Firms vs. Insiders as Traders of Last Resort *

First draft

José M. Marín

Universitat Pompeu Fabra and CREA

Antoni Sureda-Gomila

Universitat Pompeu Fabra

November 15, 2006

Abstract

We explore the role of corporate insiders vs. firms as traders of last resort. We develop a simple model of insider trading in which insiders provide price support, as well as liquidity, in security markets. Consistent with the model predictions we find that in the US markets insiders' trading activities have a clear impact on return distributions. Furthermore, we provide empirical evidence on insiders transactions and firm transactions affecting returns in a different manner. In particular, while insiders' transactions (both purchases and sales) have a strong impact on skewness in the short run and to a lesser extent in short run volatility, company repurchases only have a clear impact on volatility, both in the short and the long run. We provide explanations for this asymmetry.

Journal of Economic Literature Classification Numbers: G11, G12, G14, G18.

Keywords: Insider trading, liquidity, short-horizon variance, autocorrelation, skewness.

*We thank participants at the Harvard University Research in Financial Economics Seminar and at the Universitat Pompeu Fabra Finance Workshop for their helpful comments. Jose Marin thanks the Spanish Ministry of Science and Technology (SEJ2005-03924) and CREA for financial support. Antoni Sureda-Gomila acknowledges financial support from the Spanish Ministry of Science and Technology (BES-2003-2083 Grant).

1 Introduction

Liquidity shocks can drive asset prices away from fundamental values. Corporate insiders are in a privileged position to asses the severity of the deviations. In the presence of large enough deviations, insiders can take two type of actions: execute trades on their own account (insider trading) or on the company's account (through buy back programs or seasonal equity offerings). Figure 1 provides some preliminary evidence in favor of these two hypothesis. The figures display insiders and corporate trading activity around large returns. The two figures in the left hand side clearly show that insiders purchases and sales pick right after large negative and positive returns, respectively. A similar phenomena, but with some delay, is also observed in the case of seasonal equity offerings and stock repurchases.

In a very recent paper, Hong et al. (2005) study the case of stock repurchases and argue that companies act as traders of last resort and liquidity providers. In this paper we focus on insiders transactions and argue that insiders play a similar but distinct role. In particular, their trades affect *both* the volatility and the skewness of asset returns and the impact has a shorter life span than those generated by firms' trades. Furthermore, the impact on volatility is weaker and the impact on skewness stronger for insiders transactions versus firms' transactions. These results suggests that either corporate managers specialize on a different type of mispricing when trading on their own account versus the company's account or that the market interprets both type of interventions differently. In the former case we could think of managers with a preference for positions on their own account in the presence of mispricings that revert fast. This speed of adjustment may obey to exogenous reasons (the nature of the shock itself) or may be endogenous as managers may be able to use their position to disclose figures in the income statement that speeds the revelation of the misvaluation. Regarding the interpretation of each type of traders' trades by market participants, it is important to notice that while firms transactions are preannounced (i.e., they are not anonymous), insiders' trades are only disclosed after they take place[1]. This means the, unlike firms, insiders may face a strong adverse selection problem. All these considerations call for the need to develop a full theory that analyzes the tradeoffs involved in trading on the firm's vs the manager's account,

[1]The SEC requires insiders' trading to be reported before the end of the second business day following the day of the transaction. Prior to August 29, 2002, reporting requirements were lighter. In particular, reports were required to be filled by the 10th of the month following the transaction.

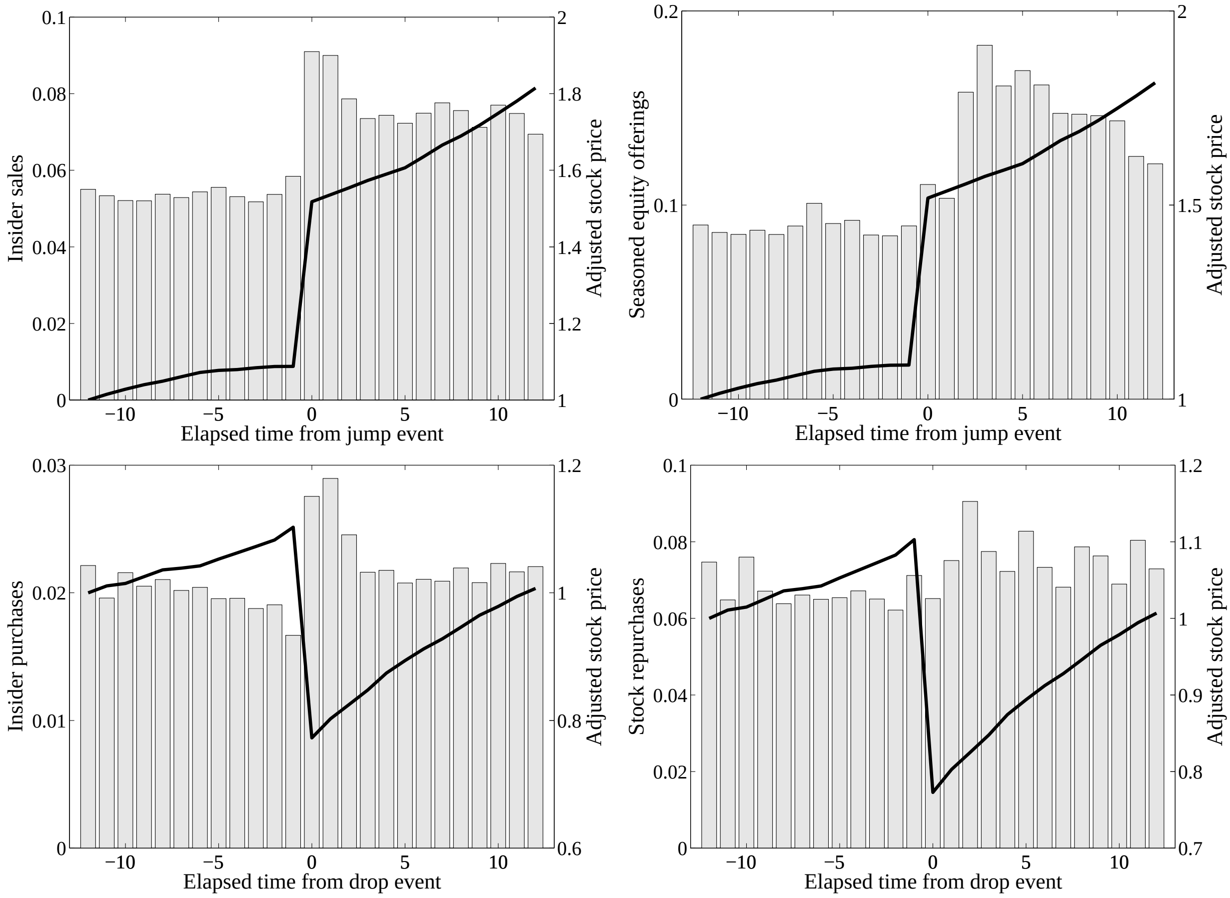

Figure 1: Insider and firm trading around large price movements of individual stocks. This graph show insider sales and seasoned equity offerings around monthly returns smaller than -20%, and insider purchases and firm repurchases around monthly returns larger than 20%. The abscissa axis displays event time in months. The graphs show the time series average of the cross-sectional average by year.

in the presence of liquidity shocks, when moral hazard and adverse selection considerations are in place. This, however, is beyond the scope of the present paper.

The idea of insiders as traders of last resort may sound suspicious at first sight. First, there are the legal restrictions on insider trading activities. On this front we must realize that only insider trading in possession of *material nonpublic information* is illegal. Transactions by insiders as traders of last resort are not prohibited in general. An example of such legal insider trades is given by Seyhun (1998):

> ...Insiders can clearly trade on the basis of their understanding and interpretation of public information outside the moratorium periods. For instance, assume that the stock price of the firm goes down sharply. The decline of stock price is, after all, public information. Now suppose that insiders do not know anything about their firm that would justify such a price decline. Insiders in this case can comfortably buy stock of their firm (and support the market) without worrying about insider-trading regulations.

Second, we have witnessed by now more that twenty years of research, both theoretical and empirical, in market microstructure emphasizing somehow the opposite to what we claim here, namely, that insider trading generates volatility and reduces liquidity. Indeed we should expect that the larger the presence of informed traders, the larger the adverse selection in the market and consequently the larger the spreads and the lower the liquidity. This insight has even been documented empirically. For instance, Chung and Charoenwong (1998) show that bid-ask spreads are wider for stocks in which insiders are more active. In our view this is perfectly consistent with our hypothesis. Notice first that insider trading must be publicized. It is indeed the publicity of these trades what resolves uncertainty and information asymmetries in asset markets that results in smaller adverse selection driven spreads and restored liquidity levels.

A third concern is the size of trading by insiders. One may argue that while the size of, say, a company buyback program is big enough to provide actual counterpart to sellers, the typical size of insider purchases is too small for that purpose. While the argument is correct, it ignores what for us is critical: the informational content of the trade *per se*. Insiders trades can be small in terms of share volume, but quite big in terms of information revelation.

A final concern is that insiders may be mainly trading for reasons other that profiting from perceived mispricing, in which case the impact of their trades on returns should be negligible. For instance, portfolio rebalancing (diversification) and keeping a controlling stake are two clear motives for insider trading. In a classic paper, Lakonishok and Lee (2001) reached the conclusion that while insider purchases are driven by information, "insider selling that is motivated by private information is dominated by portfolio rebalancing for diversification purposes". There is, however, more recent evidence linking insider sales to crashes. Marín and Olivier (2006) show robust evidence of a path of insider's high selling activity in the far past and low selling activity in the near past preceding large price drops. The current state of knowledge, hence, is that the information component in both insider sales and purchases is non negligible[2].

Although this view of insiders as traders of last resort we propose in this paper is new there is already some encouraging evidence. For instance, Seyhun (1990) shows that insiders bought large amounts of shares after the October 1987 crash. Indeed, our Figure 1 provides a stronger picture in this direction: not only insiders purchases pick after big negative returns, but also insiders sales after large positive returns. Marín and Olivier (2006) also provide evidence supportive of our hypothesis. In particular, they find that large drops in the price of a particular stock are more likely after a period of low insider trading volume (i.e. large negative returns happen in the absence of price support by insiders). Insiders also seem to trade in advance of the firm's trades. Lee et al. (1992) found that insiders buy or decrease their sales prior to fixed price repurchase announcements by their firms; similarly, Jenter (2005) reports that, in years in which a firm issues new equity, its insiders sell between \$1.4 and \$1.5 million more equity.

