rho_s \operatorname{var}[W_{sk}|\, p]/2)\}.$$

This expression follows because we restrict ourselves to linear equilibria, which preserves the normality of $W_{sk}$ conditional on $p$.[16] Since $E[W_{sk}|\, p] = x_{sk}E[v - p|\, p]$ and $\operatorname{var}[W_{sk}|\, p] = x_{sk}^2 \operatorname{var}[v - p|\, p]$, maximizing with respect to $x_{sk}$ yields a demand function for the risky asset

$$X_{sk}(p) = \frac{E[v - p|\, p]}{\rho_s \operatorname{var}[v - p|\, p]} \tag{2}$$

which is linear in $p$ since $\operatorname{var}[v - p|\, p]$ is constant and $E[v - p|p]$ is linear in $p$ due to the normality assumption. All the speculators will place the same limit order (since all of them have the same information), so that the speculators' aggregate demand $X_s(p)$ will be given by the same expression. The demand will depend on $q$ because the knowledge of $q$ is needed to infer information about $s$ from the price. It may be written as $X_s(p) = \beta_s(\overline{v} - p) - \gamma_s q$.

Similarly, hedger $j$ will choose $x_{hj}$ to maximize

$$E[U(W_{hj})|\, p, u_j] = -exp\{-\rho_h(E[W_{hj}|\, p, u_j] - \rho_h \operatorname{var}[W_{hj}|\, p, u_j]/2)\},$$

where $E[W_{hj}|\, p, u_j] = u_j E[z|\, p, u_j] + (E[v|\, p, u_j] - p)x_{hj}$ and $\operatorname{var}[W_{hj}|\, p, u_j] = u_j^2 \operatorname{var}[z|\, p, u_j] + x_{hj}^2 \operatorname{var}[v - p|\, p, u_j] + 2u_j x_{hj} \operatorname{cov}[z,\, v - p|\, p, u_j]$. >shares is given by

$$X_{hj}(p, u_j) = \frac{E[v - p|\, p, u_j] - \rho_h u_j \operatorname{cov}[z,\, v - p|\, p, u_j]}{\rho_h \operatorname{var}[v - p|\, p, u_j]} \tag{3}$$

Hedger $j$'s demand may be decomposed in two terms:

[16] Using the fact that for a normally distributed random variable $e$

$$E[exp\{e\}] = exp\{E[e] + \operatorname{var}[e]/2\}.$$

- Speculative demand: $\frac{E[v-p|p,u_j]}{\rho_h \operatorname{var}[v-p|p,u_j]}$ , which will depend on $q$ (because this helps reading the information about $s$ in the price) and on $u_j$ provided that $R_u > 0$ (because then $u_j$ contains information on $u$ which in turn helps to recover information about $s$ in the price) and

- Hedge supply: $\frac{-\operatorname{cov}[z,v-p|p,u_j]}{\operatorname{var}[v-p|p,u_j]} u_j = -\frac{\sigma_{vz}}{\sigma_v^2} u_j$. The amount of the hedger's initial endowment $(u_j)$ that is hedged in the market is proportional to the correlation between the value of the hedger's asset $z$ and the return of the risky security $v-p$ conditional on the hedger's information $\{p, u_j\}$.

  The demand of hedger $j$ can be written then as $X_{hj}(p,u_j) = \beta_h(\overline{v}-p) - \gamma_h q - \delta u_j$ .The hedgers' aggregate demand will be given by

$$X_h(p,u) = \int_0^1 x_{hj}(p,u_j)dj = \beta_h(\overline{v}-p) - \gamma_h q - \delta \int_0^1 u_j dj = \beta_h(\overline{v}-p) - \gamma_h q - \delta u.$$

Now, from the market clearing condition, $x_s + x_h + x_i = 0$, the relation between the insider's trade $x_i$ and the price is given by

$$p = \overline{v} + \lambda[x_i - \delta u - (\gamma_s + \gamma_h)q], \quad \text{where} \quad \lambda = \frac{1}{\beta_s + \beta_h}.$$

The entrepreneur's maximization problem at the market stage is the following:

$$\max_{x_i} E[-\, exp\{-\rho_i W_i\} \,|\, s,p]$$

$$\begin{aligned} s.t. W_i &= vq - C(q) + (v-p)x_i, \text{ and} \\ p &= \overline{v} + \lambda[x_i - \delta u - (\gamma_s + \gamma_h)q]. \end{aligned}$$

Given normality this is equivalent to maximizing

$$E[W_i|\, s,p] - \frac{\rho_i}{2} \operatorname{var}[W_i|\, s,p] = qE[v|\, s] - C(q) + x_i \{E[v|\, s] - p\} - \frac{\rho_i}{2}(x_i+q)^2 \operatorname{var}[v|\, s].$$

Although the price has no information to aggregate, it is still useful from the insider's point of view since it allows him to infer the exact amount of noise trading (and thus eliminate the price risk it creates). If the second order condition holds, $2\lambda + \rho_i \operatorname{var}[v|\, s] > 0$, then the insider has a well-defined demand function

$$X_i(s,p) = \frac{E[v|\, s] - p - \rho_i q \operatorname{var}[v|\, s]}{\rho_i \operatorname{var}[v|\, s] + \lambda} \tag{4}$$

where $E[v|\,s] = \overline{v} + R_{sv}(s - \overline{v})$ and $\text{var}[v|\,s] = (1 - R_{sv})\sigma_v^2$. We may write $x_i$ as

$$X_i(s,p) = \alpha_i(s - \overline{v}) + \beta_i(\overline{v} - p) - \gamma_i q$$

where $\alpha_i = \frac{R_{sv}}{\rho_i(1-R_{sv})\sigma_v^2+\lambda}$, $\beta_i = \frac{1}{\rho_i(1-R_{sv})\sigma_v^2+\lambda}$, and $\gamma_i = \frac{\rho_i(1-R_{sv})\sigma_v^2}{\rho_i(1-R_{sv})\sigma_v^2+\lambda}$.
The entrepreneur's asset position can be decomposed into two terms:

- Speculative demand: $\frac{E[v|s]-p}{\rho_i\,[v|s]+\lambda}$, according to which the insider buys (sells) if his estimate of the asset liquidation value is greater (lower) than the price. Moreover, the weight put on inside information $\alpha_i$ is increasing in the precision of the information and is decreasing in the insider's risk aversion and the slope of residual supply.

- Hedge supply: $HS_i = \frac{\rho_i\,\text{var}[v|s]}{\rho_i\,\text{var}[v|s]+\lambda} q = \gamma_i q$. It depends on real investment, which determines the initial risk born by the entrepreneur before trading on the asset market, but it is independent of the realization of his information. Note that $\gamma_i > 0$, unless $R_{sv} = 1$ (perfect information) or $\rho_i = 0$ (risk neutrality) in which case the entrepreneur does not want to hedge any part of the investment. Furthermore, it is never optimal to hedge all the risk due to real investment, $\gamma_i < 1$, provided the entrepreneur has market power, $\lambda > 0$. He reduces then his hedge supply in order to get a higher (expected) price (a price-taking entrepreneur would have a hedge supply $HS_i = q$). The entrepreneur undertakes a risky business and then sells part of the risky asset to obtain insurance. We can think of $\gamma_i = HS_i/q$ as the hedge ratio.

Following a standard procedure (Kyle (1989)) we can characterize a linear imperfectly competitive rational expectations equilibrium (a linear Bayesian equilibrium in demand functions). The details are omitted.

**Proposition 1** *If there is an imperfectly competitive rational expectations equilibrium in the security market, it is given by*

$$x_s(p) = \beta_s(\overline{v} - p) - \gamma_s q$$

$$x_h(u) = \beta_h(\overline{v} - p) - \gamma_h q - \delta u$$

$$x_i(s,p) = \alpha_i(s - \overline{v}) + \beta_i(\overline{v} - p) - \gamma_i q$$

$$p = \overline{v} - \Gamma q + \frac{\{\alpha_i(s - \overline{v}) - \delta u\}}{\Lambda}$$

*where*

$$\Lambda = \beta_s + \beta_h + \beta_i,$$

$$\Gamma = (\gamma_s + \gamma_h + \gamma_i)/\Lambda,$$

$$\alpha_i = \frac{R_{sv}}{\rho_i(1 - R_{sv})\sigma_v^2 + \lambda},$$

$$\beta_i = \frac{1}{\rho_i(1 - R_{sv})\sigma_v^2 + \lambda},$$

$$\gamma_i = \frac{\rho_i(1 - R_{sv})\sigma_v^2}{\rho_i(1 - R_{sv})\sigma_v^2 + \lambda},$$

$$\beta_s = \frac{1}{\rho_s \sigma_v^2} \frac{\left[\delta^2 \sigma_u^2 - (\alpha_i/\lambda)\sigma_v^2\right]}{\left[\delta^2 \sigma_u^2 + (R_{sv}^{-1} - 1)\alpha_i^2 \sigma_v^2\right]},$$

$$\gamma_s = \frac{-\alpha_i}{\rho_s \left[\delta^2 \sigma_u^2 + (R_{sv}^{-1} - 1)\alpha_i^2 \sigma_v^2\right](1 + \alpha_i E)} \gamma_i,$$

$$\beta_h = \frac{1}{\rho_h \sigma_v^2} \frac{\left[(1 - R_u)\delta^2 \sigma_u^2 - (\alpha_i/\lambda)\sigma_v^2\right]}{\left[(1 - R_u)\delta^2 \sigma_u^2 + (R_{sv}^{-1} - 1)\alpha_i^2 \sigma_v^2\right]}$$

$$\gamma_h = \frac{-\alpha_i}{\rho_h \left[(1 - R_u)\delta^2 \sigma_u^2 + (R_{sv}^{-1} - 1)\alpha_i^2 \sigma_v^2\right](1 + \alpha_i E)} \gamma_i,$$

$$\delta = \left(\frac{\sigma_{vz}}{\sigma_v^2}\right) \left\{1 + \frac{R_u \alpha_i}{\rho_h \left[(1 - R_u)\delta^2 \sigma_u^2 + \left(R_{sv}^{-1} - 1\right) \alpha_i^2 \sigma_v^2\right]}\right\}^{-1},$$

$$\lambda = \frac{1}{\beta_s + \beta_h}.$$

*with* $E = \frac{1}{\rho_s}\left[\delta^2 \sigma_u^2 + (R_{sv}^{-1} - 1)\alpha_i^2 \sigma_v^2\right]^{-1} + \frac{1}{\rho_h}\left[(1 - R_u)\delta^2 \sigma_u^2 + (R_{sv}^{-1} - 1)\alpha_i^2 \sigma_v^2\right]^{-1}$.

In principle, to find the equilibrium we must solve a system of 11 equations with 11 unknowns ($\Lambda$, $\Gamma$, $\alpha_i$, $\beta_i$, $\gamma_i$, $\beta_s$, $\gamma_s$, $\beta_h$, $\gamma_h$, $\delta$, $\lambda$). However, if we have the equilibrium values of $\delta$and $\lambda$, then (from the first 9 equations) the equilibrium values of the first 9 parameters ($\Lambda$, $\Gamma$, $\alpha_i$, $\beta_i$, $\gamma_i$, $\beta_s$, $\gamma_s$, $\beta_h$, $\gamma_h$)are easy to compute.

By substituting the equations $\alpha_i = \frac{R_{sv}}{\rho_i(1-R_{sv})\sigma_v^2+\lambda}$, $\beta_s = \frac{1}{\rho_s\sigma_v^2}\frac{\left[\delta^2\sigma_u^2-(\alpha_i/\lambda)\sigma_v^2\right]}{\left[\delta^2\sigma_u^2+(R_{sv}^{-1}-1)\alpha_i^2\sigma_v^2\right]}$, and $\beta_h = \frac{1}{\rho_h\sigma_v^2}\frac{\left[(1-R_u)\delta^2\sigma_u^2-(\alpha_i/\lambda)\sigma_v^2\right]}{\left[(1-R_u)\delta^2\sigma_u^2+(R_{sv}^{-1}-1)\alpha_i^2\sigma_v^2\right]}$into the last two equations, we obtain the following two equations in $(\delta, \lambda)$.

$$\frac{R_u R_{sv}}{[\rho_i(1 - R_{sv})\sigma_v^2 + \lambda]}\delta = \rho_h \left[\left(\frac{\sigma_{vz}}{\sigma_v^2}\right) - \delta\right] \left\{(1 - R_u)\delta^2 \sigma_u^2 + \frac{(1 - R_{sv})R_{sv}\sigma_v^2}{[\rho_i(1 - R_{sv})\sigma_v^2 + \lambda]^2}\right\} \qquad (5)$$

$$\lambda = \frac{\sigma_v^2}{\delta^2\sigma_u^2} \frac{\left\{1 + \frac{\alpha_i}{\rho_s[\delta^2\sigma_u^2 + \alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]} + \frac{\alpha_i}{\rho_h[(1-R_u)\delta^2\sigma_u^2 + \alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]}\right\}}{\left\{1 + \frac{1}{\rho_s[\delta^2\sigma_u^2 + \alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]} + \frac{1-R_u}{\rho_h[(1-R_u)\delta^2\sigma_u^2 + \alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]}\right\}} \tag{6}$$

There is a linear equilibrium if and only if there is a solution to the above two-equation system in $(\delta, \lambda)$with $\lambda \geq 0$.

The next lemma specifies equilibrium restrictions for some endogenous parameters.

**Lemma 2** *In equilibrium the endogenous parameters satisfy the following inequalities:*

$$\lambda \geq \sigma_v^2 \left(\frac{\rho_s \rho_h}{\rho_s + \rho_h}\right),$$

$$\frac{\sigma_{vz}}{\sigma_v^2} \geq \delta \geq 0,$$

$$0 \leq \gamma_s + \gamma_h + \gamma_i \leq \gamma_i \leq 1,$$

*and*

$$\Gamma\Lambda \leq 1.$$

*Moreover,* $0 < |\gamma_s + \gamma_h| < \gamma_i < 1$, $\gamma_s < 0$, $\gamma_h < 0$, $\Lambda > 0$, $\Gamma > 0$, $\alpha_i \geq 0$, $\beta_i \geq 0$, $\beta_s \geq 0$, *and* $\beta_h \geq 0$.

Existence of a linear equilibrium can not be guaranteed. It is easy to find values of the exogenous parameters such that no linear equilibrium exists. However, the market never breaks down when the insider has no private information. The non-existence result is not surprising. Bhattacharya and Spiegel (1991) showed that when there is competition among strategic informed traders and rational hedgers the market may break-down. The reason is adverse selection. When the insider has no information there is no adverse selection problem. When he has private information then hedgers have also an informational advantage with respect to uninformed speculators. For example, if $R_u$ is close to 1 then hedger $j$ can recover from the price essentially the information of the insider because he observes $u_j$ and this is very close to $u$ . A linear equilibrium always exists when the adverse selection problem is moderate. This happens when the combined informational advantage of the insider and the hedgers is not very high; more precisely, when the risk-adjusted informational advantage of the insider ($R_{sv}/\rho_i$ ) and/or the hedgers ($R_u/\rho_h$ ) is sufficiently small.[17] This means

[17] It is worth noting that equilibrium may exist even if $R_{sv} = 1$. This will be so if, for some appropriate values of other parameters, $R_u/\rho_h$ is small enough.

in particular that a linear equilibrium exists when the main motive for trade for hedgers and the entrepreneur is insurance. This happens when they are very risk averse ( $\rho_h$ and/or $\rho_i$large) and/or their informational advantage small ($R_u$ and/or $R_{sv}$ small). The following proposition states the result.

**Proposition 3** *Given fixed values of the exogenous parameters $\sigma_{vz}$, $\sigma_u^2$, $\sigma_v^2$, $\sigma_z^2$, $\rho_s$, a unique linear equilibrium exists if $(R_{sv}/\rho_i)$ and/or $(R_u/\rho_h)$ are small. As $R_u/\rho_h$ or $R_{sv}/\rho_i$ tend to 0 the equilibrium parameter $\delta$ tends to $\frac{\sigma_{vz}}{\sigma_v^2}$.*

**Proof.** See Appendix. ■

Simulations in our range of "reasonable parameter values" BC1 show that largest value of $R_{sv}$, $\overline{R}_{sv}$ $(R_u/\rho_h)$ for which there is equilibrium is decreasing in $R_u/\rho_h$. For example, we have that $\overline{R}_{sv}$ $(.25/3) = .1156$, $\overline{R}_{sv}$ $(.16/3) = .2601$, $\overline{R}_{sv}$ $(.25/10) = .5625$, $\overline{R}_{sv}$ $(.01/3) = 1$.

The expected price is equal to the prior expected liquidation value minus a risk premium, $\overline{p} = \overline{v} - \Gamma q$. The risk premium is positive and is directly proportional to the level of investment, where $\Gamma = (\gamma_s + \gamma_h + \gamma_i)/(\beta_s + \beta_h + \beta_i)$.

We define the price precision as the inverse of the variance of the liquidation value given the information contained in the price. It is an index of the informativeness of the price about the liquidation value, $v$. The price contains information about $v$ if and only if traders with fundamentals information trade on the basis of that information. Thus, it is natural to expect that the higher the traders' sensibility to fundamentals information, the more informative the price. This is true in equilibrium.

The entrepreneur, on average, is a net supplier of the risky asset. That is, $Ex_i = q(\beta_i\Gamma - \gamma_i) < 0$ On one hand, since the risk premium is positive, the ex ante expected value of the speculative demand is positive. On the other hand, the entrepreneur sells a non-random quantity of the risky asset to hedge his real investment. In equilibrium, the entrepreneur's hedge supply is greater than his expected speculative demand.

## 3.2 Hedgers and noise traders

Many market microstructure models assume the existence of noise traders, agents that trade randomly for unspecified reasons. Noise traders are typically assumed to be agents that trade for liquidity reasons. Their utility is evaluated in terms of "cost of trading" or losses they make. In the usual CARA-Normal models the expected losses of noise traders (trading $u$ ) are $\frac{1}{\Lambda}\sigma_u^2$ where $\Lambda$ is an index of market depth.

Are there circumstances in which rational expected utility maximizing agents give rise to demands for assets of the "noise trader" form? Are expected losses an appropriate measure of their welfare? Our model has a response for these questions: The order flow will contain an exogenous supply $u$ (independent of any deep parameter of the model) whenever $z$ is perfectly correlated with $v$ and the risk-adjusted informational advantage of a hedger is vanishingly small ($R_u/\rho_h$ tending to 0 ).[18] This happens if hedgers are infinitely risk averse ($\rho_h \to \infty$ ) or if there is no correlation between each individual endowment shock $u_j$ and the average $u$ ($R_u \to 0$ ). In the first case hedgers just get rid of all the risk associated to their endowment and supply $u$ in the aggregate.[19] In the second hedgers are exactly like speculators because they have no informational advantage. In the aggregate they supply again $u$ but now they take a speculative position also. In both cases we can evaluate their expected utility. Indeed, according to the proposition above as $R_u/\rho_h$ or $R_{sv}/\rho_i$ tend to 0 the equilibrium demand of the hedgers tends to $X_h(p) = \beta_h(\overline{v}-p) - \gamma_h q - u$ if $\sigma_{vz} = \sigma_v^2$ , with $\beta_h \geq 0$ and $\gamma_h < 0$. (Furthermore, as $R_{sv}/\rho_i \to 0$ , $\gamma_h \to 0$ .) If $\rho_h \to \infty$ then $\beta_h = \gamma_h = 0$ .

### 3.3 Investment

For a given $q$ the insider's ex ante expected utility is given by

$$J_i(q) = E[-exp\{-\rho_i W_i\}] = -|SG_i||IG_i|exp\{-\rho_i[q\overline{v} - C(q) - (\rho_i/2)q^2\sigma_v^2]\}$$

where

$$\begin{aligned} |SG_i| &= \left\{1 + \frac{\rho_i(R_{sv}\sigma_v^2 + \delta^2\lambda^2\sigma_u^2)}{[\rho_i(1-R_{sv})\sigma_v^2 + 2\lambda]}\right\}^{-1/2}, \\ |IG_i| &= exp\{-(\rho_i^2/2)\sigma_v^2 dq^2\}, \end{aligned}$$

[18] See Srakar (1994) for results in related models.

[19] Hedger j's initial wealth may be written as $W_{hj} = u_j z = \frac{\sigma_{vz}}{\sigma_v^2}u_j v + \sigma_z\sqrt{1-r_{vz}^2}u_j\xi$. Hedger $j$ has an initial endowment $u_j$ of an asset with future (random) value $z$ or, equivalently, we may think that he has a portfolio of $\frac{\sigma_{vz}}{\sigma_v^2}u_j$ shares of the stock with liquidation value $v$ and $\sigma_z\sqrt{1-r_{vz}^2}u_j$ shares of some stock with future value $\xi$ (where $\xi$ is independent of $v$). In order to minimize risks, it is clear that hedger j's optimal strategy consists in selling his shares $\frac{\sigma_{vz}}{\sigma_v^2}u_j$ (since $\xi$ is independent of $v$ and there is no tradable security correlated with $\xi$).

$$d = \frac{\rho_i \sigma_v^2}{\rho_i \sigma_v^2 + 2\lambda + \rho_i \lambda^2 \delta^2 \sigma_u^2} \left\{ 1 + \frac{(1 - R_{sv})\lambda}{[\rho_i (1 - R_{sv})\sigma_v^2 + \lambda]} \frac{\alpha_i E}{(1 + \alpha_i E)} \right\}^2,$$

and

$$E = \frac{1}{\rho_s [\delta^2 \sigma_u^2 + \alpha_i^2 (R_{sv}^{-1} - 1)\sigma_v^2]} + \frac{1}{\rho_h [(1 - R_u)\delta^2 \sigma_u^2 + \alpha_i^2 (R_{sv}^{-1} - 1)\sigma_v^2]}.$$

The insider's ex ante expected utility is the product of three terms: the utility derived from the speculative demand $|SG_i|$, the utility coming from real investment, and the utility derived from the insurance achieved via the hedge supply $|IG_i|$.

