Liquidity Formation and Preopening Periods in Financial Markets

September 18, 2017

Abstract

This paper studies the role of preopening periods in liquidity formation and welfare in financial markets. Because no transaction occurs during these preopening periods, their economic significance could be questioned. We model a market where costly participation and asymmetric information prevent latent liquidity to be expressed. At equilibrium, risk-averse insiders use preopening periods to better coordinates supply and demand of liquidity by communicating liquidity needs, which thus improves welfare. However, communicating the private information on asset value at preopening periods does not always improve liquidity formation and welfare. The outsider benefits from a reduction in the entry cost and the adverse selection risk but the insider may face a loss in the informational rent. Our findings have implications for portfolio management and the design of financial markets.

Keywords: Asymmetric Information, Liquidity Formation, Preopening Periods

1 Introduction

Many stock markets around the world (e.g. NASDAQ, Toronto Stock Exchange, Paris Bourse, Milan Borsa, and Madrid Borsa) allow traders to place non-binding orders before trading actually occurs. These orders result in tentative prices that are publicly disseminated. Because preopening periods do not give rise to transactions, their economic significance could be questioned. However, the empirical and theoretical literature in market microstructure has shown that, despite the absence of transactions, preopening periods reveal information. Biais, Hillion, and Spatt (1999), Cao, Ghysels, and Hatheway (2000), Barclay and Hendershott (2003), Barclay and Hendershott (2008), Jiang, Likitapiwat, and McInish (2012) and Pagano, Peng, and Schwartz (2013) empirically document that indicative prices in preopening periods reflect learning of stocks equilibrium valuation in different markets. Vives (1995) and Medrano and Vives (2001) propose models to show that tentative prices reveal information if the orders placed during the preopening period can be executed with a non-null probability. Less attention however has been focused on the potential influence of preopening periods on liquidity formation and welfare. This paper proposes a theoretical model to addresses these issues.

We consider a theoretical model with one risky asset and two traders: an insider and an outsider. The insider receives an endowment shock, which grants him the risky asset with positive probability. The insider is risk averse and the outsider risk neutral, it is thus optimal for the insider to sell the risky asset to the outsider to hedge his position and for the outsider to provide liquidity to the insider. Our analysis is based on two premises. First, we consider that the liquidity provider (the outsider) has to pay a cost to participate in the market. This cost can be thought of as an opportunity cost related to the time spent learning about market conditions. Second, we consider that there are information asymmetries between traders. In particular, we assume that the insider possesses superior information not only on his liquidity needs (endowment shock) but also on the asset value which can be high or low. These two frictions magnify the difficulty of providing liquidity to the market.

In this framework, the insider uses the preopening period to place non-binding orders to communicate his liquidity needs and private signals on asset value to the outsider. Since preopening periods do not translate into actual trades, under what conditions the insider has incentive to truthfully reveal his information to the outsider is a major concern. We find that truthful communication on liquidity needs is always feasible since no conflicts of interest between the traders arises regarding the endowment shock. However, truthful communication on private signals concerning asset value is not always feasible, because the insider receiving low quality asset may have incentive to mimic the one with high quality asset.

Truthful transmission on asset values is only feasible under two scenarios. One is when the gains from trade are small and the adverse selection very severe. In this case, the outsider optimally chooses to shut down trading after announcement of high quality asset. Therefore, the insider will not obtain any informational rent regardless of his private signals on asset values, which ensures that he has no incentive to manipulate the information at the preopening stage. The other situation is when the entry cost is sufficiently high, in which case the outsider can credibly punish the lying behavior of the insider by staying out of the market given announcement by the insider that the asset is of high quality. This no entry decision contingent on high quality signal report works as a punishment mechanism to ensure that the insider has no incentive to lie.