The first goal of this paper is to develop a model of insider trading where insiders act as traders of last resort. The model is simple but rich enough to provide testable implication on the impact of insider trading on return distributions. We work out a there period extension of the Grossman-Stiglitz model (Grossman and Stiglitz (1980)) where insiders transactions are disclosed

[2]It is also important emphasizing here that non informational considerations are also relevant in the case of share repurchases. Many companies running out of good investment opportunities have often initiated general payout programs including stock repurchases. In this case the repurchases are not the result of perceived misvaluations. They may be associated to low future return volatility, but the latter is the result of the lack of good risky project rather than the repurchases themselves. Still is seems that misvaluation is the dominating factor. For instance, using survey data Brav et al. and Graham and Harvey conclude that most managers consider misvaluation important or very important when deciding whether to issue new stock or buy it back.

the period after they take place. We also introduce an exogenous trading cost for transactions done by insiders. The first departure is justified on institutional grounds as insiders in actual markets must report their trades before the second business day following the day of the transaction. The second departure makes insiders interventions only worthwhile when the mispricing is large enough. There are several reasons for insiders not to intervene when the mispricing is small. On the one hand, insiders transactions are scrutinized by the SEC, which means that insiders always face a positive probability of being prosecuted. On the other hand, typically insiders' portfolios are overweighted on their own stock. This means insiders will only find worthwhile to increase their holdings when the mispricing is large enough to compensate their extra poor diversification. All these considerations point at a cost of trading that, unlike other type of investors, insiders bear. Furthermore, the argument about diversification suggests this cost is larger for insiders purchases than for insiders sales[3]. Our model provides several testable implications. We focus on those related to the role of insiders as price supporters. The first prediction of the model is that in the absence of a strong adverse selection problem the short term volatility of the risky asset return is decreasing in both insiders sales and purchases. The second prediction is that the skewness of the risky asset return is increasing on insiders purchases and decreasing on insiders sales. All these predictions are corroborated in the empirical part of the paper.

As previously stated, very recently Hong et al. (2005) have found that firms might act as traders of last resort. Those firms that are less financially constrained can repurchase their own stock when the stock price is significantly lower than its fundamental value. They find evidence of lower short term return variance relative to long term return variance, and larger skewness in the distribution of returns, for those less financially constrained firms, which are those more capable of repurchasing their own shares[4]. However, firms don't have the same ability to become sellers of last resort when their equity becomes overvalued; this is because seasoned equity offerings are more costly and require more time to execute than share repurchases. The latter are much more frequent than the former, Fama and French (2005) estimate that the fraction of firms with seasoned equity offerings in a given year during the period 1983–1992 was 5.7%, and 6.3% for the period 1993–2002; conversely,

[3]In some cases, the cost for insider sales might be larger than the cost of insider purchases: for instance, during lockup periods or when short selling constraints are binding, the cost for insider sales can be infinite.

[4]Hong et al.'s results on skewness are weaker than those on short term variance, more specifically, they do not find significant coefficients when the firm's financial constrainedness is measured using the Kaplan-Zingales index.

according to Grullon and Michaely (2002), 84.2% of the firms that initiated a cash distribution to their shareholders in 2000, also initiated a buyback program. Although it is easier for a firm to repurchase shares than issue new ones, there is evidence that firms also do the latter when they perceive that their shares are overpriced. In the survey of Brav et al. (2005), 86.4% of the surveyed financial executives consider that it is important or very important whether their stock is a good investment relative to its true value when taking a stock repurchase decision; on the other hand, in another survey (Graham and Harvey (2001)) 66.94% of the surveyed considered important or very important the amount by which their stock was overvalued or undervalued when considering issuing common stock.

We have then two clear candidates for traders of last resort: firms and insiders. It is not obvious however if their actions are complementary or substitutes. This motivates our second main goal in this paper which consist on empirically asses the relevance and nature of each type of trading in price supporting and liquidity provision.

The structure of this paper is as follows. In the next section we develop a theoretical framework of insider trading in the presence of liquidity shocks. In Section 3 we present the empirical study that confirms the model predictions regarding insider trading and compare these finding to those associated with share repurchases. The final Section 4 is dedicated to some concluding remarks and the proposal of new lines for future research.

2 The model

Let us consider an economy with three dates, $t = 1$, 2, and 3, and two assets. The first is a risk free asset that pays a gross rate of return of 1 each period. The second asset pays an uncertain dividend at $t = 3$, d_3, where:

$$d_3 = s + \varepsilon.$$

This risky asset, to which we refer as the stock, is held by long term investors who want to keep it until it pays its dividend. However, at $t = 1$, some of these investors have to trade an exogenous and random amount of shares that, aggregated, equals to x. With P_t we denote the price of one share of stock at date t, for $t = 1$, 2, and 3.

Apart from these long term investors, in the economy there are also two other types of agents, informed and uninformed traders. Informed traders have an informational advantage as they observe the dividend related information, s, before the market opens for trade at $t = 1$. We will refer to the informed traders as *the informed* or *the insiders* and use the index I for the variables that refer to them. In the same way, we will refer to the uninformed traders as *the uninformed* and use the index U for them. Both type of traders display CARA utility on their terminal wealth with a risk aversion coefficient equal to r_i, for $i = I \,\text{and}\, U$. There is a continuum of informed and uninformed traders with masses equal to λ and $1-\lambda$ respectively. We will denote the shares held by the traders at each instant as $x_{i,t}$ for $i = I \,\text{and}\, U$ and $t = 1,\, 2,\, \text{and}\, 3$. Note that, in this economy, the market clearing condition can be expressed as

$$\lambda\, x_{I,t} + (1-\lambda)\, x_{U,t} = -x, \;\text{ for } t = 1 \,\text{and}\, 2.$$

Both traders have rational expectations and choose their optimal portfolio conditional on the information that they have at each point in time. We assume that the trade done by insiders at $t = 1$ is made public before the market opens for trade at $t = 2$. Denoting by $\mathcal{I}_{i,t}$ the information set of a trader of type i at t and given that informed traders are not endowed with securities before the market opens at $t = 1$, we have:

$$\mathcal{I}_{I,1} = \{s,\, P_1\}, \mathcal{I}_{U,1} = \{P_1\}, \mathcal{I}_{U,2} = \{P_1,\, P_2,\, x_{I,1}\}.$$

Furthermore, we assume that the informed cannot trade at $t = 2$, thus $x_{I,2} = x_{I,1}$ and that they pay a cost per share they trade given by:

$$k(x_{I,1}) = \begin{cases} k_+\, x_{I,1} & \text{if } x_{I,1} > 0, \\ -k_-\, x_{I,1} & \text{if } x_{I,1} < 0. \end{cases}$$

This trading cost will play an important role in our analysis as it is the parameter that controls for the capacity of insiders to act when a liquidity shock occurs. The larger the $k's$ are, the less active insiders will be in the market place. For instance, a very large k_+ (k_-) will severely restrict insiders purchases (sales) and consequently will reduce the role of insiders supporting prices when a negative (positive) shock occurs. In sections 2.1 and 2.2 we perform several comparative exercises on the $k's$ which constitute the basis for our empirical analysis in section 3.

In figure 2 we summarize the timing of events in the present model.

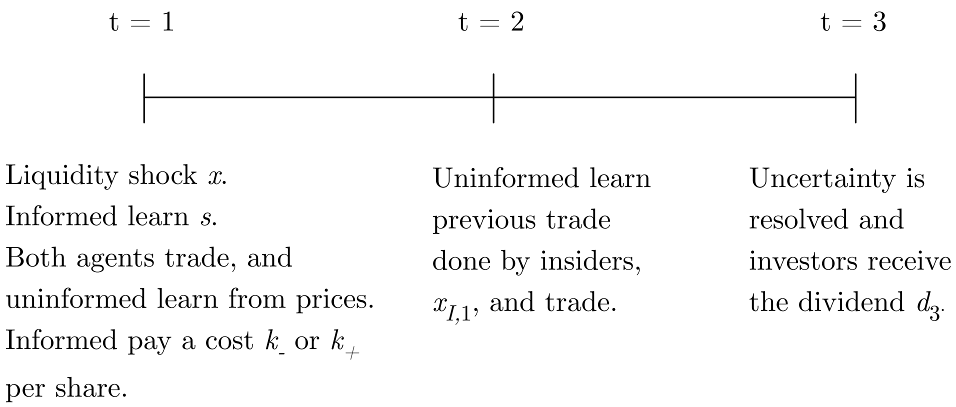

Figure 2: Timing of events.

Finally, we assume that all the random variables in the model, x, s, and ε are jointly normally distributed with

$$\begin{pmatrix} x \\ s \\ \varepsilon \end{pmatrix} \sim \mathcal{N}\left(\begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_x^2 & 0 & 0 \\ 0 & \sigma_s^2 & 0 \\ 0 & 0 & \sigma_\varepsilon^2 \end{pmatrix}\right)$$

2.1 Equilibrium and comparative statics

We solve for the equilibrium prices and holdings by backward induction. All the proofs can be found in the Appendix.

2.1.1 Equilibrium at $t = 2$

Note first that at the final date, $t = 3$, all uncertainty is resolved. Agents consume their final wealth and there is no trade. Since the stock pays the certain dividend d_3 in this date, the price is given by:

$$P_3 = x + \varepsilon.$$

At date $t = 2$ uninformed traders learn the trades done by insiders in the previous round of trade. Since the informed traders only trade once, we can get a closed form solution for their optimal demand at $t = 1$. The following lemma establishes the desired result.

Lemma 1 *The optimal demand of an informed trader at $t = 1$ is given by*

$$x_{I,1} = \begin{cases} \frac{s-P_1+k_-}{r_I\,\sigma_\varepsilon^2} & \textit{if } s < P_1 - k_-, \\ 0 & \textit{if } P_1 - k_- \leq s \leq P_1 + k_+, \\ \frac{s-P_1-k_+}{r_I\,\sigma_\varepsilon^2} & \textit{if } s > P_1 + k_+. \end{cases}$$

Due to the existence of (possibly asymmetric) trading costs there are three possible regions associated to the three possible actions the insider can take: purchases of shares, sales of shares and no trade. These transactions contain information which is relevant for uninformed traders at date $t = 2$. In particular, when the insider is active in the market at $t = 1$, the uninformed will fully learn the size of the asset payoff related information, s, and the liquidity shock, x, at $t = 2$. When the informed does not trade at $t = 1$ the uninformed traders update their beliefs but do not reach full knowledge at $t = 2$. The following proposition characterizes an equilibrium at $t = 2$.

Proposition 2 *An equilibrium at $t = 2$ is given by the holdings*

$$x_{I,2} = \begin{cases} \frac{s-P_1+k_-}{r_I\,\sigma_\varepsilon^2} & \textit{if } s < P_1 - k_-, \\ 0 & \textit{if } P_1 - k_- \leq s \leq P_1 + k_+, \\ \frac{s-P_1-k_+}{r_I\,\sigma_\varepsilon^2} & \textit{if } s > P_1 + k_+ \end{cases}$$

$$x_{U,2} = \begin{cases} \frac{-1}{1-\lambda}\left(x + \lambda\,\frac{s-P_1+k_-}{r_I\,\sigma_\varepsilon^2}\right) & \textit{if } s < P_1 - k_-, \\ \frac{-x}{1-\lambda} & \textit{if } P_1 - k_- \leq s \leq P_1 + k_+, \\ \frac{-1}{1-\lambda}\left(x + \lambda\,\frac{s-P_1-k_+}{r_I\,\sigma_\varepsilon^2}\right) & \textit{if } s > P_1 + k_+; \end{cases}$$

and the price

$$P_2 = \begin{cases} s + \frac{r_U\,\sigma_\varepsilon^2}{1-\lambda}\left(x + \lambda\frac{s-P_1+k_-}{r_I\,\sigma_\varepsilon^2}\right) & \textit{if } s < P_1 - k_-, \\ \frac{r_U(\sigma_\varepsilon^2+\sigma_s^2)}{1-\lambda}x - \sigma_s\frac{\phi(\frac{P_1+k_+}{\sigma_s}-\frac{r_U\,\sigma_s\,x}{1-\lambda})-\phi(\frac{P_1-k_-}{\sigma_s}-\frac{r_U\,\sigma_s\,x}{1-\lambda})}{\Phi(\frac{P_1+k_+}{\sigma_s}-\frac{r_U\,\sigma_s\,x}{1-\lambda})-\Phi(\frac{P_1-k_-}{\sigma_s}-\frac{r_U\,\sigma_s\,x}{1-\lambda})} & \textit{if } P_1 - k_- \le s \le P_1 + k_+, \\ s + \frac{r_U\,\sigma_\varepsilon^2}{1-\lambda}\left(x + \lambda\frac{s-P_1-k_+}{r_I\,\sigma_\varepsilon^2}\right) & \textit{if } s > P_1 + k_+; \end{cases} \quad (2.1)$$

where ϕ and Φ are the probability density function and the cumulative distribution function of a standard normal random variable.