The optimal investment level solves $\max_q J_i(q)$. This is equivalent to solving

$$\max_q [q\overline{v} - C(q) - 0.5\rho_i \sigma_v^2 q^2 (1 - d)].$$

The optimal level of real investment is obtained by equating (expected) marginal value $\overline{v}$ to marginal cost $C'(q) + \rho_i \sigma_v^2 (1 - d)q$, which is the sum of the marginal production costs and the (opportunity) cost related to the riskiness of real investment. The optimal level of real investment is increasing in $d$, which is a measure of hedging effectiveness of the asset market from the entrepreneur's point of view,

$$q^{IT} = \frac{\overline{v} - c_1}{c_2 + \rho_i \sigma_v^2 (1 - d)}. \quad (7)$$

As expected the direct impact of an increase in risk aversion $\rho_i$ or risk $\sigma_v^2$ is to decrease $q^{IT}$. There are other indirect effects operating through $d$ but the simulations we have performed with the model (see below) indicate that the direct effects prevail. Obviously, an increase in the cost parameters $c_1$, $c_2$ unambiguously decrease investment.

Finally, the insider's ex ante expected utility may be written as $EU_i \equiv J_i(q^{IT}) = -|SG_i| exp\{-.5\rho_i(\overline{v} - c_1)q^{IT}\}$.

The speculators' ex ante expected utility is given by

$$EU_s \equiv E[-exp\{-\rho_s W_s\}] = -|SG_s| exp \left\{ -0.5 \frac{(\Gamma q)^2}{\text{var}[E(v|\,p) - p] + \text{var}[v|\,p]} \right\}$$

where

$$|SG_s| = \left\{ 1 + \frac{\text{var}[E(v|\,p) - p]}{\text{var}[v|\,p]} \right\}^{-1/2},$$

$$\text{var}[E(v|\,p) - p] = \frac{\left[\delta^2 \sigma_u^2 + \alpha_i^2 R_{sv}^{-1} \sigma_v^2 - \alpha_i \Lambda \sigma_v^2\right]^2}{(\Lambda^2 \sigma_v^2)\left[\delta^2 \sigma_u^2 + \alpha_i^2 (1 - R_{sv}) R_{sv}^{-1} \sigma_v^2\right]}$$

and

$$\mathrm{var}[v|p] = \sigma_v^2 \frac{\left[\delta^2\sigma_u^2 + \alpha_i^2(1-R_{sv})R_{sv}^{-1}\sigma_v^2\right]}{\left[\delta^2\sigma_u^2 + \alpha_i^2 R_{sv}^{-1}\sigma_v^2\right]}.$$

Note that, for given $\Lambda$ and $\lambda$, $EU_s$ increases with the risk premium $\Gamma q$, which is nothing else than the expected margin $E(v-p) = \overline{v} - \overline{p} = \Gamma q$ .

The expressions for the expected utility of a hedger $EU_h$ are complicated (see Section A.1 in the Appendix) but simulations show that, for given $\Lambda$ and $\lambda$, $EU_h$ also increases with the risk premium $\Gamma q$. To gain intuition why $E[U(W_h)]$ decreases with $\overline{p} = \overline{v} - \Gamma q$ note that when the hedger hedges his endowment the return is precisely $p$ and a higher expected level of $p$ increases the risk borne by the agent. (If $v = z$, so that $\sigma_{vz} = \sigma_v^2$ , and the endowment is completely hedged $x_{hj} = -u_j$ , then $W_{hj} = u_j z + (v-p)x_{hj} = u_j p$ ). Furthermore, it is possible to show that if hedgers are risk averse enough then $EU_h$ increases with $\Lambda$, and decreases in $Var\,[p]$ , for given other equilibrium parameters.[20]

## 4 Equilibrium with public disclosure

We wish to compare the equilibrium with insider trading, which is described in Proposition 1, with the equilibrium in the same market without insider trading. What is meant exactly with a "market without insider trading"? A wide variety of restrictions on insider trading could be considered. We will explore in the next section the consequences of prohibiting insider trading via a disclose-or-abstain rule. Two relevant benchmarks will be a disclosure regime (PD) in which the entrepreneur publicly reveals his inside information $s$ and a no-information regime (NI) in which the entrepreneur has no private information, $R_{sv} = 0$. In this section we explore the two benchmarks in which there is symmetric information about $v$.

If the insider publicly reveals his private information $s$ before trading in the asset market, all the agents share the same information about $v$. The next proposition describes the equilibrium in this case.

**Proposition 4** *PD Regime. If $R_{sv} < 1$ and the entrepreneur publicly discloses his inside information before trading on it, then there is a unique linear imperfectly competitive rational expectations*

[20] It can be seen also that in this case $EU_h$ increases with the risk premium $\Gamma q$ for given $\Lambda$ and $\lambda$.

*equilibrium in the asset market characterized by*

$$x_s(s,p) = \beta_s(\overline{v} - p) + \alpha_s(s - \overline{v})$$

$$x_h(u) = \beta_h(\overline{v} - p) + \alpha_h(s - \overline{v}) - \delta u$$

$$x_i(s,p) = \alpha_i(s - \overline{v}) + \beta_i(\overline{v} - p) - \gamma_i q$$

$$p = E[v|\,s] - \Gamma q - \frac{\delta u}{\Lambda}$$

*where* $\Lambda = \beta_s + \beta_h + \beta_i$, $\Gamma = \frac{\gamma_i}{\Lambda}$ $\alpha_i = \frac{R_{sv}}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]}$, $\beta_i = \frac{1}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]}$, $\gamma_i = \frac{\rho_i(1-R_{sv})\sigma_v^2}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]}$, $\alpha_s = \frac{R_{sv}}{[\rho_s(1-R_{sv})\sigma_v^2]}$, $\beta_s = \frac{1}{[\rho_s(1-R_{sv})\sigma_v^2]}$, $\alpha_h = \frac{R_{sv}}{[\rho_h(1-R_{sv})\sigma_v^2]}$, $\beta_h = \frac{1}{[\rho_h(1-R_{sv})\sigma_v^2]}$, $\delta = (\sigma_{vz}/\sigma_v^2)$, *and* $\lambda = \frac{\rho_h\rho_s}{\rho_h+\rho_s}(1 - R_{sv})\sigma_v^2$.

*The level of real investment chosen by the entrepreneur is given by* $q = \frac{\overline{v}-c_1}{c_2+\rho_i\sigma_v^2(1-d)}$ *where* $D = \frac{\rho_i(1-R_{sv})\sigma_v^2+2\lambda}{\rho_i\Lambda^2+\rho_i^2\beta_i^2[\rho_i(1-R_{sv})\sigma_v^2+2\lambda]\delta^2\sigma_u^2}\left(\frac{\gamma_i}{\lambda}\right)^2$.

**Proof.** See Appendix. ■

For a given $q$ the insider's expected utility is given by

$$E[-exp\{-\rho_i W_i\}] = -|SG_i|exp\{-\rho_i[q\overline{v} - C(q) - 0.5\rho_i q^2(\sigma_v^2 - D)]\}$$

where $|SG_i| = \left\{1 + \rho_i[\rho_i(1 - R_{sv})\sigma_v^2 + 2\lambda]\left(\frac{\beta_i}{\Lambda}\right)^2\delta^2\sigma_u^2\right\}^{-1/2}$. A speculator's expected utility is given by

$$E[-exp\{-\rho_s W_{sk}\}] = -|SG_s|exp\left\{-\frac{(\gamma_i q)^2}{2\left[\Lambda^2(1 - R_{sv})\sigma_v^2 + \delta^2\sigma_u^2\right]}\right\}$$

where $|SG_s| = \left[1 + \frac{\delta^2\sigma_u^2}{\Lambda^2(1-R_{sv})\sigma_v^2}\right]^{-1/2}$.

*Remark:* If everybody knows the exact value of $v$, $R_{sv} = 1$, the security market breaks down. Otherwise equilibrium always exists because neither the entrepreneur nor the hedgers have an informational advantage. If $R_{sv} = 1$, the unique possible equilibrium price is $p = v$ (at any price above -below- $v$ all the traders would like to buy -sell- an unbounded amount of shares), but at that price nobody has any incentive to trade because of risk aversion.

When $s$ is public information the hedgers do not have an informational advantage since $u$ is revealed by the price. The outsiders (hedgers and speculators) do not face adverse selection since the entrepreneur does not have any informational advantage either. In this case there is a linear equilibrium for all parameter configurations (except if $R_{sv} = 1$) . Outsiders are more willing to provide liquidity and the price impact of the entrepreneur's demand will tend to be lower. Moreover, the riskiness of the asset, from the outsiders' point of view, is now lower since they have more information. Both effects tend to increase the outsiders' trading intensity and, consequently, the depth of the market.

The expected price equals the expected liquidation value conditional on the public information about $v$ minus the risk premium.

Note that the only equilibrium parameter affected by $\sigma_{vz}$ is $\delta$. In particular, $q^{PD}$ is independent of $\sigma_{vz}$ . If $\delta = 1$ then hedgers supply $u$ in the aggregate. Furthermore, the entrepreneur's hedge ratio $\gamma_i$ is independent of $R_{sv}$ (and of any variance of the random variables in the model) and depends only on the degree of risk aversion of the agents in the economy.

The strategies of the outsiders do not depend on $q$.[21] This is so because $s$ is known and it need not be inferred from the price. At the same time since there is no informational asymmetry between the insider and the outsiders, the entrepreneur's speculative demand and the expected production return (conditional on the entrepreneur's information) are uncorrelated. That is, $\text{cov}\{X_i(s,p), E[v|s]\} = 0$. This is in contrast to the case of insider trading.

We now derive the equilibrium of the model when the insider does not have any private information before trading in the asset market. The equilibrium may be directly derived from the last proposition letting $R_{sv} = 0$ and is described in the following corollary.

**Corollary 5** *NI Regime. If the entrepreneur does not have any inside information ($R_{sv} = 0$), then there is an unique linear imperfectly competitive rational expectations equilibrium in the asset market, that is characterized by*

$$x_s(p) = \beta_s(\overline{v} - p)$$

$$x_h(u) = \beta_h(\overline{v} - p) - \delta u$$

$$x_i(s,p) = \beta_i(\overline{v} - p) - \gamma_i q$$

$$p = \overline{v} - \Gamma q - \frac{\delta u}{\Lambda}$$

*where* $\Lambda = \beta_s + \beta_h + \beta_i$, $\Gamma = \sigma_v^2 \left[\frac{2}{\rho_i} + \frac{1}{\rho_h} + \frac{1}{\rho_s}\right]^{-1}$, $\lambda = \frac{\rho_h \rho_s}{\rho_h + \rho_s}\sigma_v^2$, $\delta = (\sigma_{vz}/\sigma_v^2)$, $\beta_i = \frac{(\rho_s + \rho_h)}{[\rho_i(\rho_s + \rho_h) + \rho_s \rho_h]\sigma_v^2}$, $\gamma_i = \frac{\rho_i(\rho_s + \rho_h)}{[\rho_i(\rho_s + \rho_h) + \rho_s \rho_h]}$, $\beta_s = \frac{1}{[\rho_s \sigma_v^2]}$, *and* $\beta_h = \frac{1}{[\rho_h \sigma_v^2]}$.

[21] The speculator's demand is given by $X_s(p,s) = \frac{E[v|s] - p}{\rho_s \text{var}[v|s]}$. Hedger's $j$ demand is given by $X_{hj}(p,s,u_j) = \frac{E[v|s] - p}{\rho_h \text{var}[v|s]} - \frac{\sigma_{vz}}{\sigma_v^2} u_j$.

The next proposition and claim analyze the main effects of changes in the precision of information about $v$ with public disclosure. It also allows us to compare the equilibria described in the proposition 4 (with public revelation of inside information) and the corollary 5 (no inside information).

**Proposition 6** *Assume that the entrepreneur publicly discloses his inside information before trading takes place. If $R_{sv}$ increases, then*

1. *Trading intensities ($\alpha_i$, $\beta_i$, $\alpha_s$, $\beta_s$, $\alpha_h$, and $\beta_h$) increase.*
2. *The market becomes deeper ($\Lambda$ increases).*
3. *The level of real investment decreases.*
4. *The stock price becomes more informative.*
5. *The risk premium ($\frac{\gamma_i q}{\Lambda}$) is lower and the average stock price is higher.*
6. *The expected utility of both the insider and the speculators decrease.*

**Claim 7** *(Simulations: BC1,2 and variations, see Table 1) If $R_{sv}$ increases then*

- *prices are more volatile, and*
- *the expected utility of hedgers decreases. This means that in all simulations performed $EU_h^{NI} > EU_h^{PD}$.*

*Remark:* Increasing public information is typically Pareto inferior and the "welfare" criterion of minimizing noise trader losses is therefore typically misleading. Indeed, as $R_{sv}$ increases market depth $\Lambda$ increases at the same time that the expected utility of all traders goes down[22]. This is so because for hedgers the increase in $\Lambda$ is more than compensated by an increase in the variance of prices and a decrease in the risk premium. This can not happen in a noise trader model.

This proposition collects the main effects of public information on real investment and on the efficiency of financial markets. If the precision of public information increases, all the agents trade

[22]Recall that in a noise trader model the expected losses of noise traders are proportional to $\Lambda$.

more aggressively because the ex post volatility of the risky asset is lower. As a direct consequence, the stock price will be more informative, since traders react more to their information. Moreover, the market depth is higher, since it is proportional to the traders' aggregate price sensibility. The impact on price volatility is ambiguous: More informative prices will tend to be more volatile but at the same time the market is becoming deeper. The first effect dominates unless $\sigma_v$ $\sigma_u$ is very large.

The level of real investment $q$ is decreasing in $R_{sv}$. The reason is the Hirshleifer effect: public information reduces the risk sharing opportunities provided by financial markets since it destroys insurance opportunities for the entrepreneur and hedgers (the latter by revealing information correlated with their endowment shock).

The risk premium $(\gamma_i/\Lambda)q$ is decreasing in the precision of public information because increases in $R_{sv}$ make market depth $\Lambda$ to increase and $q$ to decrease (and the hedge ratio of the entrepreneur $\gamma_i$ is independent of $R_{sv}$ ). If the precision of $s$ increases, the entrepreneur's hedge supply $\gamma_i q$ decreases, as well as his expected net asset position $\frac{dE[x_i]}{dR_{sv}} < 0$ (indeed, $E[x_i] = \gamma_i q((\beta_i/\Lambda) - 1)$ ). This happens because the optimal level of real investment is decreasing in $R_{sv}$.

The effect of increases in $R_{sv}$ on the expected utility of the entrepreneur is negative. This is so because both speculative and production related gains diminish with better public information (the latter because $q$ decreases). The same true for the expected utility of speculators. The expected utility of hedgers decreases in the simulations performed. The decrease in the risk premium, compounded with the increased volatility, outweigh the positive effect of an increased market depth.

# 5 Effects of Insider Trading

If the market is subject to a disclose-or-abstain rule the entrepreneur should either publicly reveal his inside information $s$ or abstain to trade on the basis of that information.[23] To examine the desirability of such a disclose-or-abstain rule we need to know what are the effects of imposing the rule. Suppose first that the entrepreneur/insider learns $s$ for free in the course of his activity. Then when faced with the choice or disclosing $s$ and trading or not disclosing and not being able to trade

[23] If the entrepreneur has private information perhaps he can commit his portfolio to an independent trust with instructions to do as well as possible but, obviously, with no inside information. Then instead of abstaining from trade he (the trust's manager) will trade as if $R_{sv} = 0$ .

on the information, he will choose to disclose because by not trading he can not hedge at all the investment risk.[24] This means then that the relevant welfare comparison is between a disclosure regime (PD) and insider trading (IT).[25]

Suppose now that to learn $s$ costs some effort. Then the entrepreneur will never spend any effort in learning $s$ if the information has to be disclosed before use. (Indeed, if he obtains the information he will like to disclose it and trade but we know from Proposition 6 that the entrepreneur is better off when no information about $v$ is available. Therefore he will choose not to collect any information).[26] This means that the relevant welfare comparison is between a regime in which the entrepreneur has no private information, $R_{sv} = 0$ (NI) and insider trading (IT).

The relevant benchmarks of comparison are then the equilibrium with insider trading (IT), the equilibrium with public disclosure of $s$ (PD)and the equilibrium with no private information on $v$ (NI).

*Remark:* A disclose-or-abstain rule effects a Pareto improvement when with insider trading the market collapses.

## 5.1 Insider trading versus no information on $v$

In this subsection we compare the equilibrium when insider trading is permitted with the equilibrium in a similar market in which the entrepreneur does not have any inside information. That is, we compare the equilibrium described in proposition 1 with the equilibrium described in corollary 5. All we have to do is to analyze the comparative statics of the endogenous parameters that characterize the equilibrium when insider trading is allowed with respect to $R_{sv}$. We do so in the case in which we can ensure that there is a unique equilibrium ($R_u/\rho_h$ small). The robustness of the results are checked with simulations (see Claim below).

[24] It is possible to check that the expected utility of the insider and speculators strictly decreases if there is no trade either in relation to the public disclosure or the no information regimes. This is also the case for hedgers provided that their expected utility does not diverge to minus infinity. For the entrepreneur we have that $EU_i^{NoTrade} < EU_i^{PD} < EU_i^{NI}$.

[25] However, if the entrepreneur can commit his portfolio to a trust then according to Proposition he will prefer to "abstain" rather than "disclose" because the expected utility of the insider decreases with $R_{sv}$ when information is public. In this case the relevant comparison would be between the no information regime and insider trading.

[26] The result also holds if the entrepreneur can hire an agent to invest on his behalf. Then if he obtains the information he can not use it and therefore will never pay for the information.

#### 5.1.1 Comparative statics of IT equilibria with respect to $R_{sv}$

**Proposition 8** *Let $\frac{R_u}{\rho_h}$ be close to 0. If the entrepreneur has and trades on inside information, then:*

1. *The insider's trading intensity increases,* $\alpha_i^{IT} > \alpha_i^{NI}$ $(\frac{d\alpha_i^{IT}}{dR_{sv}} > 0)$.
2. *Speculators and hedgers trade less aggresively,* $\beta_s^{IT} < \beta_s^{NI}$ *and* $\beta_h^{IT} < \beta_h^{NI}$ $(\frac{d\beta_s^{IT}}{dR_{sv}} < 0$ *and* $\frac{d\beta_h^{IT}}{dR_{sv}} < 0)$. *Similarly,* $\lambda^{IT} > \lambda^{NI}$ $(\frac{d\lambda^{IT}}{dR_{sv}} > 0)$.
3. *If $\rho_i$ is not too large, market depth decreases,* $\Lambda^{IT} < \Lambda^{NI}$ $(\frac{d\Lambda^{IT}}{dR_{sv}} < 0)$.
4. *Price precision increases,* $\tau^{IT} > \tau^{NI}$ $(\frac{d\tau^{IT}}{dR_{sv}} > 0)$.
5. *If $\rho_i$ is not too high then* $var\left[p^{IT}\right] > var\left[p^{NI}\right]$ $(\frac{dvar\left[p^{IT}\right]}{dR_{sv}} > 0)$.
6. *If $R_{sv}$ is close to 1 real investment decreases,* $q^{IT} < q^{NI}$ $(\frac{dq^{IT}}{dR_{sv}} < 0)$.
7. *If $R_{sv}$ is close to 1 the average stock price will increase,* $\overline{p}^{IT} > \overline{p}^{NI}$.
8. *The insider's speculative gains will be higher ( $|SG_i^{IT}| < |SG_i^{A}|$ ) while his production and insurance gains will be lower* $(exp\{-.5\rho_i(\overline{v}-c_1)q^{IT}\} > exp\{-.5\rho_i(\overline{v}-c_1)q^{NI}\})$ *if $R_{sv}$ is close to 1. We have that* $E[U_i^{IT}] > E[U_i^{NI}]$ *for $\rho_i$ low.*
9. *If $R_{sv}$ is close to 1 the speculators' ex ante expected utility will be reduced,* $E[U_s^{IT}] < E[U_s^{NI}]$.