Since the informed traders cannot trade at $t = 2$ their holdings are the same as in period $t = 1$. This means that the uninformed do not trade either at $t = 2$. The price however is very different depending on whether the informed bought, sold or did not trade at $t = 1$. In the regions associated to past insider activity prices reflect the new information the uninformed traders have learned and the risk premium associated to their previous holdings. In the region corresponding to lack of previous activity by insiders the price is less informative[5].

2.1.2 Equilibrium at $t = 1$

Note that the equilibrium price 2.1 in Proposition 2 is not even a piecewise linear function of the liquidity shock x. This precludes us from finding a closed form solution for the equilibrium at $t = 1$. We have no other choice than to solve solve numerically for the equilibrium. In the Appendix we describe the numerical methodology used.

In order to get a clear picture of the economic forces behind the equilibrium, we examine now the impact of a liquidity shock on the equilibrium price at $t = 1$. In figure 3 we plot P_1 as a function of x on the domain of 3 standard deviations from the mean of x. In each of the four panels, we perform some comparative statics varying one parameter at a time. In the upper left panel we examine the impact of the trading costs the informed traders face, keeping $k_- = k_+$, on P_1. There are two opposing forces on the impact of trading costs on the variance of the price. On the one

[5]In this region there is a price indeterminacy. In particular there are equilibria in which the price may depend on s. These equilibria are unreasonable in the sense that they are not measurable with respect to any of the traders' equilibrium demands. We rule out this type of bubbly equilibrium in this paper. For further details on this type of equilibria that arises when informed traders face trading constraints see Marín and Olivier (2006) and Marín and Olivier (2000).

hand, the larger the trading costs, the less active insiders will be in the market place and hence the smaller their capacity to provide price support. Liquidity shocks have a larger impact on prices what results on a larger slope of the P_1 function. This effect will imply an increase on the variance of the price as we will corroborate in the next section. On the other hand, the larger the trading cost, the lower the averse selection in the market (as insiders activity is decreased), and the lower the slope of P_1. This effect will result on a decrease of the price volatility. From the graph, we see that both effects are present, but the liquidity effect dominates for small trading costs while the adverse selection effect dominates for large trading costs. In 2.2 we elaborate on the way in which these to effects affect the variance of the price.

In the upper right plot in figure 3 we keep fixed $k_+ = 0.05$ and plot P_1 for different values of k_-. We observe that, whenever $k_- \neq k_+$, the impact of liquidity shocks becomes asymmetric and depends on the sign of x. The larger is the cost of selling stocks by the insider, k_-, the larger the impact of a positive liquidity shock on the price compared to a negative liquidity shock of the same magnitude in absolute value. As we will show in the next section, this implies that the larger is k_- the largest is the skewness of P_1.

In the two bottom panels of figure 3, we perform some comparative statics for σ_ε^2 and σ_s^2. The graphs show that the larger is the non predictable part of the dividend, σ_ε^2, the larger the impact of the liquidity shocks in P_1. Similarly, the larger the volatility of the informed traders' private signal s (or, in other words, the larger the asymmetries of information) the larger the averse selection in the market and, as a consequence, the larger the impact of x on P_1.

2.2 Effects of trading costs on the price distribution

Our model delivers testable implications regarding the distribution of short term stock returns. Note first, that the variance and skewness of P_1 and P_2 coincides with the variance and skewness of dollar returns from $t = 0$ (before trading at $t = 1$) to $t = 1$ and $t = 2$, respectively. In figure 4 we plot the variance and skewness of P_1 and P_2 as a function of the trading costs informed traders face. In the plots that display the variance we keep $k_- = k_+$ while in the plots that display the skewness we fix $k_+ = 0.05$ and we graph the effect of moving k_-.

As argued in the previous section there are two opposing effects in the way in which trading

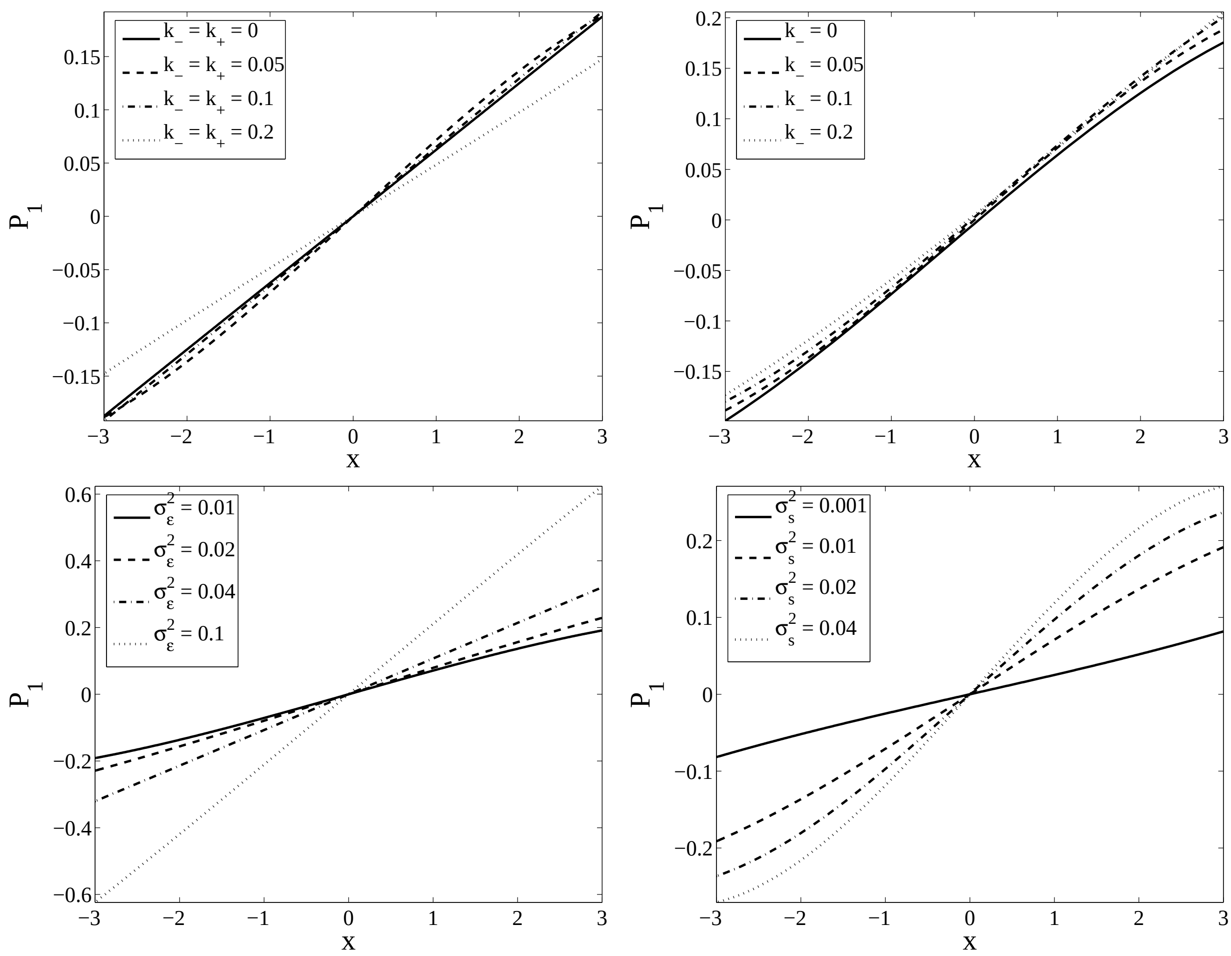

Figure 3: Equilibrium price P_1 as a function of the liquidity shock, x. The graphs show variations of the base case parametrization that is $\sigma_x^2 = 1$, $\sigma_s^2 = 0.01$, $\sigma_\varepsilon^2 = 0.04$, $r_I = 1$, $r_U = 2$, $\lambda = 0.1$, and $k_- = k_+ = 0.1$. The informed's signal s is fixed to be 0. The first graph, starting at the top left, displays P_1 as a function of x for different informed's trading costs, keeping $k_- = k_+$. In the second graph, we have fixed $k_+ = 0.05$ and we plot P_1 for different values of k_-. At the first graph of the second row, we vary σ_ε^2, while in the last graph we vary σ_s^2.

costs affect prices. These two effects are also present on the way in which trading costs affect the variance of the prices. On one hand, the larger the trading costs, the less liquidity will provided by insiders, increasing the impact of liquidity shocks on the price. This effect increases the price volatility. On the other hand, the larger the trading cost, the lower the averse selection in the market, and the lower the variance of prices. The two top graphs in figure 4 show that for small trading costs the first effect dominates, while for large trading costs the second effect dominates. With the parametrization $\sigma_x^2 = 1$, $\sigma_s^2 = 0.01$, $\sigma_\varepsilon^2 = 0.01$, $r_I = 2$, $r_U = 1$, and $\lambda = 0.1$, the cutting point happens at a trading cost around 7%.

Figure 4 also shows that, for a reasonable set of parameters, an increase in the cost of selling shares by the informed traders, increases the price skewness. Indeed, when the insiders face a large cost for sales and a positive liquidity shock ($x > 0$) happens, they cannot sell stocks and provide liquidity. In the absence of this price support this positive demand shocks generates a increase in the price that results in larger skewness in the price. By symmetry, the skewness of the prices is decreasing in the cost of purchases that informed traders face.

These exercises make clear the way in which trading costs affect the variance and the skewness of the dollar return of the risky asset. Since trading costs are a proxy for the informed traders capacity to buy and sell stock, we can establish testable implication on the relationship between insiders trading activities and return distributions. More specifically the model predicts that the skewness of the return must increase with insiders purchases (decrease with k_+) and decrease with insiders sales (increase with k_-). The effect on the variance of the returns depends on which of the two opposing effects described above dominates. When the liquidity provision effect dominates (or when the adverse selection effect is weak), both insiders sales and purchases reduce the variance of the return. We now turn to our empirical study where these hypothesis are tested. In our empirical exercise we test these hypothesis separately and in combination with the hypothesis put forward in Hong et al. (2005) that relates stock repurchases by firms to the volatility and the skewness of returns.