**Proof.** The key to the proof is to show that for $R_u/\rho_h$ be close to 0, $\frac{d\lambda}{dR_{sv}} > 0$. See the Appendix. ■

**Claim 9** *(Simulations). For reasonable parameter values (BC1,2):*

1. $\Lambda^{IT} < \Lambda^{NI}$ $((\frac{d\Lambda}{dR_{sv}}) < 0)$.
2. $\mathrm{var}[p^{IT}] > \mathrm{var}[p^{NI}]$ $(\frac{d\,\mathrm{var}[p]}{dR_{sv}} > 0)$.
3. $q^{IT} < q^{NI}$ $((\frac{dq}{dR_{sv}}) < 0)$.
4. $\overline{p}^{IT} > \overline{p}^{NI}$ $(\frac{d\overline{p}}{dR_{sv}} > 0)$.
5. $E[U_i^{IT}] < E[U_i^{NI}]$ *($E[U_i]$ is either decreasing or U-shaped with $R_{sv}$).*
6. $E[U_s^{IT}] < E[U_s^{NI}]$ $(\frac{dE[U_s]}{dR_{sv}} < 0)$.
7. $E[U_h^{IT}] < E[U_h^{NI}]$ $(\frac{dE[U_h]}{dR_{sv}} < 0)$.

Simulations are performed for the base cases (BC1 and 2). However, the results (as well as the analytical results (1), (2), (4)) hold also for $R_u/\rho_h$ not close to 0 (in particular for $R_u$=.16 and $R_u$=.25).

In the simulations performed (see Table 1 where results for BC1are displayed) some quantitative effects are notable. (1) $\Lambda^{NI}$ is much larger than $\Lambda^{IT}$ even for $R_{sv}$ small (from $R_{sv} = 0$ to $R_{sv} = 1/20$ $\Lambda$ drops by 91%). (2) A similar effect (although not so drastic) holds for $q$ (from $R_{sv} = 0$ to $R_{sv} = 1/20$ $q$ drops by 34\%).(3) Price precision doubles as $R_{sv}$ increases from 0 to 1 and price volatility increases dramatically at the beginning ( by 214% from $R_{sv} = 0$ to $R_{sv} = 1/20$) (4) $E[U_i^{IT}]$ changes moderately as $R_{sv}$ ranges from 0 to 1: it falls at most by 7%. (5) $E[U_h^{IT}]$ falls by 35% from $R_{sv} = 0$ to $R_{sv} = 1/20$ and by a further 88% until $R_{sv} = 1$.

For BC2 the drop in the expected utilities of the traders when there is insider trading is phenomenal (from $R_{sv} = 0$ to $R_{sv} = 1/20$ $E[U_i]$ drops by a factor of $10^5$ and $E[U_h]$ by a factor of 300; to $R_{sv} = 1$ there is a further drop by a factor of $10^6$ in the first case and by 200% in the second). In BC2 investment has no real cost and therefore $q$ is much larger and the entrepreneur needs to hedge much more.

TABLE 1 HERE

We find that $E[U_i^{IT}] > E[U_i^{NI}]$ when $\rho_i$ =.2 or lower with the rest of parameters as in BC1(for $\rho_i$ =.1 $E[U_i^{IT}]$ increases with $R_{sv}$ for all $R_{sv}$).

In high "noise" environments but otherwise for "reasonable" parameter values (for example, BC1 with $\sigma_u = .7$) we have also that $E[U_i^{IT}]$ increases with $R_{sv}$ for all $R_{sv}$. (For $\sigma_u = .5$, $E[U_i^{IT}]$ is U-shaped with $R_{sv}$ with $E[U_i^{IT}] > E[U_i^{NI}]$ for $R_{sv}$ high .)

Some explanations follow.

1. When insider trading is permitted, the insider trades more aggressively, $\alpha_i^{IT} > \alpha_i^{NI}$. Two reasons explains this result: The expected return from the insider's point of view is increasing in the precision of insider information and the insider feels a lower risk because he has more information.

2. The speculators and the hedgers trade less aggressively with insider trading, $\beta_s^{IT} < \beta_s^{NI}$ and $\beta_h^{IT} < \beta_h^{NI}$, because they face adverse selection. Since the entrepreneur trades more aggressively, the order flow is more likely to reflect the inside information and, as a result,

uninformed traders become less willing to trade. As a direct consequence of this fact, the marginal impact of the entrepreneur's asset position on the current price will be higher when insider trading is permitted, $\lambda^{IT} > \lambda^{NI}$.

3. For reasonable parameter values, market depth is reduced by insider trading. Market depth is equal to the sum of the price sensitivities of demands, $\Lambda = \beta_s + \beta_h + \beta_i$. That is, market depth is high (low) if the demands of the different agents increase a lot (little) when the price decrease a little. When insider trading is permitted speculators and hedgers are less willing to trade, that is, become less sensitive to changes in current price. Furthermore, since the price impact of the entrepreneur's asset position is higher, he will tend to reduce his trades. Both effects tend to make the market thinner. In the simulations market depth is reduced drastically. For a low risk aversion of the insider this has to be true always. Indeed, when $R_{sv}$ increases there are two effects on $\Lambda$. A positive direct effect given $\lambda$ (because the insider responds more to the price) which is weighted by $\rho_i$, and a negative indirect effect which increases $\lambda$. (As a result also, if insider trading is allowed, the amount of the hedgers' initial endowment that is covered decreases; that is, $\delta$ is decreasing in $R_{sv}$.)

4. Price precision is increased by insider trading. The equilibrium price is informationally equivalent to $\alpha_i(s - \overline{v}) - \delta u$ , so that price precision is given by

$$\tau = \left[\sigma_v^2 - \frac{(\alpha_i \sigma_{sv})^2}{\alpha_i^2 \sigma_s^2 + \delta^2 \sigma_u^2}\right]^{-1} = \frac{\alpha_i^2 \sigma_v^2 + R_{sv} \delta^2 \sigma_u^2}{\sigma_v^2 \left[\alpha_i^2 \sigma_v^2 (1 - R_{sv}) + R_{sv} \delta^2 \sigma_u^2\right]}.$$

Price precision is increasing in $\alpha_i$ and decreasing in $\delta$. That is, the informativeness of current prices increases with the amount of trading motivated by fundamentals information and decreases with the amount of noise created by hedging trades. If insider trading is permitted, $\alpha_i$ increases because the entrepreneur is better informed and market depth decreases, and, consequently, $\delta$ is reduced by hedgers. Both effects tend to increase price precision.

5. For reasonable parameter values, current prices will be more volatile with insider trading. Price volatility is caused by noise trading and by information about $v$. When insider trading is permitted, moreover, price volatility due to noise trading increases if the market becomes thinner (and this happens for reasonable parameter values or if $\rho_i$ is sufficiently close to

zero).[27]

6. Permitting insider trading tends to reduce the level of real investment since it reduces the risk sharing opportunities provided by the asset market. This is because it creates an adverse selection problem which makes speculators and hedgers less willing to share the risk coming from real production.

7. The average stock price tends to increase with insider trading. Two effects explain this result. The insider's hedge supply is lower since the level of real investment is lower and the insider's speculative demand is higher since it is increasing in the precision of inside information. A countervailing effect is that market depth may decrease tending to increase the risk premium. The latter effect tends to be dominated for reasonable parameter values and when $R_{sv}$ is close to 1 .

8. If insider trading is permitted, the insider's speculative gains will be higher while his insurance and production gains will be lower, $|SG_i^{IT}| < |SG_i^{NI}|$ and $exp\{-.5\rho_i(\overline{v} - c_1)q^{IT}\} > exp\{-.5\rho_i(\overline{v} - c_1)q^{NI}\}$. On the one hand, speculative gains increase with the precision of inside information. On the other hand, inside information creates an adverse selection problem: Speculators and hedgers become less willing to share the risk coming from production. As a result, the entrepreneur's gains coming from real investment and the level of real investment go down. The entrepreneur's expected utility may increase or decrease depending on whether the speculative effect dominates or not. If the entrepreneur is sufficiently risk averse, his expected utility will decrease when insider trading is allowed. The opposite result will hold if he is very close to risk neutral. In fact, if the entrepreneur is risk neutral then his expected profits are always larger with insider trading and increasing in $R_{sv}$ (and the expected profits in the NI regime are in turn larger than in the PD regime). In our range of reasonable parameter values the insurance losses from insider trading dominate the speculative gains.

9. If inside information is sufficiently precise, the speculators' expected utility will be reduced

[27] Price volatility is given by $\text{var}[p] = (\sigma_u/\Lambda)^2 + R_{sv}((\rho_i(1 - R_{sv})\sigma_v^2 + \lambda)^{-1}/\Lambda)^2\sigma_v^2$. We have that $(\rho_i(1 - R_{sv})\sigma_v^2 + \lambda)^{-1}/\Lambda = \frac{\lambda}{2\lambda + \rho_i(1 - R_{sv})\sigma_v^2}$, which is increasing in $R_{sv}$ since $\frac{d\lambda}{dR_{sv}} > 0$ . Therefore, $\frac{d\,\text{var}[p]}{dR_{sv}} > 0$ if the conditions that make $\Lambda$ decreasing in $R_{sv}$ hold. That is, if the parameters of the model take reasonable values or if $\rho_i$ is sufficiently close to zero.

by insider trading, $EU_s^{IT} < EU_s^{NI}$ because in this situation the average stock price goes up (and, as a direct result, the expected return $[\overline{v} - \overline{p}]$ goes down) and speculators trade less aggressively.. For reasonable parameter values we have also that $[\overline{v} - \overline{p}]$ goes down with insider trading and therefore we have the same result.

10. Three effects tend to reduce hedgers' expected utility under insider trading. First, obtaining insurance is more costly when insider trading is allowed because the market is thinner. Second, the increase in price volatility also tends to hurt hedgers, specially if they are very risk averse. Furthermore, when insider trading reduces risk premia this also hurts hedgers' expected utility. The three effects happen for reasonable parameter values.

The picture that emerges for reasonable parameter values, is the following: Insider trading reduces market depth and investment, and increases the expected price (reducing the risk premium) and the price precision with the result that the expected utility of all traders decreases. Insider trading is Pareto inferior. The possibility remains that if $\rho_i$ is very low the insider improves with insider trading. However for this to happen the entrepreneur must be close to risk neutral, an unlikely event.

### 5.2 Insider trading versus public disclosure

Finally, we compare the equilibrium when insider trading is permitted (IT) with the equilibrium when the entrepreneur publicly announces his private information before trading takes place (PD). That is, we compare the equilibria described in propositions 1 and 4. We present analytical results for the case in which we can ensure that there is a unique equilibrium ($R_u/\rho_h$ small) and we check the robustness of the results with simulations (see Claim).

**Proposition 10** *Let $\frac{R_u}{\rho_h}$ be close to 0, then with insider trading*

1. *The insider trades less aggressively: $\alpha_i^{IT} < \alpha_i^{PD}$.*

2. *The outsiders are less less responsive to price movements, $\beta_s^{IT} < \beta_s^{PD}$ and $\beta_h^{IT} < \beta_h^{PD}$ for $R_{sv} > 0$ (and $\beta_s^{PD} - \beta_s^{IT}$ and $\beta_h^{PD} - \beta_h^{IT}$ are increasing in $R_{sv}$).*

3. *The market becomes thinner: $\Delta^{IT} < \Lambda^{PD}$.*

4. *Price precision is reduced:* $\tau^{IT} < \tau^{PD}$. *If* $R_{sv}$ *is close to 1 then* $Var\left[p^{PD}\right] > 2Var\left[p^{IT}\right]$.

5. *If* $R_{sv}$ *is close to 1 then* $q^{IT} > q^{PD}$.

6. *The speculative gains of the insider are larger. If* $R_{sv}$ *is close to 1 (and/or* $\rho_i$ *is close to 0), then* $E[U_i^{IT}] > E[U_i^{PD}]$.

7. *If* $R_{sv}$ *is close to 1 (and/or* $\rho_i$ *is close to 0),* $E[U_{sk}^{IT}] > E[U_{sk}^{PD}]$. .

**Claim 11** *For reasonable parameter values:*

1. *Insider trading reduces* $Var\ p$ *and the risk premium.*
2. $q^{IT} < q^{PD}$ *(except for* $R_{sv}$ *very close to* 1).
3. $E[U_i^{IT}] < E[U_i^{PD}]$ *(except for* $R_{sv}$ *very close to* 1).
4. $E[U_s^{IT}] < E[U_s^{PD}]$ *(except for* $R_{sv}$ *very close to* 1).
5. *Insider trading increases (decreases) the expected utility of hedgers if* $R_{sv}$ *is high (low)*

*Remark:* In high noise scenarios $R_{sv}$ need not be so close to 1 for $q^{IT} > q^{PD}$ (for example, this holds for BC1 with $\sigma_u$=.7 when $R_{sv} \geq 14/20$).

*Remark:* In high noise scenarios $R_{sv}$ need not be so close to 1 to obtain $q^{IT} > q^{PD}$ (for example, this holds with $\sigma_u$=.7 and the other parameters as in BC1 when $R_{sv} \geq 14/20$).

Some explanations follow.

1. Public disclosure makes the insider trade more intensely.

2. If inside information becomes public, the informational asymmetry and the adverse selection problem disappear. This makes outsiders (speculators and hedgers) more responsive to price, $\beta_h^{IT} < \beta_h^{PD}$ and $\beta_s^{IT} < \beta_s^{PD}$. As a direct consequence, the residual supply faced by the insider is less sensitive to his demand, $\lambda^{IT} > \lambda^{PD}$, and therefore the insider also trades more aggressively.

3. Market depth is equal to the traders' price sensibility. It follows from the above result that it will be higher if inside information becomes public, $\Lambda^{IT} < \Lambda^{PD}$.

4. Due to the same reason the asset price is more informative if the inside information is made public since more traders are reacting more to information about $v$, $\tau^{IT} < \tau^{PD}$. Price precision increases a lot because with PD competitive agents see $s$. There are two sources of volatility: information and hedging $u$. With PD the price is more informative but also the market is deeper. In

the simulations we find that the informational effect dominates always and price volatility decreases in the IT regime.

5. The effect on real investment of making public the inside information depends on the trade-off between the following effects. If inside information is made public there are more risk sharing opportunities since the adverse selection problem faced by the outsider is eliminated (and they are more willing to share the risk due to real investment). However, at the same time more information may destroy insurance opportunities (Hirshleifer effect). The adverse selection effect dominates, unless the information of the insider is very precise, so that real investment is reduced by insider trading, $q^{IT} < q^{PD}$. This tends to reduce the risk premium in the IT regime. Note that when $R_{sv} = 1$ the market collapses with PD and $q^{PD}$ equals the investment level with no trade, which is less than with $q^{IT}$. We have then that $q^{IT} > q^{PD}$ and the same result holds for $R_{sv}$ very close to 1.

6. The speculative gains of the entrepreneur are higher with IT and when $R_{sv}$ is high then $E[U_i^{IT}] > E[U_i^{PD}]$. This holds a fortiori when IT increases $q$ ($R_{sv}$ very close to 1). However, typically the decrease in $q$ in the IT regime is large and $E[U_i^{IT}] < E[U_i^{PD}]$ .

7. If $R_{sv}$ is very close to 1 (and/or $\rho_i$ small) the insurance gains for the speculators in the IT and PD cases are close while the speculative gains are higher in the IT case. The result is that for those parameter configurations $E\left[U_s^{IT}\right] > E[U_s^{PD}]$. However, for reasonable parameter configurations IT reduces $q$ and the speculators can insure less both the entrepreneur and the hedgers (who reduce $\delta$) with the result that $E\left[U_s^{IT}\right] < E[U_s^{PD}]$.

8. Insider trading here creates adverse selection and reduces market depth and (typically) risk premia, worsening the position of hedgers, but at the same time (typically) it reduces price volatility also, tending to improve their position. The net effect is ambiguous. When $R_{sv}$ is high then $q^{IT}$ and $q^{PD}$ are close together (and $q^{IT} > q^{PD}$ for $R_{sv}$ very close to 1), the price volatility effect dominates and hedgers are better off with insider trading. When $R_{sv}$ is low then $q^{IT}$ tends to be much smaller than $q^{PD}$, and the price volatility effect is dominated.

It is also interesting to examine what happens to the expected utility of hedgers conditional on their endowment. For $R_{sv}$ low more than 50% of hedgers prefer the equilibrium in the PD regime (those with a shock less than some small $u > 0$). For $R_{sv}$ high more than 50% of hedgers prefer the equilibrium in the IT regime. Only those hedgers with a shock close to 0 prefer the PD equilibrium. This is so even though sometimes the (ex ante) expected utility of hedgers diverges to minus infinity (for example, in BC1 o BC2 with $\rho_h = 6$).

It is worth noting that for $R_{sv}$ high hedgers improve with insider trading despite the fact that market depth decreases, contradicting the implicit welfare criterion of noise trader models. Even in the case that $\rho_h$ is high, and the demands of traders approach those of the noise trading model, the welfare analysis derived from the noise trader model based on looking at market depth only is incorrect. Indeed, what matters is expected utility and then risk premia and price volatility are important.

The general picture is the following. Except for a very large risk-adjusted informational advantage of the insider, insider trading reduces market depth, price volatility and risk premia as well as real production and the expected utility of the insider and the speculators. The effect on hedgers is ambiguous and depends on the precision of information of the insider. The result is that for a low $R_{sv}$ insider trading is Pareto inferior, for a very high $R_{sv}$ it is Pareto superior and for intermediate levels only hedgers improve with insider trading.

## 6 Conclusions

Our model can shed light on several public policy issues in relation to insider trading: (1) A disclose-or-abstain rule; (2) laissez-faire policy; (3) the rationale for the European Directive considering only "precise" information; (4) the new regulations concerning the early selective release of material information; and (5) whether high tech highly volatile industries need a special treatment.

(1) The consequences of a disclose-or-abstain rule are the following:

- It may avoid a market breakdown (and this is Pareto superior when with IT the market collapses).
- If the entrepreneur/insider learns $s$ for free in the course of his activity then he will choose to disclose. The relevant welfare comparison is between a public disclosure regime (PD) and insider trading (IT).[28] The welfare consequences of IT depend then on the information precision of the insider. If it is imprecise the adverse selection effect dominates, $q$ decreases

[28]However, if the entrepreneur can commit his portfolio to a trust then he will prefer to "abstain" rather than "disclose" because the expected utility of the insider decreases with $R_{sv}$ when information is public. In this case the relevant comparison would be between the no information regime and insider trading.

and IT will tend to be Pareto inferior; if it is very precise the Hirshleifer effect dominates, $q$ increases and IT will tend to be Pareto superior. In an intermediate range only hedgers benefit from insider trading (because it reduces price volatility).

- If the entrepreneur/insider learns $s$ at some cost then the entrepreneur will never spend any effort in learning $s$.[29] This means that the relevant welfare comparison is between a regime in which the entrepreneur has no private information, $R_{sv} = 0$ (NI) and insider trading (IT). Then $q$ decreases and with IT, which tends to be bad for everyone except for the insider when he is very close to risk neutrality. (See Table 2.)

<table>
<tr><th>Information of<br>insider</th><th>Free<br>PD Benchmark</th><th>Costly<br>NI Benchmark</th></tr>
<tr><td>Very<br>precise<br>(and/or $\rho_i \approx 0$)</td><td>$q \uparrow$<br>Pareto<br>Superior</td><td>$q \downarrow$<br>$EU_i \uparrow$<br>$EU_s, EU_h \downarrow$</td></tr>
<tr><td>Precise</td><td>$q \downarrow$<br>$EU_i \downarrow, EU_s \downarrow$<br>$EU_h \uparrow$</td><td rowspan="2">$q \downarrow$<br>Pareto<br>Inferior</td></tr>
<tr><td>Imprecise</td><td>$q \downarrow$<br>Pareto<br>Inferior</td></tr>
</table>

Table 2: Effects of Insider Trading

In the welfare analysis we may also take into account positive external effects of investment (that is, on other agents in the economy). If we take this perspective and we give little weigth to the utility of the insider then we should conclude that a disclose or abstain rule is optimal when information is costly to acquire. Indeed, then the relevant benchmark for comparison is the NI regime and insider trading always decreases investment and decreases the utility of all participants with the only exception of the insider when he has a large risk weighted informational advantage.

[29] The result also holds if the entrepreneur can hire an agent to invest on his behalf. Then if he obtains the information he can not use it and therefore will never pay for the information.

However, when information is obtained by the entrepreneur at no cost then the rule is not such a good idea. When information is of intermediate quality then insider trading helps hedgers. When $R_{sv}$ is very high (and/or $\rho_i$ very low), the rule will hurt everyone. This situation is more likely to arise (that is, it arises for a larger range of precisions of information of the insider) if the volatility of the fundamentals and/or "noise" is large as in high tech highly volatile industries (like biotechnology for example).

(2) The consequences of laissez-faire:

With no insider trading regulation one should expect insider trading to arise only in those circumstances where it is favorable to the insider. Otherwise corporate chapters should take care of the problem. When insider trading hurts the entrepreneur/coalition of insiders corporate chapters should impose and enforce an abstain-or-disclose rule because it is in the interest of the initial owners of the firm.[30] This means that whenever private and social incentives about the desirability of insider trading are aligned we will have an optimal outcome. This happens when insider trading is either Pareto superior or Pareto inferior. However, when information is obtained by the entrepreneur at no cost and is of intermediate quality then a laisser-faire policy will hurt hedgers (in relation to a disclose-or-abstain rule) because information will be disclosed. A countervailing effect will be that with public disclosure investment will increase. The net welfare result is likely to be ambiguous then.[31] With costless information acquisition a laissez faire policy seems appropriate therefore (the ambiguity in the welfare assessment for moderately precise information seems to call for prudence and no intervention).