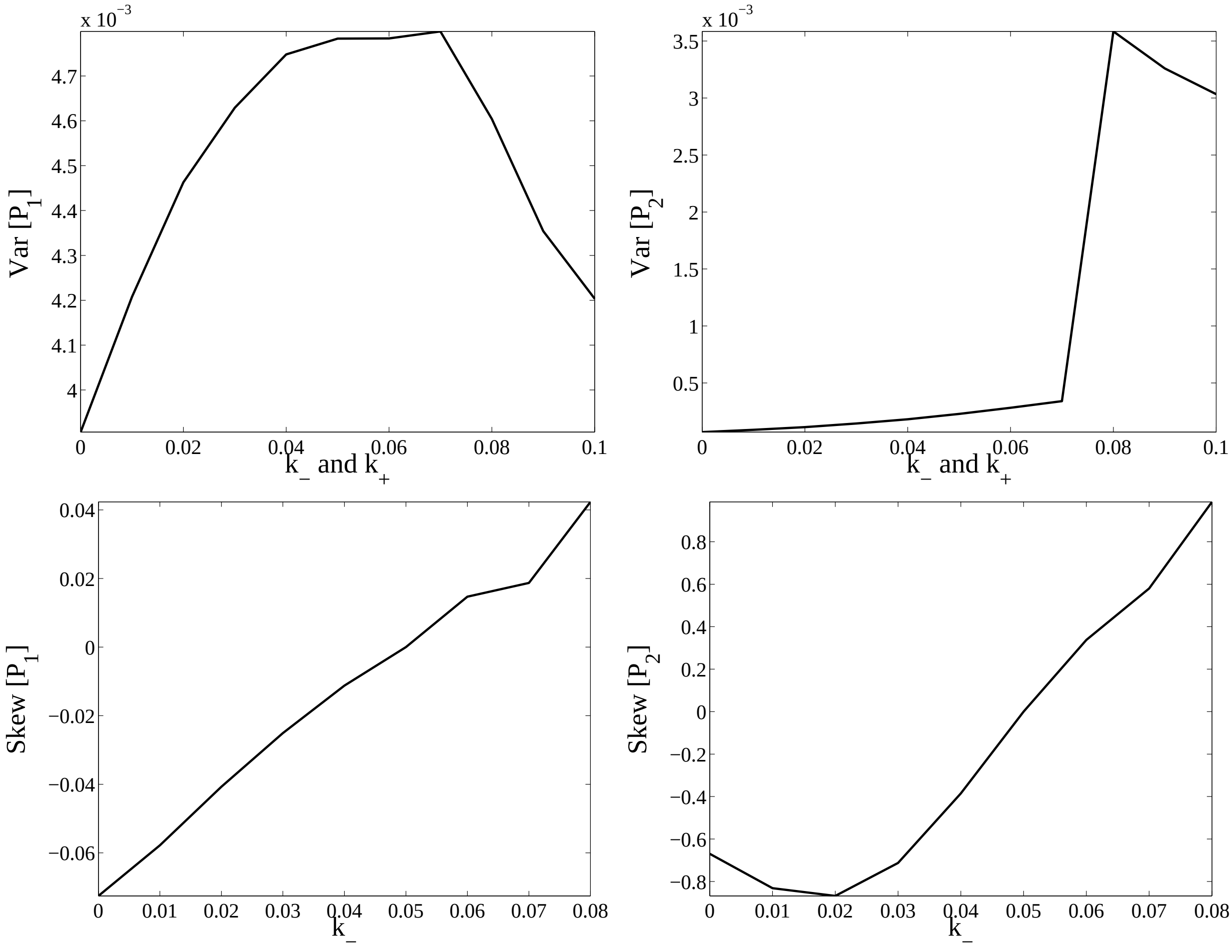

Figure 4: Effects of informed's trading costs on the price variance and skewness due to liquidity shocks. The graphs show variations of the base case parametrization that is $\sigma_x^2 = 1$, $\sigma_s^2 = 0.01$, $\sigma_\varepsilon^2 = 0.01$, $r_I = 2$, $r_U = 1$, $\lambda = 0.1$, and $k_- = k_+ = 0.05$. The informeds' signal s is fixed to be 0. The two graphs at the top display the variance of P_1 and P_2 as a function of the informed trading costs (keeping k_- and k_+ equal). The two graphs at the bottom display the skewness of P_1 and P_2 as a function of k_-, when k_+ is kept constant and equal to 0.05.

3 Empirical analysis

The main objective of the empirical analysis is to asses whether insider trading affect returns distribution. In particular, we focus on its impact on the short-horizon volatility and the skewness of stock returns. We also compare the results for insider trading with those obtained for the case of share repurchases. We start describing the dataset and defining all variables involved in our study.

3.1 Description of the data

Using data from CRSP, COMPUSTAT and Thompson Financial Insider Trading Dataset (TFIT) from January 1986 to December 2003, we construct the variables defined below for each non-financial firm and year pair. The construction of most variables follows Hong et al. (2005), who provide further details on the dataset construction process, and whose notation we follow.[6].

3.1.1 Insider trading variables

We consider as *insiders* all the traders that are defined as such by the *Section 16(a)* of the *Security and Exchange Act of 1934 (SEA)*, by which large beneficial shareholders and managers of a publicly traded firm are required to file their transactions in the company stock with the *Securities and Exchange Commission (SEC).* This definition includes the managers of publicly traded companies, in particular the chairman, directors, CEOs, CFOs, officers, presidents, vice presidents, affiliates, members of committees, etc, and large shareholders. Our definition of insiders does not include other people that might posses non-public information about the company, but that are not considered insiders under the *Section 16(a)* of the *Security and Exchange Act of 1934 (SEA).* From this definition, it is clear that any information advantage that is given to firms is also an information advantage of insiders.

We define $\mathrm{IPUR}_{i,t}$ as the value of all the shares purchased by insiders of firm i during year t divided by the average daily market capitalization of firm i during year t. Similarly, we define $\mathrm{ISAL}_{i,t}$ as the value of all the shares sold by insiders of firm i during year t divided by the average market capitalization of firm i during year t.

[6]The only variables that are not defined in Hong et al. (2005) are those related to insider trading activity, $\mathrm{IPUR}_{i,t}$ and $\mathrm{ISAL}_{i,t}$, and the measures of return variance using one year of data, $\mathrm{DVARY}_{i,t}$ and $\mathrm{MVARY}_{i,t}$.

3.1.2 Measures of return variance and skewness

The measures of return variance and skewness that we construct are those used by Hong et al. (2005). To compute these variables, we use continuously compounded returns.

The measures of return variance are $\mathrm{TVAR}_{i,t}$, which is the variance of the two non overlapping three years returns of firm i using data from year t to $t+5$; $\mathrm{AVAR}_{i,t}$, which is the variance of the six non overlapping one year returns of firm i using data from year t to $t+5$; and $\mathrm{SVAR}_{i,t}$, $\mathrm{QVAR}_{i,t}$, $\mathrm{MVAR}_{i,t}$, $\mathrm{WVAR}_{i,t}$, and $\mathrm{DVAR}_{i,t}$, which are constructed as $\mathrm{AVAR}_{i,t}$, but using semiannual, quarterly, monthly, weekly and daily returns, respectively. All these measures of variance are annualized.

Apart from the previous variables, we also have constructed measures of variance using only data corresponding to year t. We call them $\mathrm{DVARY}_{i,t}$ and $\mathrm{MVARY}_{i,t}$, and they are build as $\mathrm{DVAR}_{i,t}$ and $\mathrm{MVAR}_{i,t}$, but instead of using data from year t to year $t+5$ we only data corresponding to year t.

For each firm and year, we also compute the skewness of quarterly, monthly, weekly, and daily returns of firm i during year t, denoted by $\mathrm{QSKEW}_{i,t}$, $\mathrm{MSKEW}_{i,t}$, $\mathrm{WSKEW}_{i,t}$, and $\mathrm{DSKEW}_{i,t}$, respectively.

3.1.3 Other variables

We use the four measures of financial constrainedness employed by Hong et al. (2005). The first is the value of common shares repurchased by firm i during year t adjusted by the firm's net income, this variable is denoted $\mathrm{REPURCHASES}_{i,t}$. It is computed as the purchased common and preferred stock (COMPUSTAT annual 115) minus the reduction in the preferred stock liquidation value (the reduction in the annual data item 10), divided by net income (172). The second is the firm's age $\mathrm{AGE}_{i,t}$, computed as the number of years from the first appearance in CRSP. Finally, the last two are the Kaplan-Zingales index, $\mathrm{KZ}_{i,t}$, and a reduced version of this index that does not include neither book leverage nor Tobin's Q, this latter variable, $\mathrm{KZ3}_{i,t}$. KZ and KZ3 are computed as:

$$\begin{aligned}
\mathrm{KZ}_{i,t} =& -1.002\frac{\text{Cash Flow}_{i,t}}{\text{Assets}_{i,t-1}} - 39.368\frac{\text{Cash Dividends}_{i,t}}{\text{Assets}_{i,t-1}} \\
& -1.315\frac{\text{Cash Balance}_{i,t}}{\text{Assets}_{i,t-1}} + 3.139\,\text{Leverage}_{i,t} + 0.283\,\mathrm{Q}_{i,t}. \\
\mathrm{KZ3}_{i,t} =& -1.002\frac{\text{Cash Flow}_{i,t}}{\text{Assets}_{i,t-1}} - 39.368\frac{\text{Cash Dividends}_{i,t}}{\text{Assets}_{i,t-1}} - 1.315\frac{\text{Cash Balance}_{i,t}}{\text{Assets}_{i,t-1}}.
\end{aligned}$$

Note that KZ and KZ3 are increasing with financial constrainedness.

The other variables in our study, all defined for each firm i during year t, are the logarithm of firm's average daily market capitalization, $\mathrm{LOGSIZE}_{i,t}$, its market leverage, $\mathrm{MLEV}_{i,t}$, the logarithm of the market to book ratio, $\mathrm{LOGMB}_{i,t}$, the average monthly return, $\mathrm{RET}_{i,t}$, and the average daily turnover, $\mathrm{TURNOVER}_{i,t}$. Finally, $\mathrm{INDUSTRYDUMMIES}_{i,t}$ is a set of dummies for the 48 industries in Fama and French (1997).[7]

3.1.4 Descriptive statistics

Table 1 contains the time series average of cross-sectional means and standard deviations for the variables that we have previously defined. These summary statistics are similar to those in previous studies, for instance Lakonishok and Lee (2001) or Marín and Olivier (2006) for insider trading activity, and Hong et al. (2005) for the other variables.

Insiders are, on average, net sellers of stock. This suggests that the cost of purchasing shares is larger than the cost of selling them, $k_+ > k_-$ in our model. However, we must take into account that most of insiders sales could be motivated for diversification purposes and not for misvaluation opportunities.

As Hong et al. (2005), we find that the short term variances are larger than the long term variances, which implies a negative autocorrelation in stock returns. Furthermore, skewness is positive for short horizons and decreases with the time interval, becoming negative for quarterly returns.