The difference between a laissez-faire policy and a mandated abstain-or-disclose rule is in the type of errors they induce. The advantage of laisser-faire is that it avoids prohibiting insider trading when it turns out to be Pareto superior (and this tends to happen more in highly volatile industries). The cost is that situations will arise where it pays for the firm to allow insider trading but outsiders are hurt.[32] Both laissez-faire and a mandated abstain-or-disclose rule will have the same effects

[30] Laissez faire outcomes can be approximated also with a default rule prohibiting insider trading only if the corporate chapter has not stated a policy in this regard. (See Bainbridge (1999))

[31] When $R_{sv}$ is very high (and/or $\rho_i$ very low), and information is obtained by the entrepreneur at a cost, with a laisser-faire policy there will be insider trading (because the insider will chose to become informed provided the cost of information is not too large) but hedgers and speculators will be hurt.

[32] Khanna et al (1994) in a model with two informed agents, an insider and an outsider, find that private and social incentives with respect to insider trading may differ.

when insider trading hurts the insider but benefits hedgers.

The preceding analysis suggests the following rule ot thumb: With costly information acquisition a mandated abstain-or-disclose rule is appropriate while with free information acquisition laissez faire is better.

Taking into account that costly information acquisition should be more easily verifiable and detectable, the rule of thumb can be put into practice in the following way:

- Enforce an abstain-or-disclose rule with a high standard of proof for inside information.

In this way basically insiders only have to worry about information which is costly to acquire.

(3) Is there a basis for prohibiting insider trading only with precise information (as in the European Directive)?

It dos not seem so. Indeed, the only case where potentially insider trading is Pareto superior is with precise information and whenever it is imprecise insider trading is Pareto inferior.

(4) Does selective early disclosure of material information diminishes welfare? The typical situation involving early selective disclosure of information (to large fund investors, for example) does not involve a cost of information acquisition for the insider. The rule of thumb would advocate a laissez faire policy.

(5) Is there a case for a differential treatment for high tech highly volatile industries? Here the constellation of factors points at laissez-faire as the best policy. Indeed, insiders are likely to be very well informed and to learn the information in the course of their activity (a new drug discovery for example). This is the only case where insider trading will increase investment. (This is a subcase again of the laissez faire recommendation in the rule of thumb.)

## References


[1] Aboody, D. and B. Lev, 1999, "R&D and Insider Gains", mimeo.

[2] Ausubel, L. M., 1990, "Insider Trading in a Rational Expectations Economy", The American Economic Review, vol. 80, no. 5, December, 1022-1041.

[3] Bernhardt, D., B. Hollifield and E. Hughson, 1995, "Investment and Insider Trading", Review of Financial Studies, 8, 2, 501-543.

[4] Bernhardt, D. and E. Hughson, 2000, "Intraday Trade in Dealership Markets", mimeo.

[5] Bhattacharya, U. and H. Daouk, 1999, "The World Price of Insider Trading", mimeo, Indiana Univeristy.

[6] Bhattacharya, S. and Nicodano, G., 1999, "Insider Trading, Investment, and Welfare: A Perturbation Analysis", ICIER Working Paper no. 4/97

[7] Bhattacharya, U., and M. Spiegel, 1991, "Insiders, Outsiders, and Market Breakdowns", The Review of Financial Studies, vol. 4, no. 2, 255-282.

[8] Bray, M., 1985, "Rational Expectations, Information and Asset Markets: An Introduction", Oxford Economic Papers 37, 161-95.

[9] Campbell, T., 1979, "Optimal investment financing decisions and the value of confidentiality", Journal of Financial and Quantitative Analysis, 14, 913-924.

[10] Carlton, D. and Fischel, D., 1983, "The Regulation of Insider Trading", Stanford Law Review, 35, 673-694.

[11] Damodaran, A. and C. Liu, 1993, "Insider Trading as a Signal of Private Information", Review of Financial Studies, 6, 79-120.

[12] Danthine, J. P., and S. Moresi, 1993, "Volatility, information, and noise trading", European Economic Review 37, 961-982.

[13] Demange, G. and G. Laroque, 1995,"Private Informaiton and the Design of Securities", Journal of Economic Theory, 65, 233-257.

[14] Demsetz, H., 1986, "Corporate Control, Insider Trading and Rates of Return", American Economic Review, Papers and Proceedings, 76, 313-316.

[15] Dennert, J., 1992, "Insider Trading and the Cost of Capital in a Multi-Period Economy", LSE Financial Markets Group, Discussion Paper No. 128.

[16] Dennert, J., 1993, "Insider Trading and the Allocation of Risks", LSE Financial Markets Group, Discussion Paper No. 77.

[17] Diamond, D. and P. Dybvig, 1983, "Bank Runs, Deposit Insurance, and Liquidity", Journal of Political Economy, 91, 3, 401-419.

[18] Diamond, D. and R. Verrecchia, 1981, "Information Aggregation in a Noisy Rational Expectations Economy", Journal of Financial Economics, 9, 3, 221-235.

[19] Dow, J. and R. Rahi, 2001, "Insider Trading, Investment and Welfare", mimeo.

[20] Fishman, M. and K. Hagerty, 1989, "Disclosure Decisions by Firms and the Competetion for Price Efficienty", Journal of Finance, 44, 3, 633-646.

[21] Fishman, M. and K. Hagerty, 1992, "Insider Trading and the Efficiency of Stock Prices", Rand Journal of Economics, 23, 1, 106-122.

[22] Fried, J. , 1998, "Reducing the Profitability of Corporate Insider Trading Through Pretrading Disclosure", Southern California Review, 71, 303-392.

[23] Hirshleifer, J., 1971, "The Private and Social Value of Information and the Reward to Inventive Acitvity", American Economic Review, 61, 561-574.

[24] Holmstrom, B. and J. Tirole, 1993, "Market Liquidity and Performance Monitoring", Journal of Political Economy, 101, 4, 678-709.

[25] Khanna, N., S. Slezak and M. Bradley, 1994, "Insider Trading, Outside Search, and Resource Allocation: why Firms and Society May Disagree on Insider Trading Restrictions", Review of Financial Studies, 7, 3, 575-608.

[26] Kyle, A. S., 1989, "Informed Speculation with Imperfect Competition", Review of Economic Studies 56, 317-356.

[27] Leland, H. E., 1992, "Insider Trading: Should it Be Prohibited?", Journal of Political Economy 100, 859-887

[28] Manne, H. G., 1966, Insider Trading and the Stock Market. New York: The Free Press.

[29] Manne, H. G., 1980, "In Defense of Insider Trading", in R. A. Posner and K. E. Scott (eds), Economics of Corporation Law and Securities Regulation. Boston, Toronto: Little, Brown and Company, 130-142.

[30] Manove, M., 1989, "The Harm from Insider Trading and Informed Speculation", Quarterly Journal of Economics, 104, 823-84

[31] Medrano, L. and X. Vives, 2002, "Information, Investment, and Welfare", mimeo.

[32] Maug, E., 1999, "Insider Trading Legislation and Corporate Governance", forthcoming in European Economic Review.

[33] Qi, J., 1996, "Efficient Investment and Financial Intermediation", Journal of Banking and Finance, 20, 891-900.

[34] Rahi, R., 1996, "Adverse Selection and Security Design", Review of Economic Studies, 63, 287-300.

[35] Repullo, R., 1999, "Some Remarks on Leland's Model of Insider Trading", Economica, 66, 359-374.

[36] Sarkar, A., 1994, "On the Equivalence of Noise Trader and Hedger Models in Market Microstructure", Journal of Financial Intermediation, 3, 204-212.

[37] Seyhun, N., 1986, "Insiders' Profits, Costs of Trading and Market Efficiency", Journal of Financial Economics, 16, 189-212.

[38] Seyhun, N., 1992, "The Effectiveness of the Insider Trading Sanctions", Journal of Law and Economics, 149, 172-175.

[39] Spiegel, M. and A. Subrahmanyam, 1992, "Informed Speculation and Hedging in a Noncompetitive Securities Market", Review of Financial Studies, 5, 2, 307-329.

[40] Yosha, O., 1995, "Information Disclosure and the Choice of Financing Source", Journal of Financial Intermediation, 4, 3-20.

# A Appendix

**Proof of Lemma 2.** First, let us prove that $\frac{\sigma_{vz}}{\sigma_v^2} \geq \delta \geq 0$. The second order condition of the insider's optimization problem implies that (in any equilibrium) $\lambda > 0$. Now, for any given $\lambda > 0$, equation (5) is a cubic equation in $\delta$, so that it has at least a real solution. It is easy to check that this equation, $\frac{R_u R_{sv}}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]}\delta = \rho_h \left[ \left( \frac{\sigma_{vz}}{\sigma_v^2} \right) - \delta \right] \left\{ (1-R_u)\delta^2\sigma_u^2 + \frac{(1-R_{sv})R_{sv}\sigma_v^2}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]^2} \right\}$, has no negative solution in $\delta$, for any $\lambda > 0$. Suppose there is an equilibrium and $\widehat{\lambda}$ is the equilibrium value of $\lambda$. For any $\delta$<0 the left-hand side, $\frac{R_u R_{sv}}{[\rho_i(1-R_{sv})\sigma_v^2+\widehat{\lambda}]}\delta$, is negative while the rigth-hand side, $\rho_h \left[ \left( \frac{\sigma_{vz}}{\sigma_v^2} \right) - \delta \right] \left\{ (1-R_u)\delta^2\sigma_u^2 + \frac{(1-R_{sv})R_{sv}\sigma_v^2}{[\rho_i(1-R_{sv})\sigma_v^2+\widehat{\lambda}]^2} \right\}$, is positive, so that this equation has no negative solution and, consequently, the equilibrium value of $\delta$ cannot be negative. On the other hand, for any $\delta \geq \frac{\sigma_{vz}}{\sigma_v^2}$ the left-hand side is positive while the rigth-hand is negative, so that the equilibrium value of $\delta$ cannot be greater than $\frac{\sigma_{vz}}{\sigma_v^2}$. Therefore, for any candidate equilibrium (for which we know $\lambda > 0$), the solutions of equation (5) must be in the interval $(0, \sigma_{vz}/\sigma_v^2]$.

Now, let us prove that, in equilibrium, $\lambda \geq \sigma_v^2(\frac{\rho_s\rho_h}{\rho_s+\rho_h})$. Taking into account that $\alpha_i$ only depends on $\lambda$ and some exogenous parameters, equation (6) may be seen as a equation in $(\delta, \lambda)$. For any given $\delta \in [0, \sigma_{vz}/\sigma_v^2]$, it may be written as a (fifth degree) polynomial equation in $\lambda$. Moreover it is easy to check that, if it has a positive solution, it is such that $\lambda \geq \sigma_v^2(\frac{\rho_s\rho_h}{\rho_s+\rho_h})$.Equation (6) may be written as

$$\frac{1}{\lambda}\{1+K\} = \frac{1}{\rho_s\sigma_v^2}\frac{\delta^2\sigma_u^2}{[\delta^2\sigma_u^2 + \alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]} + \frac{1}{\rho_h\sigma_v^2}\frac{(1-R_u)\delta^2\sigma_u^2}{[(1-R_u)\delta^2\sigma_u^2 + \alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]}.$$

where $K = \frac{\alpha_i}{\rho_s[\delta^2\sigma_u^2+\alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]} + \frac{\alpha_i}{\rho_h[(1-R_u)\delta^2\sigma_u^2+\alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]} \geq 0$. Since $\frac{\delta^2\sigma_u^2}{\delta^2\sigma_u^2+\alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2}$ and $\frac{(1-R_u)\delta^2\sigma_u^2}{(1-R_u)\delta^2\sigma_u^2+\alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2}$ are both equal or lower than 1, it is obvious that (in any equilibrium)

$$\frac{1}{\lambda}\{1+K\} \leq \frac{1}{\rho_s\sigma_v^2} + \frac{1}{\rho_h\sigma_v^2}.$$

And, since $K = \frac{\alpha_i}{\rho_s[\delta^2\sigma_u^2+\alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]} + \frac{\alpha_i}{\rho_h[(1-R_u)\delta^2\sigma_u^2+\alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]} \geq 0$, we have that

$$\frac{1}{\lambda} \leq \frac{1}{\lambda}\{1+K\} \leq \frac{1}{\rho_s\sigma_v^2} + \frac{1}{\rho_h\sigma_v^2}$$

which directly implies that

$$\lambda \geq \left( \frac{1}{\rho_s\sigma_v^2} + \frac{1}{\rho_h\sigma_v^2} \right)^{-1} = \sigma_v^2\left( \frac{\rho_s\rho_h}{\rho_s+\rho_h} \right).$$

The rest of inequalities are obvious from the characterization of the equilibrium. For instance, in any equilibrium $\lambda > 0$ , it is clear that

$$\gamma_i = \frac{\rho_i(1-R_{sv})\sigma_v^2}{\rho_i(1-R_{sv})\sigma_v^2+\lambda}$$

is greater than zero and lower than one. Moreover, since $\alpha_i = \frac{R_{sv}}{\rho_i(1-R_{sv})\sigma_v^2+\lambda} \geq 0$ and $\gamma_i \geq 0$, both are (equal or) lower than zero

$$\gamma_s = \frac{-\alpha_i}{\rho_s\left[\delta^2\sigma_u^2+(R_{sv}^{-1}-1)\alpha_i^2\sigma_v^2\right](1+\alpha_i E)}\gamma_i \leq 0$$

$$\gamma_h = \frac{-\alpha_i}{\rho_h\left[(1-R_u)\delta^2\sigma_u^2+(R_{sv}^{-1}-1)\alpha_i^2\sigma_v^2\right](1+\alpha_i E)}\gamma_i \leq 0.$$

On the other hand,

$$\gamma_i+\gamma_s+\gamma_h = \frac{\gamma_i}{(1+\alpha_i E)} \leq 0.$$

where $E = \frac{1}{\rho_s}\left[\delta^2\sigma_u^2+(R_{sv}^{-1}-1)\alpha_i^2\sigma_v^2\right]^{-1} + \frac{1}{\rho_h}\left[(1-R_u)\delta^2\sigma_u^2+(R_{sv}^{-1}-1)\alpha_i^2\sigma_v^2\right]^{-1} \geq 0$. It is then clear that

$$0 \leq \gamma_s+\gamma_h+\gamma_i \leq \gamma_i \leq 1,$$

$$0 \leq \Gamma\Lambda = (\gamma_s+\gamma_h+\gamma_i) \leq 1,$$

and, since $0 \leq \gamma_i \leq 1.$ and $0 \leq \gamma_s+\gamma_h+\gamma_i \leq \gamma_i \leq 1$,,

$$0 < |\gamma_s+\gamma_h| < \gamma_i < 1.$$

Inequalities $\Lambda > 0$, $\Gamma > 0$, $\alpha_i \geq 0$, $\beta_i \geq 0$, $\beta_s \geq 0$, and $\beta_h \geq 0$ are directly derived from the characterization of equilibria in proposition 1 and the above results.

#

**Proof of Proposition 3.** Let us check first that if $R_u/\rho_h$ and/or $R_{sv}/\rho_i$ tend to 0 the equilibrium parameter $\delta$ tends to $\frac{\sigma_{vz}}{\sigma_v^2}$. Equation (5) may be written as

$$\frac{R_u}{\rho_h}\frac{R_{sv}}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]}\delta = \left[\frac{\sigma_{vz}}{\sigma_v^2}-\delta\right]\left\{(1-R_u)\delta^2\sigma_u^2+\frac{(1-R_{sv})R_{sv}\sigma_v^2}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]^2}\right\}$$

or as

$$\frac{R_u}{\rho_h}\alpha_i\delta = \left[\frac{\sigma_{vz}}{\sigma_v^2}-\delta\right]\left\{(1-R_u)\delta^2\sigma_u^2+\frac{(1-R_{sv})R_{sv}\sigma_v^2}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]^2}\right\}$$

since $\alpha_i = \frac{R_{sv}}{\rho_i(1-R_{sv})\sigma_v^2+\lambda}$. If $\frac{R_u}{\rho_h}$ is low, then it is obvious that $\delta$ will be close to $\frac{\sigma_{vz}}{\sigma_v^2}$ (since $(1-R_u)\delta^2\sigma_u^2+\frac{(1-R_{sv})R_{sv}\sigma_v^2}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]^2}>0$). On the other hand, if $\frac{R_{sv}}{\rho_i}$ is low, then $\alpha_i = \frac{R_{sv}}{\rho_i(1-R_{sv})\sigma_v^2+\lambda}$ will be close to zero (this is clear if $R_{sv}$ is close to zero and also if $\rho_i$ is sufficiently large since $\lambda \geq \sigma_v^2(\frac{\rho_s\rho_h}{\rho_s+\rho_h}) > 0$) and, as a direct consequence, $\delta$ will also be close to $\frac{\sigma_{vz}}{\sigma_v^2}$. Therefore, if $\frac{R_u}{\rho_h}$ and/or $\frac{R_{sv}}{\rho_i}$ tends to 0, the equilibrium parameter $\delta$ tends to $\frac{\sigma_{vz}}{\sigma_v^2}$.

There is equilibrium if and only if there is a solution to equations (5) and (6) satisfying the second order condition $\lambda > 0$. Moreover, from Lemma 2, we know that (in any equilibrium) $\lambda \geq \sigma_v^2(\frac{\rho_s\rho_h}{\rho_s+\rho_h})$, and $\frac{\sigma_{vz}}{\sigma_v^2} \geq \delta \geq 0$.

Equation (5) may be written as $g_1(\delta,\lambda) = g_2(\delta,\lambda)$, where $g_1(\delta,\lambda) = \frac{R_u R_{sv}}{\rho_h[\rho_i(1-R_{sv})\sigma_v^2+\lambda]}\delta$ and $g_2(\delta,\lambda) = \left[\frac{\sigma_{vz}}{\sigma_v^2} - \delta\right]\left\{(1-R_u)\delta^2\sigma_u^2 + \frac{(1-R_{sv})R_{sv}\sigma_v^2}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]^2}\right\}$. For any $\lambda > 0$, it is obvious that there is a solution $\delta$ of the equation $g_1(\delta,\lambda) = g_2(\delta,\lambda)$, since $g_1(\delta,\lambda)$ is strictly increasing in $\delta$, $g_1(0,\lambda) = 0$, $g_2(\delta,\lambda)$ is continuous, $g_2(0,\lambda) > 0$ and $g_2\left(\frac{\sigma_{vz}}{\sigma_v^2},\lambda\right) = 0$. Is it possible to have more than a solution $\delta$ in the interval $\left[0,\frac{\sigma_{vz}}{\sigma_v^2}\right]$? If $\frac{\partial g_2(\delta,\lambda)}{\partial\delta} < 0$ for all $\delta \in \left[0,\frac{\sigma_{vz}}{\sigma_v^2}\right]$, we know that there is only one solution solution $\delta$ to $g_1(\delta,\lambda) = g_2(\delta,\lambda)$ for each $\lambda > 0$. The above partial derivative is given by

$$\frac{\partial g_2(\delta,\lambda)}{\partial\delta} = -\frac{(1-R_{sv})R_{sv}\sigma_v^2}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]^2} - \left[3\delta - 2\frac{\sigma_{vz}}{\sigma_v^2}\right](1-R_u)\sigma_u^2\delta.$$

From this expression, if $\delta > \frac{2}{3}\frac{\sigma_{vz}}{\sigma_v^2}$, then $3\delta - 2\frac{\sigma_{vz}}{\sigma_v^2} > 0$ and, as a direct consequence $\frac{\partial g_2(\delta,\lambda)}{\partial\delta} < 0$. But, if $\delta < \frac{2}{3}\frac{\sigma_{vz}}{\sigma_v^2}$, then $\frac{\partial g_2(\delta,\lambda)}{\partial\delta}$ may be greater than zero (in fact, it is easy to have parameter values such that $\frac{\partial g_2(\delta,\lambda)}{\partial\delta} > 0$). Therefore, in general we cannot guarantee uniqueness of the solution of the equation $g_1(\delta,\lambda) = g_2(\delta,\lambda)$ for any $\lambda > 0$ and, consequently, we cannot establish existence of a well-defined implicit function $\delta(\lambda)$ for every $\lambda > 0$.