[7] The measures of insider trading activity, variance, skewness, stock repurchases and the components of the Kaplan-Zingales indexes are winsorized to mitigate the impact of anomalous or extreme observations. Insider trades have been cross-checked with CRSP data to eliminate problematic records as in Lakonishok and Lee (2001). We have excluded from our sample the firms for which we do not have any insider trade in the whole sample period.

Table 1: Summary Statistics. Time series average of cross-sectional means and standard deviations. Data from 1986-2003.

	Mean	StDev
IPUR	.00183866	.00645876
ISAL	.00722405	.01813813
DVAR	.48864484	.50720914
WVAR	.33559615	.28896252
MVAR	.29700674	.25787447
QVAR	.29543764	.26406154
SVAR	.28302673	.28190983
AVAR	.30408996	.34246279
TVAR	.28311923	.48023924
DVARY	.55611991	.661616
MVARY	.35965479	.40246706
DSKEW	.10654422	1.0255157
WSKEW	.14004511	.8605122
MSKEW	.04886174	.81684978
QSKEW	-.03964613	1.0265205
REPURCHASE	.16202193	.46403992
AGE	14.908976	14.406529
KZ	.8073567	.85847819
KZ3	-.6765437	1.245824
LOGSIZE	11.610331	2.0021146
MLEV	.22520186	.00558925
LOGMB	.67140609	.04823989
RET	-.00025596	.86430321
TURNOVER	.00479945	.22323016

The times series average of the cross-sectional correlations between the measures of financial constrainedness and insider trading activity are reported in Table 2. This table shows that insider trading activity is larger in younger firms, and that insiders tend to purchase shares of financially constrained firms; hence, when firms have difficulties in providing price support, insiders might provide it. This intimates that insiders' purchases and firms' repurchases might be substitutes in providing price support. Note that insider sales are more negatively correlated with KZ than KZ3, this suggests that insiders tend to sell less in firms with high investment opportunities, measured by Tobin's Q.

Table 2: Time series average of cross-sectional correlations between financial constraintness measures and insider trading activity. Data from 1986-2003

	REPURCHASE	AGE	KZ	KZ3	IPUR	ISAL
REPURCHASE	1					
AGE	.08478125	1				
KZ	-.07308364	-.11764388	1			
KZ3	-.06999179	-.21181013	.73401205	1		
IPUR	-.01442049	-.05959318	.02933922	.05206674	1	
ISAL	-.01909647	-.14802733	-.03124193	-.01639203	.02590551	1

3.2 Effects of IT on returns' distribution

In this section we examine the effects of insider trading on the short-horizon variance and skewness of stock returns.

3.2.1 Effects of IT on short term variance

We first estimate the effect of insider trading and financial constrainedness on the short-horizon return variance, controlling for long-horizon return variance, TVAR, and other variables that have been found relevant in previous studies, following the Hong et al. (2005) setup. In particular, we estimate the model:

$$
\begin{aligned}
\mathrm{STVAR}_{i,t} = {} & \beta_1\,\mathrm{CONSTRAINT}_{i,t-1} + \beta_2\,\mathrm{IPUR}_{i,t-1} + \beta_3\,\mathrm{ISAL}_{i,t-1} + \beta_4\,\mathrm{TVAR}_{i,t} \\
& + \beta_5\,\mathrm{LOGSIZE}_{i,t-1} + \beta_6\,\mathrm{MLEV}_{i,t-1} + \beta_7\,\mathrm{LOGMB}_{i,t-1} + \beta_8\,\mathrm{RET}_{i,t-1} \\
& + \beta_9\,\mathrm{TURNOVER}_{i,t-1} + \mathrm{INDUSTRYDUMMIES}_{i,t-1}\,\Delta + \epsilon_{i,t}\,, \\
\text{for } & i = 1 \ldots N\,.
\end{aligned}
\tag{3.1}
$$

In the estimation of model (3.1) we use the Fama-MacBeth type regressions (Fama and MacBeth (1973)) correcting for autocorrelation using Newey-West standard errors (Newey and West (1987)). The measures of short-horizon variance, denoted as STVAR in (3.1), are DVAR (daily), WVAR (weekly), MVAR (monthly), QVAR (quarterly), SVAR (semiannual), and AVAR (annual). Recall that all these measures of variance are computed with non overlapping time periods using data from year t to $t+5$. The measures of financial constrainedness, denoted by CONSTRAINT in 3.1, are stock repurchases (REPURCHASES), firm's age (AGE), and the two Kaplan-Zingales indexes (KZ and KZ3). The estimation results are reported in Table 3. Note that each column of the table corresponds to a different measure of financial constrainedness and that the last column does not include any of the previous measures as an explanatory variable.

Insider sales and purchases, when significant, have a negative sign predicting short-horizon variance, which is what we expected according to our model if adverse selection is low. When the measure of short-horizon variance is computed using daily returns, both insider sales and purchases are significant and negative. An increase of two standard deviations in insider purchases and sales leads to a decrease of 0.01587 and 0.01291 in daily variance, respectively, or 3.13% and 2.55% of the cross-sectional variance in DVAR; note that an increase of two standard deviations in firm repurchases leads to a decrease of 4.03% of the cross-sectional variance in DVAR. For longer horizon variances, insider purchases tend to be significant, but not insider sales. Note that insider might sell shares for a variety of reasons, but it is reasonable to think that they only will purchase shares when the market price is below the fundamental price according to insider's valuation. Insider transactions have an impact on shorter-horizon variances (DVAR or WVAR), but not on longer-horizon variances. Table 3 is consistent with Hong et al.'s findings regarding the role of firms being buyers of last resort.

Table 3: Fama-MacBeth regressions of short-horizon return variance on insider trading activity. Variance measueres are computed using 5 years of data. Newey-West corrected t-statistics in parentheses.

CONSTRAINT:	REPURCHASE	AGE	KZ	KZ3	
Dependent variable is $\mathbf{DVAR}_{i,t}$					
$\mathrm{CONSTRAINT}_{i,t-1}$	–0.022**	0.000*	0.035**	0.036**	
	(–4.947)	(2.333)	(10.719)	(11.907)	
$\mathrm{IPUR}_{i,t-1}$	–0.970	–1.242+	–1.343	–1.363+	–1.229+
	(–1.266)	(–1.733)	(–1.628)	(–1.655)	(–1.727)
$\mathrm{ISAL}_{i,t-1}$	–0.421+	–0.341+	–0.322	–0.335	–0.356*
	(–1.813)	(–1.888)	(–1.375)	(–1.441)	(–1.977)
Dependent variable is $\mathbf{WVAR}_{i,t}$					
$\mathrm{CONSTRAINT}_{i,t-1}$	–0.019**	–0.000	0.028**	0.030**	
	(–6.180)	(–1.097)	(20.805)	(18.002)	
$\mathrm{IPUR}_{i,t-1}$	–0.457	–0.592+	–0.578	–0.593	–0.573+
	(–1.398)	(–1.732)	(–1.485)	(–1.520)	(–1.658)
$\mathrm{ISAL}_{i,t-1}$	0.009	0.004	0.052	0.039	0.012
	(0.051)	(0.034)	(0.317)	(0.237)	(0.103)
Dependent variable is $\mathbf{MVAR}_{i,t}$					
$\mathrm{CONSTRAINT}_{i,t-1}$	–0.017**	–0.000	0.026**	0.028**	
	(–5.541)	(–1.301)	(13.450)	(12.039)	
$\mathrm{IPUR}_{i,t-1}$	–0.032	–0.082	–0.116	–0.130	–0.061
	(–0.092)	(–0.263)	(–0.314)	(–0.349)	(–0.191)
$\mathrm{ISAL}_{i,t-1}$	0.037	0.014	0.093	0.082	0.025
	(0.297)	(0.168)	(0.737)	(0.655)	(0.306)
Dependent variable is $\mathbf{QVAR}_{i,t}$					
$\mathrm{CONSTRAINT}_{i,t-1}$	–0.017**	–0.000+	0.024**	0.027**	
	(–5.678)	(–1.930)	(12.120)	(11.178)	
$\mathrm{IPUR}_{i,t-1}$	–0.325	–0.450+	–0.449	–0.463	–0.430+
	(–1.171)	(–1.839)	(–1.416)	(–1.445)	(–1.719)
$\mathrm{ISAL}_{i,t-1}$	0.046	0.002	0.080	0.068	0.022
	(0.707)	(0.047)	(1.552)	(1.328)	(0.421)
Dependent variable is $\mathbf{SVAR}_{i,t}$					
$\mathrm{CONSTRAINT}_{i,t-1}$	–0.018**	–0.000+	0.023**	0.025**	
	(–4.669)	(–1.841)	(14.137)	(12.326)	
$\mathrm{IPUR}_{i,t-1}$	–0.340	–0.446	–0.424	–0.439	–0.428
	(–1.028)	(–1.580)	(–1.220)	(–1.252)	(–1.485)
$\mathrm{ISAL}_{i,t-1}$	0.027	–0.041	0.063	0.053	–0.025
	(0.434)	(–0.517)	(1.030)	(0.871)	(–0.317)
Dependent variable is $\mathbf{AVAR}_{i,t}$					
$\mathrm{CONSTRAINT}_{i,t-1}$	–0.015**	–0.001*	0.024**	0.026**	
	(–3.758)	(–2.327)	(12.913)	(14.936)	
$\mathrm{IPUR}_{i,t-1}$	–0.147	–0.082	–0.100	–0.114	–0.061
	(–0.343)	(–0.314)	(–0.273)	(–0.309)	(–0.228)
$\mathrm{ISAL}_{i,t-1}$	–0.049	–0.133	0.028	0.015	–0.109
	(–0.405)	(–0.962)	(0.223)	(0.120)	(–0.771)

+ significant at 10% level, * significant at 5% level, ** significant at 1% level