However, if $\frac{R_u}{\rho_h}$ and/or $\frac{R_{sv}}{\rho_i}$ is close to 0, the candidate $\delta$ is close to $\frac{\sigma_{vz}}{\sigma_v^2}$ and $\frac{\partial g_2(\delta,\lambda)}{\partial\delta}$ will be lower than zero in any solution. Therefore, if $\frac{R_u}{\rho_h}$ and/or $\frac{R_{sv}}{\rho_i}$ is close to zero, we can guarantee uniqueness of the solution and, consequently, we can establish existence of a well-defined implicit function $\delta(\lambda)$ for every $\lambda > 0$. By substituting $\delta(\lambda)$ in equation (6), we get a single equation in $\lambda$

$$\lambda\delta^2(\lambda)\sigma_u^2\left\{1 + \frac{1}{\rho_s[\delta^2(\lambda)\sigma_u^2 + \alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]}\right\} +$$

$$+\lambda\delta^2(\lambda)\sigma_u^2\frac{(1-R_u)}{\rho_h[(1-R_u)\delta^2(\lambda)\sigma_u^2 + \alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]} =$$

$$\sigma_v^2\left\{1 + \frac{\alpha_i}{\rho_s[\delta^2(\lambda)\sigma_u^2 + \alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]} + \frac{(1-R_u)\alpha_i}{\rho_h[(1-R_u)\delta^2(\lambda)\sigma_u^2 + \alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]}\right\},$$

where $\alpha_i = \frac{R_{sv}}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]}$. This equation may be written as $h_1(\lambda) = h_2(\lambda)$, where $h_1(\lambda) = \lambda\delta^2(\lambda)\sigma_u^2\left\{1 + \frac{1}{\rho_s[\delta^2(\lambda)\sigma_u^2+\alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]} + \frac{1-R_u}{\rho_h[(1-R_u)\delta^2(\lambda)\sigma_u^2+\alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]}\right\}$ and $h_2(\lambda) = \sigma_v^2\left\{1 + \frac{\alpha_i}{\rho_s[\delta^2(\lambda)\sigma_u^2+\alpha_i^2(R_s^{-}}\right.$
where $\alpha_i = \frac{R_{sv}}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]}$ and $\delta(\lambda)$ is close to $\frac{\sigma_{vz}}{\sigma_v^2}$.

Each positive solution of this equation will characterize an equilibrium. Let us prove that this equation has positive solutions provided $\frac{R_u}{\rho_h}$ and/or $\frac{R_{sv}}{\rho_i}$ is close to 0.

If $\lambda = 0$, then $h_1(\lambda) = 0$ and $h_2(\lambda) = \sigma_v^2 > 0$. If $\lambda \to +\infty$, then $\alpha_i \to 0$, $h_2(\lambda) \to \sigma_v^2$, and $h_1(\lambda) \to +\infty$. Moreover, both functions, $h_1(\lambda)$ and $h_2(\lambda)$, are continuous for $\lambda > 0$. As a result, we can guarantee that equation $h_1(\lambda) = h_2(\lambda)$ has a positive solution. Equilibria will be characterized by the positive solutions $\widehat{\lambda}$ of equation $h_1(\lambda) = h_2(\lambda)$ and the values of $\widehat{\delta}$ given by the implicit function $\delta(\lambda)$, $\widehat{\delta} = \delta(\widehat{\lambda})$.

We have proved existence of equilibrium, for $\frac{R_u}{\rho_h}$ and/or $\frac{R_{sv}}{\rho_i}$ sufficiently close to 0. Let us prove uniqueness. There will be a unique equilibrium if $\frac{dh_1(\lambda)}{d\lambda} > \frac{dh_2(\lambda)}{d\lambda}$ in any positive solution $\lambda$ of the equation $h_1(\lambda) = h_2(\lambda)$, where

$$h_1(\lambda) = \lambda\delta^2(\lambda)\sigma_u^2\left\{1 + \frac{1}{\rho_s[\delta^2(\lambda)\sigma_u^2 + \alpha_i^2(R_{sv}^{-1} - 1)\sigma_v^2]}\right\} +$$

$$+\lambda\delta^2(\lambda)\sigma_u^2\frac{(1-R_u)}{\rho_h[(1-R_u)\delta^2(\lambda)\sigma_u^2 + \alpha_i^2(R_{sv}^{-1} - 1)\sigma_v^2]},$$

$$h_2(\lambda) = \sigma_v^2\left\{1 + \frac{\alpha_i}{\rho_s[\delta^2(\lambda)\sigma_u^2 + \alpha_i^2(R_{sv}^{-1} - 1)\sigma_v^2]} + \frac{(1-R_u)\,\alpha_i}{\rho_h[(1-R_u)\delta^2(\lambda)\sigma_u^2 + \alpha_i^2(R_{sv}^{-1} - 1)\sigma_v^2]}\right\},$$

and where $\alpha_i = \frac{R_{sv}}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]}$ and $\delta(\lambda)$ is implicitly defined by the unique positive solution of equation

$$\frac{R_u R_{sv}}{\rho_h[\rho_i(1-R_{sv})\sigma_v^2+\lambda]}\delta = \left[\frac{\sigma_{vz}}{\sigma_v^2} - \delta\right]\left\{(1-R_u)\delta^2\sigma_u^2 + \frac{(1-R_{sv})R_{sv}\sigma_v^2}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]^2}\right\}.$$

(Remember that function $\delta(\lambda)$ is only defined for positive values of $\lambda$ and is well-defined provided that $\frac{R_u}{\rho_h}$ and/or $\frac{R_{sv}}{\rho_i}$ is sufficiently close to 0).

We have to check whether $\frac{dh_1(\lambda)}{d\lambda}$ is greater or lower than $\frac{dh_2(\lambda)}{d\lambda}$ (for any possible positive solution of the equation $h_1(\lambda) = h_2(\lambda)$).

It is obvious that $\frac{d\alpha_i}{d\lambda}<0$ (since $\alpha_i = \frac{R_{sv}}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]}$) and it can be easily proved that $\frac{d\delta(\lambda)}{d\lambda} > 0$ and that, provided that $\frac{R_u}{\rho_h}\frac{R_{sv}}{\rho_i}$ is sufficiently close to 0, $\frac{d\delta(\lambda)}{d\lambda}$ is close to zero. The equation which (implicitly) defines $\delta(\lambda)$ can be written as

$$G(\delta,\lambda) = \frac{R_u}{\rho_h}\alpha_i\delta - \left[\frac{\sigma_{vz}}{\sigma_v^2} - \delta\right]\left\{(1-R_u)\delta^2\sigma_u^2 + \frac{(1-R_{sv})\alpha_i^2\sigma_v^2}{R_{sv}}\right\} = 0.$$

with $\alpha_i = \frac{R_{sv}}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]}$. It is then clear that $\frac{\partial G}{\partial\delta} > 0$ (for, provided $\frac{R_u}{\rho_h}$ and/or $\frac{R_{sv}}{\rho_i}$ is close to 0, $\frac{\sigma_{vz}}{\sigma_v^2} - \delta$ is close to 0 too) and $\frac{\partial G}{\partial\lambda} = \frac{-R_u R_{sv}}{\rho_h[\rho_i(1-R_{sv})\sigma_v^2+\lambda]^2}\delta + \left[\frac{\sigma_{vz}}{\sigma_v^2} - \delta\right]\frac{2(1-R_{sv})R_{sv}\sigma_v^2}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]^2}$. Since, for $\frac{R_u}{\rho_h}\frac{R_{sv}}{\rho_i}$

sufficienly close to 0, $\frac{\sigma_{vz}}{\sigma_v^2} - \delta$ is close to 0, the first term of $\frac{\partial G}{\partial \lambda}$ dominates the second term and, therefore, $\frac{\partial G}{\partial \lambda}$<0. By applying the Implicit-Function Theorem, if $\frac{R_u}{\rho_h}\frac{R_{su}}{\rho_i}$ is close to 0, $\frac{d\delta(\lambda)}{d\lambda} > 0$. On the other hand, we know that, as $\frac{R_u}{\rho_h}\frac{R_{su}}{\rho_i}$ tends to 0, $\delta$ tends to $\frac{\sigma_{vz}}{\sigma_v^2}$ (and, from Lemma 2, $\delta$ is allways equal or lower than $\frac{\sigma_{vz}}{\sigma_v^2}$) and $\frac{d\delta(\lambda)}{d\lambda} > 0$. If $\lambda$ increases, $\delta$ increases, but the increase of $\delta$ is very very small, since it is "allways" close to $\frac{\sigma_{vz}}{\sigma_v^2}$ and it cannot go beyond that value, for $\delta \leq \frac{\sigma_{vz}}{\sigma_v^2}$. Therefore, if $\frac{R_u}{\rho_h}$ and/or $\frac{R_{su}}{\rho_i}$ is close to 0, $\frac{d\delta(\lambda)}{d\lambda}$ is positive but very small. Put another way, as $\frac{R_u}{\rho_h}$ and/or $\frac{R_{su}}{\rho_i} \to 0$, $\frac{d\delta(\lambda)}{d\lambda}$ tends to zero from the right, $\frac{d\delta(\lambda)}{d\lambda} \to 0^+$.

Let us compare $\frac{dh_1(\lambda)}{d\lambda}$ with $\frac{dh_2(\lambda)}{d\lambda}$. Since $\frac{d\alpha_i}{d\lambda} < 0$ and, as $\frac{R_u}{\rho_h}$ and/or $\frac{R_{su}}{\rho_i}$ tends to 0, $\frac{d\delta(\lambda)}{d\lambda} \to 0^+$, the terms $\frac{1}{\rho_s[\delta^2(\lambda)\sigma_u^2+\alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]}$ and $\frac{1-R_u}{\rho_h[(1-R_u)\delta^2(\lambda)\sigma_u^2+\alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]}$ are both increasing in $\lambda$. Moreover, it can be easily checked that

$$\frac{dh_2(\lambda)}{d\lambda} = \sigma_v^2\frac{d}{d\lambda}\left\{\frac{\alpha_i}{\rho_s[\delta^2(\lambda)\sigma_u^2+\alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]}\right\}+$$

$$+\sigma_v^2\frac{d}{d\lambda}\left\{\frac{(1-R_u)\,\alpha_i}{\rho_h[(1-R_u)\delta^2(\lambda)\sigma_u^2+\alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]}\right\} \leq$$

$$\leq \frac{d}{d\lambda}\left\{\frac{1}{\rho_s[\delta^2(\lambda)\sigma_u^2+\alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]}+\frac{1-R_u}{\rho_h[(1-R_u)\delta^2(\lambda)\sigma_u^2+\alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]}\right\} \leq$$

$$\leq \frac{d}{d\lambda}\left(\lambda\delta^2(\lambda)\sigma_u^2\left\{1+\frac{1}{\rho_s[\delta^2(\lambda)\sigma_u^2+\alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]}\right\}\right)+$$

$$+\frac{d}{d\lambda}\left(\lambda\delta^2(\lambda)\sigma_u^2\left\{\frac{1-R_u}{\rho_h[(1-R_u)\delta^2(\lambda)\sigma_u^2+\alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]}\right\}\right) = \frac{dh_1(\lambda)}{d\lambda}$$

The first inequalityis due to the fact $\frac{d\alpha_i}{d\lambda}$<0, and the second one is obvious since $\left[\lambda\delta^2(\lambda)\right]$ is increasing in $\lambda$ (for $\frac{d\delta(\lambda)}{d\lambda} \geq 0$).

To summarize, we have proved that, for $\frac{R_u}{\rho_h}$ and/or $\frac{R_{su}}{\rho_i}$ suffciently close to 0, $\frac{dh_2(\lambda)}{d\lambda} \leq \frac{dh_1(\lambda)}{d\lambda}$ and, as a direct consequence, there is a unique linear equilibrium.

#

**Lemma 12** *Let* $x \sim N(0,\Sigma)$ *and* $W = c + b'x + x'Ax$, *where* $c \in R$, $b \in R^n$ *and* $A$ *is a* $(n \times n)$ *matrix Then, if* $\Sigma^{-1} + 2aA$ *is positive definite,*

$$-E[exp(-aW)] = -\left|\Sigma\right|^{-1/2}\left|\Sigma^{-1}+2aA\right|^{-1/2} exp\{-a[c-(1/2)ab'\left(\Sigma^{-1}+2aA\right)^{-1}b]\}.$$

**Proof**. See Danthine and Moresi (1993) page 16.

**Corollary 13** *If $x \sim N(\overline{x}, \sigma_x^2)$ and $y \sim N(\overline{y}, \sigma_y^2)$, then*

$$E[exp\{x - y^2\}] = \frac{1}{\sqrt{1 + 2\sigma_y^2}} exp\left\{\overline{x} + \frac{\sigma_x^2}{2} - \frac{(\overline{y} + cov[x, y])^2}{1 + 2\sigma_y^2}\right\}$$

**Proof:** See Demange and Laroque (1995).

## A.1 Hedger's expected utility

### A.1.1 Hedger's expected utility without trading

If hedger $j$ is not allow to trade in the security market, his final wealth would be given by $W_{hj} = u_j z$. Conditional on his private information $(u_j)$, hedger $j$'s expected utility is equal to

$$E[U(W_{hj})|\, u_j] = -exp\{-\rho_h(E[W_{hj}|\, u_j] - \rho_h \operatorname{var}[W_{hj}|\, u_j]/2)\},$$

where $E[W_{hj}|\, u_j] = u_j E[z]$ and $\operatorname{var}[W_{hj}|\, u_j] = u_j^2 \sigma_z^2$.

Substituting into the above expression and simplifying yield

$$E[U(W_{hj})|\, u_j] = -exp\{-\rho_h(u_j \overline{z} - \frac{\rho_h}{2} u_j^2 \sigma_z^2)\}.$$

By applying lemma **??**, hedger $j$'s expected utility is given by

$$E[U(W_{hj})] = -\left[1 - \rho_h^2 \sigma_z^2 \frac{\sigma_u^2}{R_u}\right]^{-1/2} exp\left\{\frac{\rho_h^2 \overline{z}^2 \sigma_u^2}{2\left(R_u - \rho_h^2 \sigma_z^2 \sigma_u^2\right)}\right\},$$

provided that $\rho_h^2 \sigma_z^2 \sigma_{u_j}^2 = \rho_h^2 \sigma_z^2 (\sigma_\eta^2 + \sigma_u^2) = \rho_h^2 \sigma_z^2 \frac{\sigma_u^2}{R_u} < 1$. Otherwise the expected utility diverges to $-\infty$.

### A.1.2 Hedger's expected utility conditional on information set

$$E[U(W_{hj})|\, p, u_j] = -exp\left\{-\rho_h \left(\frac{\sigma_{vz}}{\sigma_v^2}\right) p u_j - \frac{[E[v|\, p, u_j] - p]^2}{2 \operatorname{var}[v|\, p, u_j]} + \frac{\rho_h^2}{2} \sigma_z^2 (1 - R_{vz}) u_j^2\right\}$$

where

$$p = \overline{v} - \Gamma q + \frac{\{\alpha_i(s - \overline{v}) - \delta u\}}{\Lambda}.$$

### A.1.3 Hedger's expected utility conditional on his endowment

$$E[U(W_{hj})|\, u_j] = -\left\{1 + 2K_1 \frac{\delta^2}{\Lambda^2}(1-R_u)\sigma_u^2\right\}^{-1/2}.$$

$$.exp\left\{-\rho_h\left(\frac{\sigma_{vz}}{\sigma_v^2}\right)\overline{v}u_j + \frac{\rho_h^2}{2}\sigma_z^2\left(1-R_{vz}\right)u_j^2\right\}.$$

$$.exp\left\{-\frac{\alpha_i^2\Lambda^2\sigma_v^2\sigma_u^2}{2R_u\left[\alpha_i^2(1-R_{sv})R_{sv}^{-1}\sigma_v^2 + \delta^2\sigma_u^2(1-R_u)\right]}\left[\Gamma q + \frac{\delta}{\Lambda}R_u u_j\right]^2\right\}.$$

$$.exp\left\{\frac{1}{2}\frac{\delta^2}{\Lambda^2}\sigma_u^2(1-R_u)K_2^2 + K_2\left[\Gamma q + \frac{\delta}{\Lambda}R_u u_j\right]\right\}.$$

$$.exp\left\{-\frac{K_1}{1+2K_1\frac{\delta^2}{\Lambda^2}(1-R_u)\sigma_u^2}\left[\Gamma q + \frac{\delta}{\Lambda}R_u u_j + \frac{\delta^2}{\Lambda^2}(1-R_u)\sigma_u^2 K_2\right]^2\right\}$$

where

$$K_1 = \frac{\left[\alpha_i(\frac{\alpha_i}{R_{sv}} - \Lambda)\sigma_v^2 + \delta^2\sigma_u^2(1-R_u)\right]^2}{2\sigma_v^2\left[\alpha_i^2(1-R_{sv})R_{sv}^{-1}\sigma_v^2 + \delta^2\sigma_u^2(1-R_u)\right]\left[\alpha_i\frac{\alpha_i}{R_{sv}}\sigma_v^2 + \delta^2\sigma_u^2(1-R_u)\right]}$$

$$K_2 = \rho_h\frac{\sigma_{vz}}{\sigma_v^2}u_j - \frac{\Lambda\alpha_i K_1\sigma_v^2}{\alpha_i(\frac{\alpha_i}{R_{sv}} - \Lambda)\sigma_v^2 + \delta^2\sigma_u^2(1-R_u)}\left[\Gamma q + \frac{\delta}{\Lambda}R_u u_j\right]$$

or

$$K_2 = -\frac{\Lambda\alpha_i K_1\sigma_v^2}{\left[\alpha_i(\frac{\alpha_i}{R_{sv}} - \Lambda)\sigma_v^2 + \delta^2\sigma_u^2(1-R_u)\right]}\Gamma q +$$

$$+\left[\rho_h\left(\frac{\sigma_{vz}}{\sigma_v^2}\right) - \frac{\delta\alpha_i R_u K_1\sigma_v^2}{\alpha_i(\frac{\alpha_i}{R_{sv}} - \Lambda)\sigma_v^2 + \delta^2\sigma_u^2(1-R_u)}\right]u_j$$

### A.1.4 Hedger's ex ante expected utility

We can apply Lemma 12 to compute the hedger $j$'s (ex ante) expected utility by taking $a = -1$, $c = -\frac{(\Gamma q)^2}{\mathrm{var}[v|p,u_j]}$, $x' = (u_j, p - E[p])$,

$$\Sigma = \begin{pmatrix} \frac{\sigma_u^2}{R_u} & \frac{-\delta\sigma_u^2}{\Lambda} \\ \frac{-\delta\sigma_u^2}{\Lambda} & \frac{\alpha_i^2(\sigma_v^2/R_{sv})+\delta^2\sigma_u^2}{\Lambda^2} \end{pmatrix},$$

$$A = \begin{pmatrix} \frac{\rho_h^2\sigma_z^2(1-R_{vz})}{2} - \frac{\left(\alpha_i\delta\sigma_v^2\sigma_u^2\right)^2}{d^2\,\mathrm{var}[v|p,u_j]} & \frac{1}{2}\left(-\rho_h\frac{\sigma_{vz}}{\sigma_v^2} - \frac{\left(2\alpha_i\delta\sigma_v^2\sigma_u^2\right)}{d\,\mathrm{var}[v|p,u_j]}\right) \\ \frac{1}{2}\left(-\rho_h\frac{\sigma_{vz}}{\sigma_v^2} - \frac{\left(2\alpha_i\delta\sigma_v^2\sigma_u^2\right)}{d[v|p,u_j]}\right) & \frac{-m^2}{\mathrm{var}[v|p,u_j]} \end{pmatrix},$$

and

$$b = \begin{pmatrix} -\rho_h \frac{\sigma_{vz}}{\sigma_v^2}(\overline{v} - \Gamma q) - \frac{(2\Gamma q \alpha_i \delta \sigma_v^2 \sigma_u^2)}{d\,\mathrm{var}[v|p,u_j]} \\ -\frac{(2Aqm)}{\mathrm{var}[v|p,u_j]} \end{pmatrix},$$

where $d = R_u^{-1}\sigma_u^2[(1-R_u)\delta^2\sigma_u^2 + R_{sv}^{-1}\alpha_i^2\sigma_v^2]$ and $m = \frac{\alpha_i \sigma_v^2 \sigma_u^2 \Lambda}{R_u d} - 1$.

If the matrix $\Sigma^{-1} + 2aA$ is positive definite, hedger $j$'s (ex ante) expected utility will be given by

$$EU_h \equiv -E[exp(-\rho_h W_{hj})] =$$

$$= -|\Sigma|^{-1/2} \left|\Sigma^{-1} + 2aA\right|^{-1/2} exp\{-a[c - (1/2)ab' \left(\Sigma^{-1} + 2aA\right)^{-1} b]\}.$$

Otherwise, hedger $j$'s expected utility diverges to $-\infty$.

### A.1.5 Hedger's ex ante expected utility for large risk aversion

When $\rho_h$ is large ($\rho_h \to +\infty$) the following approximations hold (since then $x_{hj}(p, u_j) \to -\left(\frac{\sigma_{vz}}{\sigma_v^2}\right) u_j$):

$$E[U(W_{hj})|\, u_j] \approxeq -exp\left\{\frac{\rho_h^2}{2} u_j^2 \sigma_z^2 (1 - r_{vz}^2)\right\} \times$$

$$exp\left\{-\rho_h \frac{\sigma_{vz}}{\sigma_v^2} u_j \left(E\left[p\,|u_j\right] - \frac{\rho_h}{2}\frac{\sigma_{vz}}{\sigma_v^2} u_j var\left[p\,|u_j\,\right]\right)\right\}.$$

where

$$E\left[p\,|u_j\right] = \overline{v} - \Gamma q - \frac{\delta}{\Lambda} E[u|\, u_j] = \overline{v} - \Gamma q - \frac{\delta}{\Lambda} R_u u_j$$

and

$$var\left[p\,|u_j\,\right] = \Lambda^{-2}\left\{\alpha_i^2 \frac{\sigma_v^2}{R_{sv}} + \delta^2(1 - R_u)\sigma_u^2\right\}.$$

Note that $E[U(W_{hj})|\, u_j]$ is increasing (decreasing) in $E\left[p\,|u_j\right] - \frac{\rho_h}{2}\frac{\sigma_{vz}}{\sigma_v^2} u_j var\left[p\,|u_j\,\right]$ if $u_j$ is positive (negative). Using Lemma 12 and the fact that $E[U(W_{hj})] = E[E[U(W_{hj})|\, u_j]]$, provided that $[R_u(\sigma_u^2)^{-1} + 2\rho_h A] > 0$ where $A = -(\frac{\delta}{\Lambda} R_u \frac{\sigma_{vz}}{\sigma_v^2} + \frac{\rho_h}{2}(\frac{\sigma_{vz}^2}{\sigma_v^4} var\left[p\,|u_j\,\right] - \sigma_z^2(1 - r_{vz}^2))$, we find

$E[U(W_{hj})] \approxeq -(R_u/\sigma_u^2\ )^{-1/2}\ [R_u(\sigma_u^2)^{-1} + 2\rho_h A]^{-1/2} exp\left\{\frac{\rho_h^2}{2}\frac{(\overline{v}-\Gamma q)^2}{R_u(\sigma_u^2)^{-1}+2\rho_h A}\right\}$. If $[R_u(\sigma_u^2)^{-1} + 2\rho_h A] \leq 0$ , $E[U(W_{hj})]$ diverges to minus infinity.