In model (3.1), return variances are computed using 6 years of data. It is likely that in this long time period firm's executive compensation schemes and the board consideration of insider trading activity might change. this would affect insider trading behavior and, consequently, our empirical results. For this reason, we construct measures of daily return variance using only one year of data, DVARY, and a variable capturing monthly returns variance, MVARY, as the longer horizon returns measure, using also one year of data. Furthermore, instead of using lagged insider trading activity, we will use the current one, but instrumented by lagged trading and other variables that might affect insider trading activity. We have chosen the instrumental variables approach because of the endogeneity of insider trading activity. The instruments, apart from lagged insider sales and purchases, include lagged measures of return variance, the average monthly stock returns in the previous two years, the logarithm of the firm's lagged market capitalization, the logarithm of its lagged market to book ration, the lagged average daily turnover and firm's age. The specification of this model is

$$
\begin{aligned}
\mathrm{DVARY}_{i,t} &= \beta_1\,\mathrm{CONSTRAINT}_{i,t-1} + \beta_2\,\widehat{\mathrm{IPUR}}_{i,t} + \beta_3\,\widehat{\mathrm{ISAL}}_{i,t} + \beta_4\,\mathrm{MVARY}_{i,t} \\
&\quad + \beta_5\,\mathrm{LOGSIZE}_{i,t-1} + \beta_6\,\mathrm{MLEV}_{i,t-1} + \beta_7\,\mathrm{LOGMB}_{i,t-1} + \beta_8\,\mathrm{RET}_{i,t-1} \\
&\quad + \beta_9\,\mathrm{TURNOVER}_{i,t-1} + \mathrm{INDUSTRYDUMMIES}_{i,t-1}\,\Delta + \epsilon_{i,t}\,, \\
\mathrm{IPUR}_{i,t} &= \gamma_0 + \gamma_1\,\mathrm{IPUR}_{i,t-1} + \gamma_2\,\mathrm{ISAL}_{i,t-1} + \gamma_3\,\mathrm{DVARY}_{i,t-1} + \gamma_4\,\mathrm{MVARY}_{i,t-1} \\
&\quad + \gamma_5\,\mathrm{RET}_{i,t-1} + \gamma_6\,\mathrm{RET}_{i,t-2} + \gamma_7\,\mathrm{LOGSIZE}_{i,t-1} + \gamma_8\,\mathrm{LOGMB}_{i,t-1} \\
&\quad + \gamma_9\,\mathrm{AGE}_{i,t-1} + \gamma_{10}\,\mathrm{TURNOVER}_{i,t-1} + \tilde{\epsilon}_{i,t}\,, \\
\mathrm{ISAL}_{i,t} &= \delta_0 + \delta_1\,\mathrm{IPUR}_{i,t-1} + \delta_2\,\mathrm{ISAL}_{i,t-1} + \delta_3\,\mathrm{DVARY}_{i,t-1} + \delta_4\,\mathrm{MVARY}_{i,t-1} \\
&\quad + \delta_5\,\mathrm{RET}_{i,t-1} + \delta_6\,\mathrm{RET}_{i,t-2} + \delta_7\,\mathrm{LOGSIZE}_{i,t-1} + \delta_8\,\mathrm{LOGMB}_{i,t-1} \\
&\quad + \delta_9\,\mathrm{AGE}_{i,t-1} + \delta_{10}\,\mathrm{TURNOVER}_{i,t-1} + \tilde{\tilde{\epsilon}}_{i,t}\,, \\
&\text{for } i = 1\ldots N\,.
\end{aligned}
\tag{3.2}
$$

which we estimate using Fama-Macbeth approach correcting for autocorrelation using Newey-West standard errors.

Table 4 reports the estimated coefficients for the financial constrainedness measures and in-

Table 4: Fama-MacBeth IV regressions of short-horizon return variance on insider trading activity. The measure of short-horizon variance is daily returns variance, DVARY, and we control for monthly returns variance, MVARY; both measures are computed using one year of data. Newey-West corrected t-statistics in parentheses.

CONSTRAINT:	REPURCHASE	AGE	KZ	KZ3	
$\text{CONSTRAINT}_{i,t-1}$	–0.012**	–0.000	0.000	–0.000	
	(–2.776)	(–0.306)	(0.094)	(–0.038)	
$\widehat{\text{IPUR}}_{i,t-1}$	–5.386	–7.017+	–7.121+	–7.112+	–7.075+
	(–1.313)	(–1.903)	(–1.862)	(–1.858)	(–1.959)
$\widehat{\text{ISAL}}_{i,t-1}$	–6.292*	–5.660+	–5.471+	–5.483+	–5.284+
	(–1.970)	(–1.809)	(–1.688)	(–1.688)	(–1.671)

+ significant at 10% level, * significant at 5% level, ** significant at 1% level

sider trading activity of model 3.2. In this setup, insider purchases and sales are significant and both reduce the short-horizon variance. Insider purchases fail to be significant when lagged firm repurchases are included in the regressions, and this latter variable is the only measure of financial constrainedness that is significant in this setup.

3.2.2 Effects of IT on skewness

The second prediction of our model is that the ability of insiders to purchase shares increases the skewness of short-horizon returns and that the ability of insiders to sell decreases it. These predictions are tested using the following specification, similar to 3.1:

$$\begin{aligned} \text{SKEW}_{i,t} &= \beta_1\,\text{CONSTRAINT}_{i,t-1} + \beta_2\,\text{IPUR}_{i,t-1} + \beta_3\,\text{ISAL}_{i,t-1} \\ &\quad + \beta_5\,\text{LOGSIZE}_{i,t-1} + \beta_6\,\text{MLEV}_{i,t-1} + \beta_7\,\text{LOGMB}_{i,t-1} + \beta_8\,\text{RET}_{i,t-1} \\ &\quad + \beta_9\,\text{TURNOVER}_{i,t-1} + \text{INDUSTRYDUMMIES}_{i,t-1}\,\Delta + \epsilon_{i,t}\,, \\ &\text{for } i = 1 \ldots N, \end{aligned} \tag{3.3}$$

The dependent variable measuring skewness of stock returns, denoted by SKEW in (3.3), is computed using daily data (DSKEW), weekly (WSKEW), monthly (MSKWE), and quarterly (QSKEW). The measures of financial constrainedness, denoted by CONSTRAINT, are the same as in the previous section: stock repurchases (REPURCHASES), firm's age (AGE), and the two Kaplan-Zingales indexes (KZ and KZ3).

In table 5 we report the results of estimating (3.3) using the Fama-Macbeth approach correcting for autocorrelation using Newey-West standard errors. The sign of the coefficient for insider purchases is always positive, and always negative for insider sales; this is consistent with the predictions of our model. However, insider purchases tend to be non-significant, but for the case in which the dependent variable is QSKEW. The only measure of financial constrainedness that is significant for all measures of skewness is AGE, but all are significant predicting QSEW. Note that, as in model (3.1), lagged insider trading activity might not be a good proxy for the ability of insiders to trade.

Similarly to (3.2), we have also instrumented insider trading activity by lagged insider sales and purchases, lagged measures of return variance, the stock returns in the two previous years, the logarithm of the firm's lagged market capitalization, the logarithm of its lagged market to book ration, the lagged average daily turnover and firm's age. The specification of the IV model is similar to (3.2):

$$
\begin{aligned}
\mathrm{SKEW}_{i,t} &= \beta_1\,\mathrm{CONSTRAINT}_{i,t-1} + \beta_2\,\widehat{\mathrm{IPUR}}_{i,t} + \beta_3\,\widehat{\mathrm{ISAL}}_{i,t} \\
&\quad + \beta_5\,\mathrm{LOGSIZE}_{i,t-1} + \beta_6\,\mathrm{MLEV}_{i,t-1} + \beta_7\,\mathrm{LOGMB}_{i,t-1} + \beta_8\,\mathrm{RET}_{i,t-1} \\
&\quad + \beta_9\,\mathrm{TURNOVER}_{i,t-1} + \mathrm{INDUSTRYDUMMIES}_{i,t-1}\,\Delta + \epsilon_{i,t}\,, \\
\mathrm{IPUR}_{i,t} &= \gamma_0 + \gamma_1\,\mathrm{IPUR}_{i,t-1} + \gamma_2\,\mathrm{ISAL}_{i,t-1} \\
&\quad + \gamma_3\,\mathrm{RET}_{i,t-1} + \gamma_4\,\mathrm{RET}_{i,t-2} + \gamma_5\,\mathrm{LOGSIZE}_{i,t-1} + \gamma_6\,\mathrm{LOGMB}_{i,t-1} \\
&\quad + \gamma_7\,\mathrm{AGE}_{i,t-1} + \gamma_8\,\mathrm{TURNOVER}_{i,t-1} + \tilde{\epsilon}_{i,t}\,, \\
\mathrm{ISAL}_{i,t} &= \delta_0 + \delta_1\,\mathrm{IPUR}_{i,t-1} + \delta_2\,\mathrm{ISAL}_{i,t-1} \\
&\quad + \delta_3\,\mathrm{RET}_{i,t-1} + \delta_4\,\mathrm{RET}_{i,t-2} + \delta_5\,\mathrm{LOGSIZE}_{i,t-1} + \delta_6\,\mathrm{LOGMB}_{i,t-1} \\
&\quad + \delta_7\,\mathrm{AGE}_{i,t-1} + \delta_8\,\mathrm{TURNOVER}_{i,t-1} + \tilde{\tilde{\epsilon}}_{i,t}\,, \\
&\text{for } i = 1\ldots N,
\end{aligned}
\tag{3.4}
$$

and the model is estimated using Fama-MacBeth approach correcting for autocorrelation using Newey-West standard errors.

Table 5: Fama-MacBeth regressions of returns skewness on insider trading activity. Newey-West corrected t-statistics in parentheses.

CONSTRAINT:	REPURCHASE	AGE	KZ	KZ3	
Dependent variable is $\mathbf{DSKEW}_{i,t}$					
$\mathrm{CONSTRAINT}_{i,t-1}$	0.019	0.005**	0.009	0.002	
	(1.512)	(8.766)	(1.375)	(0.262)	
$\mathrm{IPUR}_{i,t-1}$	1.247	1.542	1.731+	1.726+	1.501
	(1.023)	(1.641)	(1.719)	(1.712)	(1.616)
$\mathrm{ISAL}_{i,t-1}$	–1.809**	–1.510**	–1.591**	–1.601**	–1.724**
	(–7.531)	(–7.130)	(–6.789)	(–6.958)	(–8.161)
Dependent variable is $\mathbf{WSKEW}_{i,t}$					
$\mathrm{CONSTRAINT}_{i,t-1}$	0.014	0.003**	0.004	–0.003	
	(1.101)	(7.756)	(0.678)	(–0.376)	
$\mathrm{IPUR}_{i,t-1}$	0.512	0.646	0.830	0.839	0.603
	(0.559)	(0.865)	(0.925)	(0.934)	(0.792)
$\mathrm{ISAL}_{i,t-1}$	–1.344**	–1.146**	–1.213**	–1.219**	–1.303**
	(–6.515)	(–6.938)	(–6.470)	(–6.518)	(–7.587)
Dependent variable is $\mathbf{MSKEW}_{i,t}$					
$\mathrm{CONSTRAINT}_{i,t-1}$	0.015*	0.002**	0.003	–0.005	
	(2.514)	(4.661)	(0.498)	(–0.903)	
$\mathrm{IPUR}_{i,t-1}$	0.183	0.501	0.667	0.671	0.462
	(0.226)	(0.828)	(0.837)	(0.840)	(0.754)
$\mathrm{ISAL}_{i,t-1}$	–0.912**	–0.871**	–1.004**	–1.007**	–0.981**
	(–2.862)	(–3.206)	(–3.503)	(–3.531)	(–3.518)
Dependent variable is $\mathbf{QSKEW}_{i,t}$					
$\mathrm{CONSTRAINT}_{i,t-1}$	0.016+	0.001*	–0.014*	–0.017**	
	(1.688)	(2.464)	(–2.166)	(–2.858)	
$\mathrm{IPUR}_{i,t-1}$	1.241*	0.814	1.174+	1.183+	0.799
	(2.291)	(1.612)	(1.925)	(1.952)	(1.558)
$\mathrm{ISAL}_{i,t-1}$	–0.280	–0.189	–0.303	–0.296	–0.244
	(–1.023)	(–0.703)	(–1.104)	(–1.090)	(–0.868)

+ significant at 10% level, * significant at 5% level, ** significant at 1% level

Table 6 reports the results obtained in the estimation of (3.4). Insider purchases increase the skewness and insider sales decrease it, consistently with our model. Insider purchases are significant when the dependent variable is daily or quarterly skewness; insider sales are always significant, but for the case of quarterly skewness. Insider transactions have a larger impact on shorter-horizon skewness (DSKEW) than on longer-horizon skewness. Note that the only measure of financial constrainedness that is significant in all the regressions is firm's age, share repurchases is significant when the dependent variable is monthly skewness, and the Kaplan-Zingales indexes when the dependent variable is quarterly skewness. In Table 6, the evidence in favor of firms being buyers of last resort is weaker than in Tables 3 and 4, but stronger in favor of insiders being liquidity providers.

4 Conclusions and further research

When liquidity shocks move asset prices away from fundamental values, corporate insiders are in a privileged position to absorb this demand for liquidity. In order to provide liquidity, insiders can trade on the firm's account, through buy back programs or seasonal equity offerings, or on their own account. In this paper we provide a theoretical framework and evidence supporting the role of corporate insiders as liquidity providers which complements the evidence provided in Hong et al. (2005) on firms playing a similar role. We identify some differences though in the way these two type of traders provide liquidity. First, while stock repurchases clearly reduce return volatility, insiders transactions may not. This is because, unlike firms, insiders face an adverse selection problem when trading. When the adverse selection effect is stronger than the price support effect, volatility may increase. This explains why our results on volatility are weaker than those linking volatility to stock repurchases. On the other hand insider trading plays a more clear role in generating skewness in returns than stock repurchases, specially in the short run.

Our findings are relevant in understanding the liquidity provision process and might enlighten policy makers on the implications of insider trading restrictions, disclosure requirements, and insider transactions publicity on the liquidity of stock markets. Moreover, the impact of insider trading on liquidity, short-horizon variance and skewness is relevant for risk management and asset pricing. Firms that restrict insider trading activity might have less liquid and more volatile stocks.

Table 6: Fama-MacBeth IV regressions of returns skewness on insider trading activity. Newey-West corrected t-statistics in parentheses.

CONSTRAINT:	REPURCHASE	AGE	KZ	KZ3	
Dependent variable is DSKEW$_{i,t}$					
CONSTRAINT$_{i,t-1}$	0.019	0.004**	0.010	0.004	
	(1.549)	(6.714)	(1.446)	(0.513)	
$\widehat{\text{IPUR}}_{i,t-1}$	6.509	6.556+	7.724*	7.700*	7.992*
	(1.520)	(1.736)	(2.086)	(2.080)	(2.157)
$\widehat{\text{ISAL}}_{i,t-1}$	–10.098**	–5.780**	–9.056**	–9.024**	–9.719**
	(–12.075)	(–5.272)	(–8.699)	(–8.932)	(–7.632)
Dependent variable is WSKEW$_{i,t}$					
CONSTRAINT$_{i,t-1}$	0.015	0.003**	0.005	–0.000	
	(1.129)	(8.051)	(0.852)	(–0.044)	
$\widehat{\text{IPUR}}_{i,t-1}$	3.525	3.540	4.162	4.183	4.671
	(1.119)	(1.218)	(1.323)	(1.331)	(1.521)
$\widehat{\text{ISAL}}_{i,t-1}$	–6.849**	–3.858**	–6.192**	–6.159**	–6.682**
	(–9.418)	(–5.122)	(–6.813)	(–6.808)	(–6.691)
Dependent variable is MSKEW$_{i,t}$					
CONSTRAINT$_{i,t-1}$	0.015*	0.002**	0.003	–0.004	
	(2.464)	(3.976)	(0.604)	(–0.664)	
$\widehat{\text{IPUR}}_{i,t-1}$	3.131	3.777	3.985	3.983	4.461
	(0.952)	(1.290)	(1.255)	(1.256)	(1.441)
$\widehat{\text{ISAL}}_{i,t-1}$	–5.232**	–2.905*	–5.453**	–5.401**	–5.288**
	(–3.088)	(–2.184)	(–3.533)	(–3.532)	(–3.430)
Dependent variable is QSKEW$_{i,t}$					
CONSTRAINT$_{i,t-1}$	0.015	0.001*	–0.014*	–0.017**	
	(1.519)	(2.324)	(–2.478)	(–3.222)	
$\widehat{\text{IPUR}}_{i,t}$	4.879*	4.474*	4.720*	4.735*	4.875*
	(2.410)	(2.110)	(2.071)	(2.095)	(2.242)
$\widehat{\text{ISAL}}_{i,t}$	–0.842	–0.039	–1.033	–0.980	–0.984
	(–0.687)	(–0.038)	(–0.836)	(–0.789)	(–0.888)

+ significant at 10% level, * significant at 5% level, ** significant at 1% level

Furthermore, the inability to provide price support on the firm's account makes financially constrained firms riskier. Finally, the presence of lockup periods, in which insiders cannot sell their holdings, can make stock prices more prone to temporal overpricing.

At the current state of our research agenda, two important questions remain that will be addressed in further work. The first is to improve our understanding of liquidity provision by insiders by focusing on large price corrections due to liquidity shocks. In this event-study type setting we will be in a better position to asses insiders actions and their impact on return distributions. The second is analyzing the effect of earlier disclosure of insider trades, as imposed by Sarbanes-Oxley Act after August of 2002. Furthermore, our results call for the need to develop a full theory that analyzes the tradeoffs involved in insiders' decision to trade on the firm's vs their own account, in the presence of liquidity shocks, when both moral hazard and adverse selection considerations are in place. All these extensions, however, are beyond the scope of the present paper.

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A Appendix

A.1 Proof of lemma 1

The informed problem at $t = 1$ is

$$\max_{x_{I,1}} \mathrm{E}\left[-\exp\Big(-r_I\big(x_{I,1}\left(P_3 - P_1\right) - k(x_{I,1})\big)\Big)\Big|\mathcal{I}_{I,1}\right]$$

it is immediate that the first order conditions derived from this optimization problem imply that the optimal informed demand is

$$x_{I,1}^{*} = \frac{\mathrm{E}\left[P_3|\mathcal{I}_{I,1}\right] - P_1 - \frac{d\,k}{d\,x_{I,1}}(x_{I,1}^{*})}{r_I\,\mathrm{Var}\left[P_3|\mathcal{I}_{I,1}\right]} =$$
$$= \frac{s - P_1 - \frac{d\,k}{d\,x_{I,1}}(x_{I,1}^{*})}{r_I\,\sigma_s^2}$$

whenever $x_{I,1}^{*} \neq 0$ because the cost k is not differentiable at 0.

Note that a sufficient condition to to have $x_{I,1}^{*} > 0$ is $s > P_1 + k_+$; similarly, a sufficient condition to to have $x_{I,1}^{*} > 0$ is $s < P_1 - k_-$. Therefore, the optimal demand of an informed trader at $t = 1$ will be given by

$$x_{I,1} = \begin{cases} \frac{s-P_1+k_-}{r_I\,\sigma_\varepsilon^2} & \text{if } s < P_1 - k_-, \\ \frac{s-P_1-k_+}{r_I\,\sigma_\varepsilon^2} & \text{if } s > P_1 + k_+. \end{cases}$$

We will show now that whenever $P_1 - k_- \leq s \leq P_1 + k_+$ the optimal demand for the informed is $x_{I,1} = 0$. Let us assume that the optimal demand is $x_{I,1} > 0$, in this case we know that $x_{I,1} = x_{I,1}^{*}$, but given that $s \leq P_1 + k_+$ we would have $x_{I,1} = x_{I,1}^{*} \leq 0$, which contradicts that $x_{I,1} > 0$. In the same way, we can show that it can't be optimal $x_{I,1} < 0$ when $s \geq P_1 - k_-$. As a consequence, the optimal demand for the informed is $x_{I,1} = 0$ whenever $P_1 - k_- \leq s \leq P_1 + k_+$.

A.2 Proof of proposition 2

At $t = 2$ the uninformed already knows the informed trade at $t = 1$, and being public information we can consider the cases in which the informed trade, $x_{I,1} \neq 0$, and the case in which the informed do not trade, $x_{I,1} = 0$, separately. Let us solve firs the equilibrium in the former case and second in the later.

Informed trade at $t = 1$

Given that the uninformed knows that $x_{I,1} \neq 0$ and that, in this case, $x_{I,1} = \frac{s-P_1+k_-}{r_I\,\sigma_\varepsilon^2}$ by lemma 1. It is clear that knowing the actual value of $x_{I,1} \neq 0$ and P_1 is informationally equivalent to know

s. It is immediate to see that the demand of an uninformed will be given by

$$x_U = \frac{s - P_2}{r_U\, \sigma_\varepsilon^2}.$$

Imposing the market clearing condition, $\lambda\, x_{I,2} + (1-\lambda)\, x_{U,2} = x$ and the fact that informed agents cannot trade at $t = 2$, $x_{I,2} = x_{I,1}$, it is immediate that

$$P_2 = s + \frac{r_u\, \sigma_\varepsilon^2}{1-\lambda}(x + \lambda\, x_{I,1}).$$

Finally, by lemma 1,

$$x_{U,2} = \begin{cases} \frac{-1}{1-\lambda}\left(x + \lambda\, \frac{s-P_1+k_-}{r_I\, \sigma_\varepsilon^2}\right) & \text{if } s < P_1 - k_-, \\ \frac{-1}{1-\lambda}\left(x + \lambda\, \frac{s-P_1-k_+}{r_I\, \sigma_\varepsilon^2}\right) & \text{if } s > P_1 + k_+; \end{cases}$$

and

$$P_2 = \begin{cases} s + \frac{r_U\, \sigma_\varepsilon^2}{1-\lambda}\left(x + \lambda \frac{s-P_1+k_-}{r_I\, \sigma_\varepsilon^2}\right) & \text{if } s < P_1 - k_-, \\ s + \frac{r_U\, \sigma_\varepsilon^2}{1-\lambda}\left(x + \lambda \frac{s-P_1-k_+}{r_I\, \sigma_\varepsilon^2}\right) & \text{if } s > P_1 + k_+. \end{cases}$$