$EU_h$ increases with $\Gamma q$ and with $\Lambda$, and decreases with $Var\,[p]$, keeping in each case the other equilibrium parameters fixed.

**Proof of Proposition 4.** If the insider publicly reveals his private information before trading on the asset market, speculator k's information set becomes $\{s,\ p\}$. Maximizing $E[U(W_{sk})|\, s, p]$ with respect to $x_{sk}$ yields the demand function for the risky asset

$$X_{sk}(p) = \frac{E[v|s] - p}{\rho_s \operatorname{var}[v|s]},$$

where $E[v|s] = \overline{v} + R_{sv}(s - \overline{v})$ and $\operatorname{var}[v|s] = (1 - R_{sv})\sigma_v^2$. It is obivous that $x_{sk}$ may be written as

$$X_s(s,p) = \beta_s(\overline{v} - p) + \alpha_s(s - \overline{v})$$

where $\alpha_s = \frac{R_{sv}}{[\rho_s(1-R_{sv})\sigma_v^2]}$ and $\beta_s = \frac{1}{[\rho_s(1-R_{sv})\sigma_v^2]}$.

Similarly, hedger $j$ will choose $x_{hj}$ to maximize $E[U(W_{hj})|\, p, s, u_j]$. From the first order condition, hedger $j$'s optimal demand for shares is given by

$$X_{hj}(p,s,u_j) = \frac{E[v|\, s] - p}{\rho_h \operatorname{var}[v|\, s]} - \left(\frac{\sigma_{vz}}{\sigma_v^2}\right) u_j,$$

since $E[v - p|\, p, s, u_j] = E[v|\, s]$, $\operatorname{var}[v - p|\, p, s, u_j] = \operatorname{var}[v|\, s]$, and $\operatorname{cov}[z,\, v - p|\, p, s, u_j] = \frac{\sigma_{vz}}{\sigma_v^2} \operatorname{var}[v|\, s]$. After integrating in $(1,2]$, the hedgers' aggregate demand will be given by

$$X_h(u) = \beta_h(\overline{v} - p) + \alpha_h(s - \overline{v}) - \delta u$$

where $\alpha_h = \frac{R_{sv}}{[\rho_h(1-R_{sv})\sigma_v^2]}$, $\beta_h = \frac{1}{[\rho_h(1-R_{sv})\sigma_v^2]}$, and $\delta = (\sigma_{vz}/\sigma_v^2)$.

From the market clearing condition, the relation between the insider's asset position and its price becomes $p = \overline{v} + \left(\frac{\alpha_s+\alpha_h}{\beta_s+\beta_h}\right)(s - \overline{v}) + (\beta_s + \beta_h)^{-1}(x_i - \delta u)$ so that $\lambda = (\beta_s + \beta_h)^{-1} = \frac{\rho_s\rho_h}{\rho_s+\rho_h} \operatorname{var}[v|s]$. Thus, the insider's optimal demand schedule is given by

$$X_i(s,p) = \alpha_i(s - \overline{v}) + \beta_i(\overline{v} - p) - \gamma_i q,$$

where $\alpha_i = \frac{R_{sv}}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]}$, $\beta_i = \frac{1}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]}$, $\gamma_i = \frac{\rho_i(1-R_{sv})\sigma_v^2}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]}$, and $\lambda = \frac{\rho_s\rho_h}{\rho_s+\rho_h}(1 - R_{sv})\sigma_v^2$. Moreover, it obviously satisfies the second order condition $2\lambda + \rho_i var[v|\, s] > 0$, since $\lambda$ is greater than zero.

From the market clearing condition and the optimal strategies of the insider, the hedgers, and the speculators, the equilibrium price is obtained.

$$p = E[v|\, s] - \frac{(\gamma_i q + \delta u)}{\Lambda}$$

where $\Lambda = \beta_s + \beta_h + \beta_i$..

Conditional on $(s, p)$, the entrepreneur's expected utility is equal to

$$E[-\, exp\{-\rho_i W_i\} |\, s, p] = -exp\left\{-\rho_i \left(E[W_i|\, s, p] - \frac{\rho_i}{2}\,\text{var}[W_i|\, s, p]\right)\right\}$$

where $E[W_i|\, s, p] = qE[v|s] - C(q) + x_i(s, p)\{E[v|\, s] - p\}$ and $\text{var}[W_i|\, s, p] = q^2 var[v|s] + var[v|\, s]\{x_i(s, p)\}^2 + 2qX_i(s, p)var[v|\, s]$.

Substituting into the above expression and simplifying yield

$$E[U(W_i)|\, s, p] = -exp\left\{\rho_i C(q) + \frac{\rho_i^2 q^2}{2}\,\text{var}[v|\, s]\right\} \times$$

$$exp\left\{-\rho_i q E[v|\, s] - \frac{\rho_i}{2}\left[\rho_i\,\text{var}[v|\, s] + 2\lambda\right] x_i^2\right\}$$

where the first exponential is non-random.

To obtain the entrepreneur's ex ante (unconditional) expected utility it suffices to apply corollary 13 by taking $\chi = -\rho_i q E[v|\, s]$ and $y = \sqrt{\frac{\rho_i}{2}\left[\rho_i(1 - R_{sv})\sigma_v^2 + 2\lambda\right]}x_i$. We have that $E\{E[v|s]\} = \overline{v}$ and $var\left[E(v|s)\right] = R_{sv}\sigma_v^2$. On the other hand, we have $E[x_i(s, p)] = -\frac{\gamma_i q}{\Lambda\lambda}$, $var[x_i(s, p)] = \left(\frac{\beta_i \delta}{\Lambda}\right)^2 \sigma_u^2$, and $cov\{E[v|s], x_i(s, p)\} = 0$. After doing some tedious manipulations we get to the following expression for the entrepreneur's ex ante expected utility

$$E[-exp\{-\rho_i W_i\}] = -|SG_i| exp\{-\rho_i[q\overline{v} - C(q) - 0.5\rho_i q^2(\sigma_v^2 - D)]\}$$

where $|SG_i| = \left\{1 + \frac{\rho_i(R_{sv}\sigma_v^2 + \lambda^2\sigma_u^2)}{[\rho_i(1 - R_{sv})\sigma_v^2 + 2\lambda]}\right\}^{-1/2}$, and
$D = \frac{\rho_i}{\rho_i\sigma_v^2 + 2\lambda + \rho_i\lambda^2\sigma_u^2}\left\{1 + g_i^2\frac{R_{sv}\sigma_v^2}{\sigma_u^2}\,\text{var}[v|\, s]\right\}^2$.

The entrepreneur chooses $q$ to maximize the above ex ante expected utility, so that it is obvious that the level of real investment will be given by $q = \frac{\overline{v} - c_1}{c_2 + \rho_i(\sigma_v^2 - D)}$ with the above value of $D$.

Similarly, speculator k's expected utility conditional in his information $(s, p)$ is equal to

$$E[-\, exp\{-\rho_s W_{sk}\}|\, s, p] = -exp\{-\rho_s(E[W_{sk}|\, s, p] - \rho_s\,\text{var}[W_{sk}|\, s, p]/2)\}$$

where $E[W_{sk}|\, s, p] = X_{sk}(s, p)\{E[v|\, s] - p\}$ and $\text{var}[W_{sk}|\, s, p] = var[v|\, s]\{x_{sk}^2(s, p)\}$.

Substituting into the above expression and simplifying yield

$$E[-\, exp\{-\rho_s W_{sk}\}|\, s, p] = -exp\left\{-\frac{(E[v|\, s] - p)^2}{2\,\text{var}[v|\, s]}\right\}.$$

where the first exponential is non-random.

To obtain speculator k's ex ante (unconditional) expected utility it suffices to apply corollary 13 by taking $\chi = 0$ and $y = \sqrt{0.5\,\mathrm{var}[v|\,s]}\,(E[v|\,s] - p)$, where $E[v|\,s] - p = \frac{\gamma_i q + \delta u}{\Lambda}$ By taking into account that $E[E(v|\,s) - p] = \frac{\gamma_i q}{\Lambda}$ and $var[E(v|\,s) - p] = \left(\frac{\delta}{\Lambda}\right)^2 \sigma_u^2$, and doing some simplifications, we get

$$E[-exp\{-\rho_s W_{sk}\}] = -|SG_s| exp\left\{-\frac{(\gamma_i q)^2}{2\left[\Lambda^2(1-R_{sv})\sigma_v^2 + \delta^2\sigma_u^2\right]}\right\}$$

where $|SG_s| = \left[1 + \frac{\delta^2\sigma_u^2}{\Lambda^2(1-R_{sv})\sigma_v^2}\right]^{-1/2}$.

#

**Proof of Proposition 6.** From the characterization of the equilibrium in the model where $s$ is public information (see Proposition 4), it directly follows that $\frac{d\lambda}{dR_{sv}} = -\frac{\rho_h\rho_s}{\rho_h+\rho_s}\sigma_v^2 < 0$. Moreover, the equilibrium values of the endogenous parameters are given by

$$\alpha_i = \frac{R_{sv}}{[\rho_i + \frac{\rho_h\rho_s}{\rho_h+\rho_s}](1-R_{sv})\sigma_v^2},$$

$$\beta_i = \frac{1}{[\rho_i + \frac{\rho_h\rho_s}{\rho_h+\rho_s}](1-R_{sv})\sigma_v^2},$$

$$\gamma_i = \frac{\rho_i}{[\rho_i + \frac{\rho_h\rho_s}{\rho_h+\rho_s}]},$$

$$\alpha_s = \frac{R_{sv}}{[\rho_s(1-R_{sv})\sigma_v^2]}, \quad \beta_s = \frac{1}{[\rho_s(1-R_{sv})\sigma_v^2]},$$

$$\alpha_h = \frac{R_{sv}}{[\rho_h(1-R_{sv})\sigma_v^2]}, \quad \delta = \frac{\sigma_{vz}}{\sigma_v^2}, \quad and \quad \beta_h = \frac{1}{[\rho_h(1-R_{sv})\sigma_v^2]}.$$

1. It is clear that $\frac{d\alpha_i}{dR_{sv}} > 0$, $\frac{d\beta_i}{dR_{sv}} > 0$, $\frac{d\gamma_i}{dR_{sv}} = 0$, $\frac{d\alpha_s}{dR_{sv}} > 0$, $\frac{d\beta_s}{dR_{sv}} > 0$, $\frac{d\alpha_h}{dR_{sv}} > 0$, $\frac{d\beta_h}{dR_{sv}} > 0$, and $\frac{d\delta}{dR_{sv}} = 0$.

2. Market depth is given by

$$\Lambda = \beta_s + \beta_h + \beta_i = \frac{1}{(1-R_{sv})\sigma_v^2}\left(\frac{1}{[\rho_i + \frac{\rho_h\rho_s}{\rho_h+\rho_s}]} + \frac{1}{\rho_s} + \frac{1}{\rho_h}\right),$$

   so that $\frac{d\Lambda}{dR_{sv}} > 0$.

3. $\frac{dq}{dR_{sv}} = \frac{\rho_i q}{[c_2 + \rho_i(\sigma_v^2 - D)]}\frac{dD}{dR_{sv}}$, where $D = \frac{\rho_i(1-R_{sv})\sigma_v^2 + 2\lambda}{\Lambda^2 + \rho_i\beta_i^2[\rho_i(1-R_{sv})\sigma_v^2 + 2\lambda]\delta^2\sigma_u^2}\left(\frac{\gamma_i}{\lambda}\right)^2$. After substituting the values of $\Lambda$ and $\lambda$, $D$ may be written as

$$D = \rho_i^2(\rho_h+\rho_s)^2\left\{\frac{\left[\rho_h\rho_s + \left(\rho_i + \frac{\rho_h\rho_s}{\rho_h+\rho_s}\right)(\rho_h+\rho_s)\right]^2}{\left[\rho_i + 2\frac{\rho_h\rho_s}{\rho_h+\rho_s}\right](1-R_{sv})\sigma_v^2} + \rho_i\delta^2\sigma_u^2\right\}^{-1}.$$

It immediately follows that $\frac{dD}{dR_{sv}} < 0$ and, consequently, $\frac{dq}{dR_{sv}} < 0$.

4. Price precision is given by $\tau = 1/var[v|p]$. The price is informationally equivalent to $R_{sv}(s - \overline{s}) - \frac{\delta u}{\Lambda}$, so that

$$var[v|p] = \sigma_v^2 - \frac{R_{sv}^2 \sigma_v^4}{R_{sv}\sigma_v^2 + \left(\frac{\delta}{\Lambda}\right)^2 \sigma_u^2}.$$

Since $\delta$ is independent of $R_{sv}$ and $\frac{d\Lambda}{dR_{sv}} > 0$, it is clear that $\frac{dvar[v|p]}{dR_{sv}} < 0$ and $\frac{d\tau}{dR_{sv}} > 0$. Price volatility is given by $var[p] = R_{sv}\sigma_v^2 + \left(\frac{\delta}{\Lambda}\right)^2 \sigma_u^2$. The first term is obviously increasing in $R_{sv}$ while the second is decreasing ($\delta$ is independent of $R_{sv}$ and $\frac{d\Lambda}{dR_{sv}} > 0$). For reasonable parameters values, $\frac{dvar[p]}{dR_{sv}} > 0$ for $\left(\frac{\delta}{\Lambda}\right)^2$ decreases less than linearly with $R_{sv}$.

5. The risk premium is defined as $RP = \overline{v} - \overline{p} = \frac{(\gamma_i q)}{\Lambda}$. In equilibrium, $\overline{p} = \overline{v} - \frac{(\gamma_i q)}{\Lambda}$ and $RP = \frac{(\gamma_i q)}{\Lambda}$. Since $\gamma_i$ is independent of $R_{sv}$ and $\frac{d\Lambda}{dR_{sv}} > 0$, it is obvious that $\frac{dRP}{dR_{sv}} < 0$ and $\frac{d\overline{p}}{dR_{sv}} > 0$.

6. The insider's ex ante expected utility is given by

$$E[-exp\{-\rho_i W_i\}] = -|SG_i| exp\{-.5\rho_i(\overline{v} - c_1)q\}$$

where $|SG_i| = \left\{1 + \rho_i[\rho_i(1 - R_{sv})\sigma_v^2 + 2\lambda]\left(\frac{\beta_i}{\Lambda}\right)^2 \delta^2 \sigma_u^2\right\}^{-1/2}$. From the above expression,

$$\frac{dE[U_i(W_i)]}{dR_{sv}} = -exp\{-.5\rho_i(\overline{v} - c_1)q\}\left(\frac{d|SG_i|}{dR_{sv}}\right) - |SG_i|\left(\frac{dexp\{-.5\rho_i(\overline{v} - c_1)q\}}{dR_{sv}}\right).$$

After substituting the values of $\beta_i$, $\lambda$, and $\Lambda$, it immediately follows that $\frac{d|SG_i|}{dR_{sv}}$ is greater than zero. On the other hand, $sign\left(\frac{dexp\{\cdot\}}{dR_{sv}}\right) = -sign\left(\frac{dq}{dR_{sv}}\right) > 0$ since $\frac{dq}{dR_{sv}} < 0$. Thus, $\frac{dE[U_i(W_i)]}{dR_{sv}} < 0$.

The speculator's ex ante expected utility is given by

$$E[-exp\{-\rho_s W_{sk}\}] = -|SG_s| exp\left\{-\frac{(\gamma_i q)^2}{2\left[\Lambda^2(1 - R_{sv})\sigma_v^2 + \delta^2\sigma_u^2\right]}\right\}$$

where $|SG_s| = \left[1 + \frac{\delta^2\sigma_u^2}{\Lambda^2(1-R_{sv})\sigma_v^2}\right]^{-1/2}$ and $\Lambda^2(1 - R_{sv})\sigma_v^2 = \frac{1}{(1-R_{sv})\sigma_v^2}\left(\frac{1}{[\rho_i + \frac{\rho_h\rho_s}{\rho_h+\rho_s}]} + \frac{1}{\rho_s} + \frac{1}{\rho_h}\right)^2$. If $R_{sv}$ increase, then $\Lambda^2(1 - R_{sv})\sigma_v^2$ increases, $\delta$ does not change, and $q$ decreases. As a result, both $|SG_s|$ and the exponential term increase, so that it becomes clear that $\frac{dE[U_s(W_s)]}{dR_{sv}} < 0$.

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**Proof of Proposition 8.** We will first prove that if $\frac{R_u}{\rho_h} \to 0$, then $\frac{d\delta(R_{sv})}{dR_{sv}}$remains strictly positive and $\frac{d\delta(R_{sv})}{dR_{sv}} \to 0$. We know that there is equilibrium if and only if there is a solution to the two-equation system (5)-(6), which may be written as

$$F(\lambda, \delta; R_{sv}) \equiv \lambda - \lambda \frac{R_u}{\rho_h} \frac{[(1-R_u)\delta^2\sigma_u^2 + \alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]^{-1}}{\left\{\frac{1}{\rho_s[\delta^2\sigma_u^2+\alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]} + \frac{1}{\rho_h[(1-R_u)\delta^2\sigma_u^2+\alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]}\right\}} +$$

$$-\frac{\sigma_v^2}{\delta^2\sigma_u^2}\left\{\frac{1}{\rho_s[\delta^2\sigma_u^2+\alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]} + \frac{1}{\rho_h[(1-R_u)\delta^2\sigma_u^2+\alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]}\right\}^{-1} +$$

$$-\frac{\sigma_v^2}{\delta^2\sigma_u^2}\alpha_i = 0$$

$$G(\lambda, \delta; R_{sv}) \equiv \frac{R_u}{\rho_h}\frac{\alpha_i}{[(1-R_u)\delta^2\sigma_u^2 + (1-R_{sv})R_{sv}^{-1}\alpha_i^2\sigma_v^2]}\delta + \left[\delta - \frac{\sigma_{vz}}{\sigma_v^2}\right] = 0,$$

where $\alpha_i = \frac{R_{sv}}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]}$. If $\frac{R_u}{\rho_h}$is small there is a unique solution and, by applying the Implicit Function Theorem we can compute the derivatives $\frac{d\lambda(R_{sv})}{dR_{sv}}$ and $\frac{d\delta(R_{sv})}{dR_{sv}}$:

$$\frac{d\lambda(R_{sv})}{dR_{sv}} = -\frac{\begin{vmatrix} \frac{\partial F}{\partial R_{sv}} & \frac{\partial F}{\partial \delta} \\ \frac{\partial G}{\partial R_{sv}} & \frac{\partial G}{\partial \delta} \end{vmatrix}}{\begin{vmatrix} \frac{\partial F}{\partial \lambda} & \frac{\partial F}{\partial \delta} \\ \frac{\partial G}{\partial \lambda} & \frac{\partial G}{\partial \delta} \end{vmatrix}}, \qquad \frac{d\delta(R_{sv})}{dR_{sv}} = -\frac{\begin{vmatrix} \frac{\partial F}{\partial \lambda} & \frac{\partial F}{\partial R_{sv}} \\ \frac{\partial G}{\partial \lambda} & \frac{\partial G}{\partial R_{sv}} \end{vmatrix}}{\begin{vmatrix} \frac{\partial F}{\partial \lambda} & \frac{\partial F}{\partial \delta} \\ \frac{\partial G}{\partial \lambda} & \frac{\partial G}{\partial \delta} \end{vmatrix}}.$$

It is easy to check that, if $\frac{R_u}{\rho_h} \to 0$, then $\frac{\partial G}{\partial \lambda} \to 0$, $\frac{\partial G}{\partial \delta} \to 1$, $\frac{\partial G}{\partial R_{sv}} \to 0$, and $\frac{\partial F}{\partial \lambda} > 0$ so that

$$\frac{d\delta(R_{sv})}{dR_{sv}} = -\frac{\frac{\partial F}{\partial \lambda}\frac{\partial G}{\partial R_{sv}} - \frac{\partial G}{\partial \lambda}\frac{\partial F}{\partial R_{sv}}}{\frac{\partial F}{\partial \lambda}\frac{\partial G}{\partial \delta} - \frac{\partial F}{\partial \delta}\frac{\partial G}{\partial \lambda}} \to \frac{0}{\frac{\partial F}{\partial \lambda}} = 0,$$

and

$$\frac{d\lambda(R_{sv})}{dR_{sv}} = -\frac{\frac{\partial F}{\partial R_{sv}}\frac{\partial G}{\partial \delta} - \frac{\partial F}{\partial \delta}\frac{\partial G}{\partial R_{sv}}}{\frac{\partial F}{\partial \lambda}\frac{\partial G}{\partial \delta} - \frac{\partial F}{\partial \delta}\frac{\partial G}{\partial \lambda}} \to -\frac{\frac{\partial F}{\partial R_{sv}}}{\frac{\partial F}{\partial \lambda}},$$

and therefore

$$sign\left(\frac{d\lambda(R_{sv})}{dR_{sv}}\right) = -sign\left(\frac{\partial F}{\partial R_{sv}}\right).$$

Moreover, after some tedious (but easy) manipulations we have that $\frac{\partial F}{\partial R_{sv}} < 0$ (just note that $sign\left(\frac{\partial F}{\partial R_{sv}}\right) =$
$-sign\left(\frac{\partial}{\partial R_{sv}}\left[\alpha_i + \left\{\frac{1}{\rho_s[\delta^2\sigma_u^2+\alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]} + \frac{1}{\rho_h[(1-R_u)\delta^2\sigma_u^2+\alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2]}\right\}^{-1}\right]\right)$ where the last partial

derivative is positive since, from Lemma 2, the equilibrium value of $\lambda$ satisfies the inequality $\lambda \geq \sigma_v^2(\frac{\rho_s \rho_h}{\rho_s+\rho_h})$).