Informed do not trade at $t = 1$

In this case, uninformed know P_1 and $x_{I,1} = 0$, which implies they know x and that $P_1 - k_- \leq s \leq P_1 + k_+$. We will define $s' = \frac{s}{\sigma_s}$, $\underline{s} = \frac{P_1-k_-}{\sigma_s}$, and $\overline{s} = \frac{P_1+k_+}{\sigma_s}$. Uninformed maximize the expected utility of their wealth conditional on their information at $t = 2$, this expected utility can be written as follows:

$$
\begin{aligned}
&\mathrm{E}\left[\,\mathcal{U}_U\left(W_{U,3}\right) \mid \mathcal{I}_{U,2}\,\right] = -\mathrm{E}\left[\;\exp\Big(-r_U\,\big(x_{U,1}\left(P_2-P_1\right)+x_{U,2}\left(\sigma_s\,s'+\varepsilon-P_2\right)\big)\Big)\;\Big|\;\underline{s}\le s'\le\overline{s}\;\right]=\\
&=\frac{-1}{\Phi(\overline{s})-\Phi(\underline{s})}\int_{\underline{s}}^{\overline{s}}\mathrm{E}\left[\;\exp\Big(-r_U\,\big(x_{U,1}\left(P_2-P_1\right)+x_{U,2}\left(\sigma_s\,s'+\varepsilon-P_2\right)\big)\Big)\;\Big|\;s'\;\right]\phi(s')\,d\,s'=\\
&=\frac{-\exp\Big(-r_U\,\big(x_{U,1}\left(P_2-P_1\right)-x_{U,2}\,P_2\big)\Big)}{\Phi(\overline{s})-\Phi(\underline{s})}\int_{\underline{s}}^{\overline{s}}\mathrm{E}\left[\;\exp\left(-r_U\,x_{U,2}\left(\sigma_s\,s'+\varepsilon\right)\right)\;\Big|\;s'\;\right]\phi(s')\,d\,s'=\\
&=\frac{-\exp\Big(-r_U\,\big(x_{U,1}\left(P_2-P_1\right)-x_{U,2}\,P_2\big)\Big)}{\Phi(\overline{s})-\Phi(\underline{s})}\\
&\qquad\int_{\underline{s}}^{\overline{s}}\exp\Big(-r_U\,x_{U,2}\,\mathrm{E}\left(\sigma_s\,s'+\varepsilon|s'\right)+\frac{r_U^2\,x_{U,2}^2}{2}\mathrm{Var}\left(\sigma_s\,s'+\varepsilon|s'\right)\Big)\,\phi(s')\,d\,s'=\\
&=\frac{-\exp\Big(-r_U\,\big(x_{U,1}\left(P_2-P_1\right)-x_{U,2}\,P_2\big)\Big)}{\Phi(\overline{s})-\Phi(\underline{s})}\int_{\underline{s}}^{\overline{s}}\exp\Big(-r_U\,x_{U,2}\,\sigma_s\,s'+\frac{r_U^2\,x_{U,2}^2\,\sigma_\varepsilon^2}{2}\Big)\,\phi(s')\,d\,s';
\end{aligned}
$$

where ϕ and Φ are the probability density function and the cumulative distribution function of a standard normal random variable. Substituting $\phi(s')=\frac{1}{\sqrt{2\,\pi}}\exp(\frac{-s'^2}{2})$ in the previous expression and taking $\exp(\frac{r_U^2\,x_{U,2}^2\,\sigma_\varepsilon^2}{2})$ outside the integral , we can rewrite the expected utility as follows:

$$
\begin{aligned}
&\mathrm{E}\left[\,\mathcal{U}_U\left(W_{U,3}\right) \mid \mathcal{I}_{U,2}\,\right]=\frac{-\exp\Big(-r_U\,\big(x_{U,1}\left(P_2-P_1\right)-x_{U,2}\,P_2-\frac{1}{2}r_U\,x_{U,2}^2\,\sigma_\varepsilon^2\big)\Big)}{\Phi(\overline{s})-\Phi(\underline{s})}\\
&\qquad\frac{1}{\sqrt{2\,\pi}}\int_{\underline{s}}^{\overline{s}}\exp\left(-r_U\,x_{U,2}\,\sigma_s\,s'-\frac{1}{2}\,s'^2\right)d\,s'=\\
&=\frac{-\exp\Big(-r_U\,\big(x_{U,1}\left(P_2-P_1\right)-x_{U,2}\,P_2-\frac{1}{2}r_U\,x_{U,2}^2\,\sigma_\varepsilon^2\big)\Big)}{\Phi(\overline{s})-\Phi(\underline{s})}\\
&\qquad\frac{1}{\sqrt{2\,\pi}}\int_{\underline{s}}^{\overline{s}}\exp\left(-\frac{1}{2}(s'+r_U\,x_{U,2}\,\sigma_s)^2+\frac{1}{2}\,r_U^2\,x_{U,2}^2\,\sigma_s^2\right)d\,s'=\\
&=\frac{-\exp\Big(-r_U\,\big(x_{U,1}\left(P_2-P_1\right)-x_{U,2}\,P_2-\frac{1}{2}r_U\,x_{U,2}^2\left(\sigma_\varepsilon^2+\sigma_s^2\right)\big)\Big)}{\Phi(\overline{s})-\Phi(\underline{s})}\\
&\qquad\frac{1}{\sqrt{2\,\pi}}\int_{\underline{s}}^{\overline{s}}\exp\left(-\frac{1}{2}(s'+r_U\,x_{U,2}\,\sigma_s)^2\right)d\,s'.
\end{aligned}
$$

With the change of variables $z = s' + r_U\, x_{U,2}\, \sigma_s$,

$$\mathrm{E}\left[\, \mathcal{U}_U\,(W_{U,3}) \mid \mathcal{I}_{U,2}\, \right] = \frac{-\exp\Big(-r_U\,\big(x_{U,1}\,(P_2 - P_1) - x_{U,2}\,P_2 - \frac{1}{2} r_U\, x_{U,2}^2\,(\sigma_\varepsilon^2 + \sigma_s^2)\big)\Big)}{\Phi(\overline{s}) - \Phi(\underline{s})} \frac{1}{\sqrt{2\,\pi}} \int_{\underline{s}+r_U\,x_{U,2}\,\sigma_s}^{\overline{s}+r_U\,x_{U,2}\,\sigma_s} \exp\big(-\frac{z^2}{2}\big)\,d\,z =$$

$$= -\frac{\Phi(\overline{s} + r_U\,x_{U,2}\,\sigma_s) - \Phi(\underline{s} + r_U\,x_{U,2}\,\sigma_s)}{\Phi(\overline{s}) - \Phi(\underline{s})} \exp\Big(-r_U\,\big(x_{U,1}\,(P_2 - P_1) - x_{U,2}\,P_2 - \frac{1}{2} r_U\, x_{U,2}^2\,(\sigma_\varepsilon^2 + \sigma_s^2)\big)\Big)$$

Note that maximizing $\mathrm{E}\left[\, \mathcal{U}_U\,(W_{U,3}) \mid \mathcal{I}_{U,2}\, \right]$ is equivalent to minimize

$$\ln\big(\Phi(\overline{s} + r_U\,x_{U,2}\,\sigma_s) - \Phi(\underline{s} + r_U\,x_{U,2}\,\sigma_s)\big) + r_U\,\big(x_{U,2}\,P_2 + \frac{1}{2} r_U\, x_{U,2}^2\,(\sigma_\varepsilon^2 + \sigma_s^2)\big)$$

thus, the first order conditions for the uninformed are

$$\sigma_s \frac{\phi(\overline{s} + r_U\,x_{U,2}\,\sigma_s) - \phi(\underline{s} + r_U\,x_{U,2}\,\sigma_s)}{\Phi(\overline{s} + r_U\,x_{U,2}\,\sigma_s) - \Phi(\underline{s} + r_U\,x_{U,2}\,\sigma_s)} + P_2 + r_U\,x_{U,2}\,(\sigma_\varepsilon^2 + \sigma_s^2) = 0.$$

The market clearing condition, $(1-\lambda)x_{U,2} + x = 0$ imposes that $x_{U,2} = \frac{-x}{1-\lambda}$ and substituting this expression in the first order conditions we obtain the equilibrium price P_2 when $P_1 - k_- \le s \le P_1 + k_+$:

$$\begin{aligned} P_2 &= \frac{r_U(\sigma_\varepsilon^2 + \sigma_s^2)}{1-\lambda} x - \sigma_s \frac{\phi(\overline{s} - \frac{r_U\,\sigma_s\,x}{1-\lambda}) - \phi(\underline{s} - \frac{r_U\,\sigma_s\,x}{1-\lambda})}{\Phi(\overline{s} - \frac{r_U\,\sigma_s\,x}{1-\lambda}) - \Phi(\underline{s} - \frac{r_U\,\sigma_s\,x}{1-\lambda})} \\ &= \frac{r_U(\sigma_\varepsilon^2 + \sigma_s^2)}{1-\lambda} x - \sigma_s \frac{\phi(\frac{P_1+k_+}{\sigma_s} - \frac{r_U\,\sigma_s\,x}{1-\lambda}) - \phi(\frac{P_1-k_-}{\sigma_s} - \frac{r_U\,\sigma_s\,x}{1-\lambda})}{\Phi(\frac{P_1+k_+}{\sigma_s} - \frac{r_U\,\sigma_s\,x}{1-\lambda}) - \Phi(\frac{P_1-k_-}{\sigma_s} - \frac{r_U\,\sigma_s\,x}{1-\lambda})}. \end{aligned}$$

A.3 Numerical approximation to the equilibrium at $t = 1$

The numerical approximation to the equilibrium is based on the *projection method* used by Bernardo and Judd (2000), as a consequence we are estimating an *ε-rational expectations equilibrium*[8]. In an ε-rational expectations equilibrium, for all states in a set of probability $1-\varepsilon$, the decisions of

[8]We shall not confuse the ε in the definition of ε-rational expectations equilibrium with the random variable ε in our model.

all traders are nearly optimal, with the absolute value of their relative error not larger than ε; and markets almost clear, with the absolute value of the excess demand not larger than ε.

The equilibrium price, $P_1(x, s)$, and uninformed demand, $x_U(P_1)$, are approximated by finite-order polynomials, which transforms our problem of computing the equilibrium in an infinite dimensional space into estimating a finite number of parameters. In particular we define the approximated equilibrium price and uninformed demand as

$$\hat{P}_1(x, s) = \sum_{i=0}^{N} \sum_{j=0}^{N-i} a_{i,j}\, H_i(x)\, H_j(s)$$
$$\hat{x}_U(P_1) = \sum_{i=0}^{N} b_i\, H_i(x)$$

where H_i is the degree i Hermite polynomial and N is the largest degree of the polynomial approximation. In our case, we have obtained the best results for $N = 3$. The choice of Hermite polynomials is because they are mutually orthogonal with respect to the normal density function with mean zero, the advantages of such a base of polynomials are discussed in Judd (1992). Our goal is to estimate the parameters $a_{i,j}$ and b_i and, to do so, we will impose several conditions derived from the uninformed first order condition and market clearing.

Following Bernardo and Judd (2000) methodology, we numerically impose the conditional expectation first order condition

$$\mathrm{E}\left[\, r_U\, (s + \varepsilon - P_1) \exp\big(- r_U\, x_{U,1}\, (s + \varepsilon - P_1)\big) \,\middle|\, P_1 \right] = 0$$

as the $(N+1)$ expectation conditions

$$\mathrm{E}\left[\, r_U\, (s + \varepsilon - P_1) \exp\big(- r_U\, x_{U,1}\, (s + \varepsilon - P_1)\big)\, H_i\big(\hat{P}_1(x, s)\big)\right] = 0, \text{ for } i = 0 \dots N;$$

and the market clearing condition is imposed using the conditions

$$\mathrm{E}\left[\, \big(\lambda\, x_I\big(\hat{P}_1(x, s), s\big) + (1 - \lambda)\, \hat{x}_U\big(\hat{P}_1(x, s)\big) + x\big)\, H_i(x)\, H_j(s)\right] = 0, \text{ for } i + j = 0 \dots N.$$

The expectations are computed using Gaussian quadrature, whose nodes and weights are obtained from the routine `qnwnorm`, that belongs to `COMPECON` toolbox, written to accompany Miranda and Fackler (2002). We use 9 Gauss nodes to compute the quadrature, we observe that increasing the number of points does not improve the estimation. Finally, to solve the resulting nonlinear system we use the trust-region dogleg algorithm as implemented in `fsolve` function from Matlab's optimization toolbox.