Therefore if $\frac{R_u}{\rho_h}$ is close to 0, then $\frac{d\lambda(R_{sv})}{dR_{sv}}$ is positive and bounded away from 0,and $\frac{d\delta(R_{sv})}{dR_{sv}}$ is close to 0 (because of continuity of the derivatives). Let then $\frac{R_u}{\rho_h}$ be close to 0.

1. Let us prove that $\frac{d\alpha^{IT}}{dR_{sv}} > 0$. In the IT equilibrium, $\beta_s = \frac{1}{\rho_s \sigma_v^2} \frac{[\delta^2\sigma_u^2 - (\alpha_i/\lambda)\sigma_v^2]}{[\delta^2\sigma_u^2 + (R_{sv}^{-1}-1)\alpha_i^2\sigma_v^2]}$, so that

$$\frac{d\beta_s}{dR_{sv}} = \frac{\partial \beta_s}{\partial \lambda}\frac{d\lambda}{dR_{sv}} + \frac{\partial \beta_s}{\partial \delta}\frac{d\delta}{dR_{sv}} + \frac{\partial \beta_s}{\partial \alpha_i}\frac{d\alpha_i}{dR_{sv}} + \frac{\partial \beta_s}{\partial R_{sv}}.$$

where it is clear that $\frac{\partial \beta_s}{\partial \lambda} \geq 0$, $\frac{\partial \beta_s}{\partial R_{sv}} \geq 0$ and $\frac{\partial \beta_s}{\partial \alpha_i} < 0$. Therefore, if $\frac{R_u}{\rho_h} \to 0$, then $\frac{d\beta_s}{dR_{sv}} \to \frac{\partial \beta_s}{\partial \lambda}\frac{d\lambda}{dR_{sv}} + \frac{\partial \beta_s}{\partial \alpha_i}\frac{d\alpha_i}{dR_{sv}} + \frac{\partial \beta_s}{\partial R_{sv}}$, where the first and third terms are positive (because $\frac{\partial \beta_s}{\partial \lambda} \geq 0$, $\frac{d\lambda(R_{sv})}{dR_{sv}} > 0$, $\frac{\partial \beta_s}{\partial R_{sv}} \geq 0$ and $\frac{d\lambda(R_{sv})}{dR_{sv}} > 0$) and $\frac{d\beta_s}{dR_{sv}} < 0$. As a direct consequence, $\frac{\partial \beta_s}{\partial \alpha_i}\frac{d\alpha_i}{dR_{sv}}$ must be negative and since $\frac{\partial \beta_s}{\partial \alpha_i} < 0$, and $\frac{d\delta(R_{sv})}{dR_{sv}} \to 0$ it is clear that

$$\frac{d\alpha^{IT}}{dR_{sv}} > 0.$$

2. $\frac{d\beta_s^{IT}}{dR_{sv}} < 0$ and $\frac{d\beta_h^{IT}}{dR_{sv}} < 0$. In the IT equilibrium, $\beta_s = \frac{1}{\rho_s \sigma_v^2} \frac{[\delta^2\sigma_u^2 - (\alpha_i/\lambda)\sigma_v^2]}{[\delta^2\sigma_u^2 + (R_{sv}^{-1}-1)\alpha_i^2\sigma_v^2]}$, $\beta_h = \frac{1}{\rho_h \sigma_v^2} \frac{[(1-R_u)\delta^2\sigma_u^2 - (\alpha_i/\lambda)\sigma_v^2]}{[(1-R_u)\delta^2\sigma_u^2 + (R_{sv}^{-1}-1)\alpha_i^2\sigma_v^2]}$ and $\lambda = \frac{1}{\beta_s+\beta_h}$. $\frac{R_u}{\rho_h}$ is close to 0 if $R_u$ is sufficiently small or $\rho_h$ tends to $\infty$ (or both). We will analyze these two cases separately.

If $R_u$ is close to 0, then it is obvious that $sign\left(\frac{d\beta_s}{dR_{sv}}\right) = sign\left(\frac{d\beta_h}{dR_{sv}}\right)$ and, since $\lambda = \frac{1}{\beta_s+\beta_h}$ and $\frac{d\lambda(R_{sv})}{dR_{sv}} > 0$, it follows that $\frac{d\beta_s}{dR_{sv}}$ and $\frac{d\beta_h}{dR_{sv}}$ must be lower than zero. On the other hand, if $\rho_h$ tends to $\infty$, then $\frac{d\beta_h}{dR_{sv}} \to 0$ and $\lambda \to \frac{1}{\beta_s}$. Since $\frac{d\lambda(R_{sv})}{dR_{sv}} > 0$, it is clear that $\frac{d\beta_s}{dR_{sv}} < 0$.

3. $\frac{d\Lambda^{IT}}{dR_{sv}} < 0$. Market depth may be written as $\Lambda = \frac{1}{\lambda} + \beta_i$, where $\beta_i = \frac{1}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]}$, or as $\Lambda = \frac{1}{\lambda} + \frac{1}{[\rho_i(1-R_{sv})\sigma_v^2+\lambda]}$. If $\rho_i$ is sufficiently close to 0, then it is obvious that $\frac{d\Lambda^{IT}}{dR_{sv}} < 0$,since $\frac{d\lambda(R_{sv})}{dR_{sv}} > 0$. Moreover, this is also true for reasonable parameter values (see simulations).

4. $\frac{d\tau^{IT}}{dR_{sv}} > 0$. In the IT equilibrium, $\tau^{IT}$ may by written as $\tau^{IT} = \tau_v\left[1 + \frac{\alpha_i^2\sigma_v^2}{\delta^2\sigma_u^2 + (R_{sv}^{-1}-1)\alpha_i^2\sigma_v^2}\right]$. If $R_{sv} = 0$, then $\tau^{IT} = \tau_v$ and, on the other hand, it is obvious that $\tau^{IT} > \tau_v$ for any $R_{sv} > 0$. Therefore, it is clear that $\tau^{IT}$ is strictly increasing in $R_{sv}$ for values sufficiently close to 0. For $R_{sv} > 0$, $\frac{d\tau^{IT}}{dR_{sv}} = \frac{\partial \tau^{IT}}{\partial \delta}\frac{d\delta}{dR_{sv}} + \frac{\partial \tau^{IT}}{\partial \alpha_i}\frac{d\alpha_i}{dR_{sv}} + \frac{\partial \tau^{IT}}{\partial R_{sv}}$,where $\frac{\partial \tau^{IT}}{\partial R_{sv}} > 0$ and $\frac{\partial \tau^{IT}}{\partial \alpha_i} > 0$ (these partial derivatives are equal to zero for $R_{sv} = 0$, but are strictly greater than zero for any value of $R_{sv}$ greater than zero). Moreover, we know that $\frac{d\delta}{dR_{sv}} \to 0$ (if $\frac{R_u}{\rho_h}$ is close to 0) and $\frac{d\alpha_i}{dR_{sv}} > 0$ (see point 1 above). Consequently, if $\frac{R_u}{\rho_h}$ is close to 0, $\frac{d\tau^{IT}}{dR_{sv}} > 0$.

5. $\frac{dvar\left[p^{IT}\right]}{dR_{sv}} > 0$. In the equilibria with IT, $var\left[p^{IT}\right] = \frac{\frac{\alpha_i^2\sigma_v^2}{R_{sv}}+\delta^2\sigma_u^2}{\Lambda^2}$. Since $\frac{\alpha_i^2}{R_{sv}}$ is increasing in $R_{sv}$ and $\frac{d\delta}{dR_{sv}} \to 0$ if $\frac{R_u}{\rho_h}$ is close to 0, it is obvious that, if $\Lambda$ is decreasing in $R_{sv}$, then $\frac{dvar\left[p^{IT}\right]}{dR_{sv}} > 0$. Thus, $\frac{dvar\left[p^{IT}\right]}{dR_{sv}} > 0$ if $\rho_i$ is sufficiently close to 0 and also for reasonable parameter values.

6.$q^{IT} < q^{NI}$. ($\frac{dq^{IT}}{dR_{sv}} < 0$). In the equilibria with IT, $q^{IT} = \frac{\overline{v}-c_1}{c_2+\rho_i\sigma_v^2(1-d^{IT})}$, where

$$d^{IT} = \frac{\rho_i\sigma_v^2}{\rho_i\sigma_v^2 + 2\lambda^{IT} + \rho_i\left(\lambda^{IT}\right)^2\delta^2\sigma_u^2}\left\{1 + \frac{(1-R_{sv})\lambda^{IT}}{\left[\rho_i(1-R_{sv})\sigma_v^2 + \lambda^{IT}\right]}\frac{\alpha_i^{IT}E^{IT}}{(1+\alpha_i^{IT}E^{IT})}\right\}^2,$$

and

$$E^{IT} = \frac{1/\rho_s}{\left[\delta^2\sigma_u^2 + \alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2\right]} + \frac{1/\rho_h}{\left[(1-R_u)\delta^2\sigma_u^2 + \alpha_i^2(R_{sv}^{-1}-1)\sigma_v^2\right]}.$$

On the other hand, $q^{NI} = \frac{\overline{v}-c_1}{c_2+\rho_i\sigma_v^2(1-d^{NI})}$, where

$$d^{NI} = \frac{\rho_i\sigma_v^2}{\rho_i\sigma_v^2 + 2\lambda^{NI} + \rho_i\left(\lambda^{NI}\right)^2\delta^2\sigma_u^2}.$$

If $R_{sv} = 0$ or $R_{sv} = 1$, then $d^{IT} = \frac{\rho_i\sigma_v^2}{\rho_i\sigma_v^2+2\lambda^{IT}+\rho_i\left(\lambda^{IT}\right)^2\delta^2\sigma_u^2}$. Since $\lambda^{IT} > \lambda^{NI}$, then $d^{IT} = \frac{\rho_i\sigma_v^2}{\rho_i\sigma_v^2+2\lambda^{IT}+\rho_i\left(\lambda^{IT}\right)^2\delta^2\sigma_u^2} < \frac{\rho_i\sigma_v^2}{\rho_i\sigma_v^2+2\lambda^{NI}+\rho_i\left(\lambda^{NI}\right)^2\delta^2\sigma_u^2} = d^{NI}$, which directly implies that $q^{IT} < q^{NI}$, because $q$ is strictly increasing in $d$. By continuity this is also true for $R_{sv}$ close to 0 or close to 1. We have that $\frac{dq^{IT}}{dR_{sv}} < 0$ if and only if $\frac{d\left(d^{IT}\right)}{dR_{sv}} < 0$. After some tedious manipulations we can see that $\frac{d\left(d^{IT}\right)}{dR_{sv}} < 0$ if $R_{sv}$ is close to 0 or to 1.

7. $\overline{p}^{IT} > \overline{p}^{NI}$ for $R_{sv}$ close to 1. In the equilibrium with insider trading, the expected price is given by $\overline{p}^{IT} = \overline{v} - \Gamma^{IT}q^{IT}$ where $\Gamma^{IT}$ may be written as $\Gamma^{IT} = \frac{\gamma_s^{IT}+\gamma_h^{IT}+\gamma_i^{IT}}{\Lambda^{IT}} = \frac{\gamma_i^{IT}}{(1+\alpha_i^{IT}E^{IT})}\frac{1}{\Lambda^{IT}}$. If $R_{sv} = 1$, then $\gamma_i^{IT} = 0$, and, as a direct consequence, $\Gamma^{IT} = 0$ and

$$\overline{p}^{IT} = \overline{v} > \overline{v} - \Gamma^{NI}q^{NI} = \overline{p}^{NI},$$

since $\Gamma^{NI}q^{NI} = \sigma_v^2\left[\frac{2}{\rho_i} + \frac{1}{\rho_h} + \frac{1}{\rho_s}\right]^{-1} q^{NI} > 0$. By continuity, this is also true for $R_{sv}$ close to 1.

8. If $\frac{R_u}{\rho_h}$ is close to 0, $\frac{d|SG_i^{IT}|}{dR_{sv}} < 0$ ($|SG_i^{IT}| < |SG_i^{NI}|$). In the equilibrium with Insider Trading, the insider's ex ante expected utility may be written as

$$E[-exp\{-\rho_i W_i^{IT}\}] = -|SG_i^{IT}|exp\{-.5\rho_i(\overline{v}-c_1)q^{IT}\}$$

where $|SG_i^{IT}| = \left\{1 + \frac{\rho_i(R_{sv}\sigma_v^2+\lambda^2\delta^2\sigma_u^2)}{[\rho_i(1-R_{sv})\sigma_v^2+2\lambda]}\right\}^{-1/2}$. From this last expression, $\frac{d|SG_i^{IT}|}{dR_{sv}} = \frac{\partial|SG_i^{IT}|}{\partial R_{sv}} + \frac{\partial|SG_i^{IT}|}{\partial\lambda}\frac{d\lambda}{dR_{sv}} + \frac{\partial|SG_i^{IT}|}{\partial\delta}\frac{d\delta}{dR_{sv}}$. It can be proved that $\frac{\partial|SG_i^{IT}|}{\partial R_{sv}} < 0$, $\frac{\partial|SG_i^{IT}|}{\partial\lambda} < 0$, $\frac{d\delta}{dR_{sv}} \to 0$ as $\frac{R_u}{\rho_h} \to 0$, and $\frac{d\lambda}{dR_{sv}} > 0$, so that $\frac{d|SG_i^{IT}|}{dR_{sv}} < 0$. As a direct consequence, $|SG_i^{IT}| < |SG_i^{NI}|$. On the other hand, for all $\rho_i > 0$, if $R_{sv}$ is close to 1, the exponential term is higher when insider trading is permitted, since $q^{IT} < q^{NI}$. If $\rho_i = 0$ then only the speculative gains matter and $EU_i^{IT} > EU_i^{NI}$.

9. We will analyze the two cases, $\frac{1}{\rho_h}$ close to zero and $R_u$ sufficiently small, separately. In the IT equilibria, if $R_{sv}$=1 and $\frac{1}{\rho_h}$ is close to 0, then $\Gamma = 0$, $\alpha_i = \frac{1}{\lambda}$, $\Lambda = \frac{2}{\lambda}$, and $\lambda$ is implicitly defined by $\delta^2\sigma_u^2 - \frac{\sigma_v^2}{\lambda^2} = \frac{\delta^2\sigma_u^2\rho_s\sigma_v^2}{\lambda}$. As a consequence, the speculators' ex ante expected utility is given by

$$E[U_{sk}^{IT}] = -|SG_s^{IT}| = \left\{1 + \frac{\delta^2\sigma_u^2\rho_s^2\sigma_v^2}{4}\right\}^{-1/2}.$$

In the NI equilibrium, if $\frac{1}{\rho_h}$ is close to 0, then $\Lambda^{NI} = \frac{2\rho_s\sigma_v^2+\rho_i\sigma_v^2}{\rho_s\sigma_v^2(\rho_s\sigma_v^2+\rho_i\sigma_v^2)}$ and the speculators' ex ante expected utility may be written as

$$E[U_{sk}^{NI}] = E[-exp\{-\rho_s W_{sk}^{NI}\}] = -|SG_s^{NI}|exp\left\{-0.5\frac{(\Gamma q)^2}{\frac{\delta^2\sigma_u^2}{\Lambda^2} + \sigma_v^2}\right\}$$

where $|SG_s^{NI}| \to \left\{1 + \delta^2\sigma_u^2\rho_s^2\sigma_v^2\left[\frac{\rho_s\sigma_v^2+\rho_i\sigma_v^2}{2\rho_s\sigma_v^2+\rho_i\sigma_v^2}\right]^2\right\}^{-1/2}$. Since $exp\left\{-0.5\frac{(\Gamma q)^2}{\frac{\delta^2\sigma_u^2}{\Lambda^2}+\sigma_v^2}\right\} < 1$ and $\frac{1}{2} \leq \frac{\rho_s\sigma_v^2+\rho_i\sigma_v^2}{2\rho_s\sigma_v^2+\rho_i\sigma_v^2} \leq 1$ (which implies that $\left[\frac{\rho_s\sigma_v^2+\rho_i\sigma_v^2}{2\rho_s\sigma_v^2+\rho_i\sigma_v^2}\right]^2 \geq \frac{1}{4}$ and therefore that $|SG_s^{IT}| > |SG_s^{NI}|$ and $-|SG_s^{IT}| < -|SG_s^{NI}|$), it is obvious that

$$E[U_{sk}^{NI}] = -|SG_s^{NI}|exp\left\{-0.5\frac{(\Gamma q)^2}{\frac{\delta^2\sigma_u^2}{\Lambda^2} + \sigma_v^2}\right\} > -|SG_s^{NI}| \geq -|SG_s^{IT}| = E[U_{sk}^{IT}].$$

By continuity, this is also true for $R_{sv}$ close to 1.

A similar proof can be done for $R_{sv} = 1$ and $R_u$ close to 0. The speculators' ex ante expected utility is given by $E[U_{sk}^{IT}] = \left\{1 + \left(\frac{1}{\rho_s} + \frac{1}{\rho_h}\right)^{-2}\frac{\delta^2\sigma_u^2\sigma_v^2}{4}\right\}^{-1/2}$ in the IT equilibria and by $E[U_{sk}^{NI}] = -|SG_s^{NI}|exp\left\{-0.5\frac{(\Gamma q)^2}{\frac{\delta^2\sigma_u^2}{\Lambda^2}+\sigma_v^2}\right\}$, with $|SG_s^{NI}| \to \left\{1 + \delta^2\sigma_u^2\left(\frac{1}{\rho_s} + \frac{1}{\rho_h}\right)^{-2}\sigma_v^2\left[\frac{\left(\frac{1}{\rho_s}+\frac{1}{\rho_h}\right)^{-1}\sigma_v^2+\rho_i\sigma_v^2}{2\left(\frac{1}{\rho_s}+\frac{1}{\rho_h}\right)^{-1}\sigma_v^2+\rho_i\sigma_v^2}\right]^2\right\}^{-1/2}$ in the NI equilibrium. Since $exp\left\{-0.5\frac{(\Gamma q)^2}{\frac{\delta^2\sigma_u^2}{\Lambda^2}+\sigma_v^2}\right\} < 1$ and $\frac{1}{2} \leq \frac{\left(\frac{1}{\rho_s}+\frac{1}{\rho_h}\right)^{-1}\sigma_v^2+\rho_i\sigma_v^2}{2\left(\frac{1}{\rho_s}+\frac{1}{\rho_h}\right)^{-1}\sigma_v^2+\rho_i\sigma_v^2} \leq 1$ (which implies that $\left[\frac{\left(\frac{1}{\rho_s}+\frac{1}{\rho_h}\right)^{-1}\sigma_v^2+\rho_i\sigma_v^2}{2\left(\frac{1}{\rho_s}+\frac{1}{\rho_h}\right)^{-1}\sigma_v^2+\rho_i\sigma_v^2}\right]^2 \geq \frac{1}{4}$ and therefore that $|SG_s^{IT}| > |SG_s^{NI}|$ and $-|SG_s^{IT}| < -|SG_s^{NI}|$), it is obvious that $E[U_{sk}^{NI}] > -|SG_s^{NI}| \geq -|SG_s^{IT}| = E[U_{sk}^{IT}]$. By continuity, this is also true for $R_{sv}$ close to 1.

#

**Proof of Proposition 10.** 1. We know that $\frac{d\lambda^{IT}}{dR_{sv}} > 0$ (see proposition 8), $\frac{d\lambda^{PD}}{dR_{sv}} < 0$ (since $\lambda^{PD} = \frac{\rho_h \rho_s}{\rho_h + \rho_s}(1 - R_{sv})\sigma_v^2$, and $\lambda^{IT}(0) = \lambda^{PD}(0)$). Thus, we can conclude that $\lambda^{IT}(R_{sv})$ is strictly greater that $\lambda^{PD}(R_{sv})$ for all $R_{sv} > 0$. Moreover, the difference $\lambda^{IT}(R_{sv}) - \lambda^{PD}(R_{sv})$ is increasing in $R_{sv}$. On the other hand, $\alpha_i^{IT} = \frac{R_{sv}}{\rho_i(1-R_{sv})\sigma_v^2 + \lambda^{IT}}$ and $\alpha_i^{PD} = \frac{R_{sv}}{\rho_i(1-R_{sv})\sigma_v^2 + \lambda^{PD}}$. Since $\lambda^{IT} > \lambda^{PD}$ for all $R_{sv} > 0$, $\alpha_i^{IT} < \alpha_i^{PD}$ for all $R_{sv} > 0$.

2. We know that $\frac{d\beta_s^{IT}}{dR_{sv}} < 0$ and $\frac{d\beta_h^{IT}}{dR_{sv}} < 0$ (see Proposition 8), $\frac{d\beta_s^{PD}}{dR_{sv}} > 0$, and $\frac{d\beta_h^{PD}}{dR_{sv}} > 0$ (since $\beta_s^{PD} = \frac{1}{[\rho_s(1-R_{sv})\sigma_v^2]}$ and $\beta_h^{PD} = \frac{1}{[\rho_h(1-R_{sv})\sigma_v^2]}$). Thus, $\beta_s^{PD} > \beta_s^{IT}$ and $\beta_h^{PD} > \beta_h^{IT}$ for all $R_{sv} > 0$. Moreover, the differences $\beta_s^{PD} - \beta_s^{IT}$ and $\beta_h^{PD} - \beta_h^{IT}$ are increasing in $R_{sv}$.

3. Market depth is given by $\Lambda = \frac{1}{\lambda} + \frac{1}{\rho_i(1-R_{sv})\sigma_v^2 + \lambda}$. Since $\lambda^{IT} > \lambda^{PD}$ for all $R_{sv} > 0$, it is obvious that $\Delta^{IT} < \Lambda^{PD}$.

4. In the IT equilibrium, the price is informationally equivalent to $\alpha_i^{IT}(s - \overline{v}) - \delta^{IT}u$. On the other hand, in the "PD" equilibrium, the price is informationally equivalent to $\left(\alpha_i^{PD} + \alpha_s^{PD} + \alpha_h^{PD}\right)(s - \overline{v}) - \delta^{PD}u$, since $s$ is now public information. If $\frac{R_u}{\rho_h}$ tends to 0, then $\delta^{IT} \to \delta^{PD} = (\sigma_{vz}/\sigma_v^2)$. Moreover, $0 \leq \alpha_i^{IT} < \alpha_i^{PD}$ and $\alpha_s^{PD} + \alpha_h^{PD} \geq 0$, so that it is clear that $\tau^{IT} = \frac{1}{var[v|p^{IT}]} < \tau^{PD} = \frac{1}{var[v|p^{PD}]}$ for all $R_{sv} > 0$.

The volatility of prices is given by

$$var\left[p^{IT}\right] = \frac{\left(\lambda^{IT}\right)^2}{\left[\rho_i(1 - R_{sv})\sigma_v^2 + 2\lambda^{IT}\right]^2} R_{sv}\sigma_v^2 + \frac{\left(\delta^{IT}\right)^2 \sigma_u^2}{\left(\Delta^{IT}\right)^2}$$

in the IT equilibrium, and by

$$var\left[p^{PD}\right] = R_{sv}\sigma_v^2 + \frac{\left(\delta^{PD}\right)^2 \sigma_u^2}{\left(\Delta^{PD}\right)^2}$$

in the PD equilibrium.

If $R_{sv} \to 1$ and $\frac{R_u}{\rho_h}$ tends to 0, then $\delta^{IT} \to \delta^{PD} = (\sigma_{vz}/\sigma_v^2)$, $\Delta^{PD} \to \infty$, and $\Lambda^{IT} = \frac{2}{\lambda^{IT}}$, where the value of $\lambda^{IT}$ is implicitly defined by $\left(\delta^{IT}\right)^2 \sigma_u^2 - \frac{\sigma_v^2}{\left(\lambda^{IT}\right)^2} = \frac{\left(\delta^{IT}\right)^2 \sigma_u^2 \rho_s \sigma_v^2}{\lambda^{IT}} \iff \left(\delta^{IT}\right)^2 \sigma_u^2 = \frac{\sigma_v^2}{\lambda^{IT}\left[\lambda^{IT} - \rho_s\sigma_v^2\right]}$. As a result, $var\left[p^{PD}\right] \to \sigma_v^2$ and

$$var\left[p^{IT}\right] \to \frac{1}{4}\sigma_v^2 + \frac{\left(\delta^{IT}\right)^2 \sigma_u^2}{\left(\Delta^{IT}\right)^2} = \frac{\sigma_v^2}{4}\left[1 + \frac{\lambda^{IT}}{\left[\lambda^{IT} - \rho_s\sigma_v^2\right]}\right] < \frac{\sigma_v^2}{2}$$

so that

$$var\left[p^{PD}\right] \to \sigma_v^2 > \frac{\sigma_v^2}{2} > var\left[p^{IT}\right].$$

5. In the equilibria with IT, $q^{IT} = \frac{\overline{v}-c_1}{c_2+\rho_i\sigma_v^2(1-d^{IT})}$, where

$$d^{IT} = \frac{\rho_i\sigma_v^2}{\rho_i\sigma_v^2 + 2\lambda^{IT} + \rho_i\left(\lambda^{IT}\right)^2\delta^2\sigma_u^2}\left\{1 + \frac{(1-R_{sv})\lambda^{IT}}{[\rho_i(1-R_{sv})\sigma_v^2 + \lambda^{IT}]}\frac{\alpha_i^{IT}E^{IT}}{(1+\alpha_i^{IT}E^{IT})}\right\}^2.$$

On the other hand, $q^{PD} = \frac{\overline{v}-c_1}{c_2+\rho_i\sigma_v^2(1-d^{PD})}$, where $d^{PD}$ may be written (after some simple -but tedious- manipulations) as

$$d^{PD} = \frac{\rho_i\left(\frac{\rho_i+2\frac{\rho_h\rho_s}{\rho_h+\rho_s}}{\frac{\rho_h\rho_s}{\rho_h+\rho_s}[\rho_i+\frac{\rho_h\rho_s}{\rho_h+\rho_s}]}\right)^2}{[\rho_i+2\frac{\rho_h\rho_s}{\rho_h+\rho_s}]\left[\frac{1}{\rho_s}+\frac{1}{\rho_h}+\frac{1}{\rho_i+\frac{\rho_s\rho_h}{\rho_s+\rho_h}}\right]^2 + \rho_i(1-R_{sv})\sigma_v^2\delta^2\sigma_u^2}(1-R_{sv}).$$

If $R_{sv}\rightarrow 1$, then $d^{PD}\rightarrow 0$ and $d^{IT}\rightarrow \frac{\rho_i\sigma_v^2}{\rho_i\sigma_v^2+2\lambda^{IT}+\rho_i\left(\lambda^{IT}\right)^2\delta^2\sigma_u^2} > 0$. Consequently, $q^{IT} > q^{PD}$.

6. In PD equilibria, the insider's ex ante expected utility is given by

$$E[-exp\{-\rho_i W_i^{PD}\}] = -|SG_i^{PD}|exp\{-.5\rho_i(\overline{v}-c_1)q^{PD}\}$$

where $|SG_i^{PD}|$ may be written as

$$|SG_i^{PD}| = \left\{1 + \frac{\rho_i\left[\rho_i+2\frac{\rho_h\rho_s}{\rho_h+\rho_s}\right]}{[\rho_i+\frac{\rho_h\rho_s}{\rho_h+\rho_s}]\left[\frac{1}{\rho_s}+\frac{1}{\rho_h}+\frac{1}{\rho_i+\frac{\rho_s\rho_h}{\rho_s+\rho_h}}\right]^2}(1-R_{sv})\left(\delta^{PD}\right)^2\sigma_v^2\sigma_u^2\right\}^{-1/2}.$$

It is obvious that $\frac{d|SG^{PD}|}{dR_{sv}} > 0$ and, from proposition 8.8, $\frac{d|SG_i^{IT}|}{dR_{sv}} < 0$, so that it is clear that, for any $R_{sv}$, $|SG_i^{PD}| > |SG_i^{IT}|$. On the other hand, if $R_{sv}$ is close to 1, then $q^{IT} > q^{PD}$ and, as a direct consequence, $exp\{-.5\rho_i(\overline{v}-c_1)q^{PD}\} > exp\{-.5\rho_i(\overline{v}-c_1)q^{IT}\}$. Therefore, provided that $R_{sv}$ is close to 1, $E[U_i^{PD}] < E[U_i^{IT}]$.

Moreover, if $\rho_i$ is close to 0, it is also true that $E[U_i^{PD}] < E[U_i^{IT}]$ since $|SG_i^{PD}| > |SG_i^{IT}|$.and $q^{IT} \simeq q^{PD}$.

7. In the PD equilibria, speculator k's ex ante expected utility is given by $E\left[U_{sk}^{PD}\right] = -|SG_{sk}^{PD}||IG_{sk}^{PD}|$ where

$$|SG_{sk}^{PD}| = \left\{1 + \left[\frac{1}{\rho_s}+\frac{1}{\rho_h}+\frac{1}{\rho_i+\frac{\rho_s\rho_h}{\rho_s+\rho_h}}\right]^{-2}(1-R_{sv})\left(\delta^{PD}\right)^2\sigma_v^2\sigma_u^2\right\}^{-1/2}$$

$$|IG_{sk}^{PD}| = exp\left\{-\frac{\left(\gamma_i^{PD}\right)^2 q^{PD}}{2}\left\{\frac{\left[\frac{1}{\rho_s}+\frac{1}{\rho_h}+\frac{1}{\rho_i+\frac{\rho_s\rho_h}{\rho_s+\rho_h}}\right]^2}{(1-R_{sv})\sigma_v^2} + \left(\delta^{PD}\right)^2\sigma_u^2\right\}^{-1}\right\}.$$

On the other hand, in the IT equilibria, speculator k's ex ante expected utility is given by

$$E[-exp\{-\rho_s W_{sk}^{IT}\}] = -|SG_{sk}^{IT}|exp\left\{-0.5\frac{(\Gamma^{IT}q^{IT})^2}{\text{var}[E(v|\,p^{IT}) - p^{IT}] + \text{var}[v|\,p^{IT}]}\right\}$$

where

$$|SG_{sk}^{IT}| = \frac{1}{\sqrt{1+\frac{\text{var}[E(v|p^{IT})-p^{IT}]}{\text{var}[v|p^{IT}]}}} = \left\{1+\frac{\text{var}[E(v|\,p^{IT})-p^{IT}]}{\text{var}[v|\,p^{IT}]}\right\}^{-1/2},$$

$$\text{var}[E(v|\,p^{IT}) - p^{IT}] = \frac{\left[\left(\delta^{IT}\right)^2\sigma_u^2 + \left(\alpha_i^{IT}\right)^2 R_{sv}^{-1}\sigma_v^2 - \alpha_i^{IT}\Lambda^{IT}\sigma_v^2\right]^2}{(\Lambda^{IT})^2\left[\left(\delta^{IT}\right)^2\sigma_u^2 + \left(\alpha_i^{IT}\right)^2 R_{sv}^{-1}\sigma_v^2\right]}$$

and

$$\text{var}[v|\,p^{IT}] = \tau_v\frac{\left[\left(\delta^{IT}\right)^2\sigma_u^2 + \left(\alpha_i^{IT}\right)^2(1-R_{sv})R_{sv}^{-1}\sigma_v^2\right]}{\left[\left(\delta^{IT}\right)^2\sigma_u^2 + \left(\alpha_i^{IT}\right)^2 R_{sv}^{-1}\sigma_v^2\right]}.$$

If $R_{sv} = 1$ and $\frac{1}{\rho_h}$ is close to 0, then $E\left[U_{sk}^{PD}\right] = -1$, $\Gamma^{IT} = 0$, $\alpha_i^{IT} = \frac{1}{\lambda^{IT}}$, and $\Lambda^{IT} = \frac{2}{\lambda^{IT}}$, where the value of $\lambda^{IT}$ is implicitly defined by $\left(\delta^{IT}\right)^2\sigma_u^2 - \frac{\sigma_v^2}{\left(\lambda^{IT}\right)^2} = \frac{\left(\delta^{IT}\right)^2\sigma_u^2\rho_s\sigma_v^2}{\lambda^{IT}}$. As a direct consequence,

$$E[U_{sk}^{IT}] = -\left\{1+\frac{\left(\delta^{IT}\right)^2\sigma_u^2\rho_s^2\sigma_v^2}{4}\right\}^{-1/2} > E\left[U_{sk}^{PD}\right].$$

Similarly, if $R_{sv} = 1$ and $R_u$ is close to 0, then

$$E[U_{sk}^{IT}] = -\left\{1+\left(\frac{1}{\rho_s}+\frac{1}{\rho_h}\right)^{-2}\frac{\left(\delta^{IT}\right)^2\sigma_u^2\sigma_v^2}{4}\right\}^{-1/2} > E\left[U_{sk}^{PD}\right].$$

By continuity, if $\frac{R_u}{\rho_h}$ is close to 0, this result, $E[U_{sk}^{IT}] > E\left[U_{sk}^{PD}\right]$, also holds for $R_{sv}$ sufficiently close to 1.

#

# TABLE 1: Results for BC1

Exogenous parameters

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0,9 | $\rho_i$ | 2 | $\rho_h$ | 3 | var(v) | 0,04 | $R_u$ | 0,01 |
| 0,02 | $\rho_s$ | 1 | Ev | 1 | var(u) | 0,01 | $R_{vz}$ | 0,8281 |
| | | | | | | | var(z) | 0,04 |

## Equilibrium with NI

| $\lambda^{NI}$ | $\alpha_i^{NI}$ | $\gamma_i^{NI}$ | $\delta^{NI}$ | $\Lambda^{NI}$ | $q^{NI}$ | $\tau^{NI}$ | $E[U_i^{NI}]$ | $E[U_s^{NI}]$ | $E[U_h^{NI}]$ |
|---|---|---|---|---|---|---|---|---|---|
| 0,030 | 0,00 | 0,7273 | 0,91 | 42,42 | 1,84 | 25,00 | -0,83173 | -0,987559 | -42,55 |

## Equilibrium with IT

| $\lambda^{IT}$ | $\alpha_i^{IT}$ | $\gamma_i^{IT}$ | $\delta^{IT}$ | $\Lambda^{IT}$ | $q^{IT}$ | $\tau^{IT}$ | $E[U_i^{IT}]$ | $E[U_s^{IT}]$ | $E[U_h^{IT}]$ |
|---|---|---|---|---|---|---|---|---|---|
| 0,495 | 0,09 | 0,1332 | 0,89 | 3,77 | 1,22 | 25,56 | -0,88195 | -0,999691 | -57,39 |
| 0,711 | 0,13 | 0,0920 | 0,88 | 2,68 | 1,15 | 26,19 | -0,88662 | -0,999843 | -60,73 |
| 0,880 | 0,16 | 0,0717 | 0,88 | 2,19 | 1,12 | 26,88 | -0,88852 | -0,999893 | -63,46 |
| 1,026 | 0,18 | 0,0587 | 0,87 | 1,89 | 1,10 | 27,60 | -0,88951 | -0,999917 | -65,99 |
| 1,157 | 0,21 | 0,0493 | 0,86 | 1,69 | 1,08 | 28,37 | -0,89008 | -0,999932 | -68,43 |
| 1,278 | 0,22 | 0,0420 | 0,86 | 1,53 | 1,07 | 29,19 | -0,89043 | -0,999941 | -70,83 |
| 1,392 | 0,24 | 0,0360 | 0,85 | 1,41 | 1,06 | 30,07 | -0,89063 | -0,999948 | -73,23 |
| 1,500 | 0,26 | 0,0310 | 0,84 | 1,31 | 1,05 | 31,00 | -0,89075 | -0,999953 | -75,64 |
| 1,604 | 0,27 | 0,0267 | 0,84 | 1,23 | 1,05 | 31,99 | -0,89081 | -0,999957 | -78,08 |
| 1,705 | 0,29 | 0,0229 | 0,83 | 1,16 | 1,04 | 33,05 | -0,89083 | -0,999960 | -80,55 |
| 1,804 | 0,30 | 0,0196 | 0,82 | 1,10 | 1,04 | 34,18 | -0,89082 | -0,999963 | -83,06 |
| 1,902 | 0,31 | 0,0166 | 0,82 | 1,04 | 1,03 | 35,40 | -0,89080 | -0,999965 | -85,63 |
| 1,998 | 0,32 | 0,0138 | 0,81 | 0,99 | 1,03 | 36,71 | -0,89077 | -0,999967 | -88,24 |
| 2,094 | 0,33 | 0,0113 | 0,80 | 0,95 | 1,03 | 38,13 | -0,89073 | -0,999969 | -90,92 |
| 2,191 | 0,34 | 0,0090 | 0,79 | 0,91 | 1,02 | 39,66 | -0,89070 | -0,999970 | -93,65 |
| 2,289 | 0,35 | 0,0069 | 0,79 | 0,87 | 1,02 | 41,32 | -0,89066 | -0,999972 | -96,44 |
| 2,390 | 0,35 | 0,0050 | 0,78 | 0,83 | 1,02 | 43,13 | -0,89064 | -0,999973 | -99,29 |
| 2,492 | 0,36 | 0,0032 | 0,77 | 0,80 | 1,02 | 45,10 | -0,89062 | -0,999974 | -102,21 |
| 2,599 | 0,36 | 0,0015 | 0,75 | 0,77 | 1,01 | 47,27 | -0,89063 | -0,999976 | -105,19 |
| 2,711 | 0,37 | 0,0000 | 0,74 | 0,74 | 1,01 | 49,66 | -0,89065 | -0,999977 | -108,23 |

## Equilibrium with PD

| $\lambda^{PD}$ | $\alpha_i^{PD}$ | $\gamma_i^{PD}$ | $\delta^{PD}$ | $\Lambda^{PD}$ | $q^{PD}$ | $\tau^{PD}$ | $E[U_i^{PD}]$ | $E[U_s^{PD}]$ | $E[U_h^{PD}]$ |
|---|---|---|---|---|---|---|---|---|---|
| 0,029 | 0,48 | 0,727 | 0,91 | 45 | 1,77 | 26,32 | -0,83794 | -0,989104 | -46,63 |
| 0,027 | 1,01 | 0,727 | 0,91 | 47 | 1,70 | 27,78 | -0,84372 | -0,990453 | -51,14 |
| 0,026 | 1,60 | 0,727 | 0,91 | 50 | 1,64 | 29,41 | -0,84909 | -0,991636 | -56,16 |
| 0,024 | 2,27 | 0,727 | 0,91 | 53 | 1,58 | 31,25 | -0,85411 | -0,992678 | -61,76 |
| 0,023 | 3,03 | 0,727 | 0,91 | 57 | 1,52 | 33,33 | -0,85881 | -0,993599 | -68,03 |
| 0,021 | 3,90 | 0,727 | 0,91 | 61 | 1,47 | 35,71 | -0,86322 | -0,994415 | -75,09 |
| 0,020 | 4,90 | 0,727 | 0,91 | 65 | 1,42 | 38,46 | -0,86735 | -0,995142 | -83,06 |
| 0,018 | 6,06 | 0,727 | 0,91 | 71 | 1,38 | 41,67 | -0,87125 | -0,995790 | -92,10 |
| 0,017 | 7,44 | 0,727 | 0,91 | 77 | 1,34 | 45,45 | -0,87493 | -0,996370 | -102,40 |
| 0,015 | 9,09 | 0,727 | 0,91 | 85 | 1,30 | 50,00 | -0,87840 | -0,996890 | -114,17 |
| 0,014 | 11,11 | 0,727 | 0,91 | 94 | 1,26 | 55,56 | -0,88168 | -0,997358 | -127,70 |
| 0,012 | 13,64 | 0,727 | 0,91 | 106 | 1,22 | 62,50 | -0,88480 | -0,997779 | -143,32 |
| 0,011 | 16,88 | 0,727 | 0,91 | 121 | 1,19 | 71,43 | -0,88775 | -0,998160 | -161,43 |
| 0,009 | 21,21 | 0,727 | 0,91 | 141 | 1,16 | 83,33 | -0,89056 | -0,998504 | -182,55 |
| 0,008 | 27,27 | 0,727 | 0,91 | 170 | 1,13 | 100,00 | -0,89323 | -0,998816 | -207,31 |
| 0,006 | 36,36 | 0,727 | 0,91 | 212 | 1,10 | 125,00 | -0,89577 | -0,999099 | -236,51 |
| 0,005 | 51,52 | 0,727 | 0,91 | 283 | 1,07 | 166,67 | -0,89819 | -0,999356 | -271,14 |
| 0,003 | 81,82 | 0,727 | 0,91 | 424 | 1,05 | 250,00 | -0,90051 | -0,999591 | -312,48 |
| 0,002 | 172,73 | 0,727 | 0,91 | 848 | 1,02 | 500,00 | -0,90272 | -0,999805 | -362,16 |
| 0,000 | - | - | 0,91 | - | - | - | - | - | - |