We further study the impact of preopening periods on liquidity formation and welfare. On the one hand, we find that the insider uses the preopening period to communicate his liquidity shocks that need to be hedged. It allows the outsider to make contingent entry decision based on endowment shock, which saves her entry cost, coordinates the supply and the demand of liquidity and reduces the likelihood of market breakdowns. Therefore, preannouncing liquidity needs improves social welfare. On the other hand, the insider with liquidity needs might also rationally reveal his private signals concerning asset value during the preopening period. This allows the outsider to make contingent entry decision on private signals, which saves her entry cost, and provides her with a mechanism to punish the insider's lying behavior. Different from communication on liquidity needs, the communication on asset values may sometimes reduce liquidity formation and welfare. The outsider always benefits from a reduction in the entry cost and the adverse selection risk but the insider may face a loss in the informational rent.

Our model is inspired by Laffont and Maskin (1990) in that it analyzes trading using contract theory. Our approach differs from theirs in two dimensions. First, in lieu of a risk-neutral insider, we consider a risk-averse insider who has two trading motivations: informed speculation and hedging. This is in line with Bhattacharya and Spiegel (1991). Second, we study the role of alternative market mechanisms, namely the presence or not of a preopening period, and their welfare implications. The role of the preopening period in coordinating supply and demand of liquidity is in line with the theoretical analysis of sunshine trading by Admati and Pfleiderer (1991). We complement their study in three aspects. Admati and Pfleiderer (1991) i) model the traders preannouncing their orders as noise traders, ii) consider that preannouncing traders are always uninformed, and iii) do not specify the mechanism through which preannouncement reaches the market. In contrast, we study a market game where all traders are utility maximizing agents. This allows us to study the strategic dimension of preannouncement and its welfare implications. We also consider that the pre-announcing traders can have superior information. This allows us to investigate the role of preannouncement in price formation and information revelation. Finally, we explicitly model the market mechanism that can accommodate preannouncements, i.e., the preopening period.

Our paper is also related to the theoretical analyses of preopening periods. Vives (1995) and Medrano and Vives (2001) show that tentative prices can reveal information if the orders placed during the preopening period can be executed with a non-null probability. We complement these findings in two ways: i) we show that, even when agents can place non-binding orders, preopening periods can generate useful pricing information, and ii) we address the issue of liquidity formation. Baruch (2005) studies the impact of transparency on market openings by comparing closed and open limit-order books. Our preopening period has a similar spirit to his open limit-order book consideration.

Our result that insiders might have an incentive to reveal their private information during a round of preplay non-binding communication echoes the findings of Spatt and

Srivastava (1991). They show that truthful preplay communication in initial public offerings can be part of an optimal auction mechanism. In their model, traders' incentives to disclose private information are related to the fact that announcing true valuations does not affect prices but maximizes traders' probability to receive the asset (in the spirit of a second price auction). In contrast, risk averse traders in our model have an incentive to truthfully reveal information because trading strategies endogenously preclude manipulation to be profitable.

The rest of this paper is organized as follows. Section 2 describes the model. Section 3 presents the equilibrium analysis. Section 4 concludes by offering implications for portfolio managers and market organizers, and by discussing robustness checks and extensions of our analysis. Proofs are in the Appendix.

2 Model

Consider a financial market for a risky asset with value $\tilde{v} = \tilde{\theta} + \tilde{\epsilon}$. $\tilde{\theta}$ is a random variable that takes the values θ_L and θ_H with equal probability, where $\theta_H > \theta_L$. $\tilde{\epsilon}$ is a centered normal variable with variance σ^2, i.e., $\tilde{\epsilon} \sim N(0, \sigma^2)$.

There are two investors: one insider (referred to as he and denoted by I), and one outsider (referred to as she and denoted by O). The insider is risk averse with a negative exponential utility function with constant absolute risk aversion parameter denoted by A. The outsider is risk neutral.

The timeline of the trading in the financial market is as in Figure 1.

At the beginning, the insider receives an endowment shock $\tilde{e}$, which takes the value 1 with probability λ and the value 0 with probability $1 - \lambda$. When the endowment shock is 1, the insider owns the risky asset. When the endowment shock is 0, the insider does not own the asset. We assume that the asset is divisible. In addition, the insider privately observes a signal $\tilde{s}$, which is correlated with $\tilde{\theta}$.

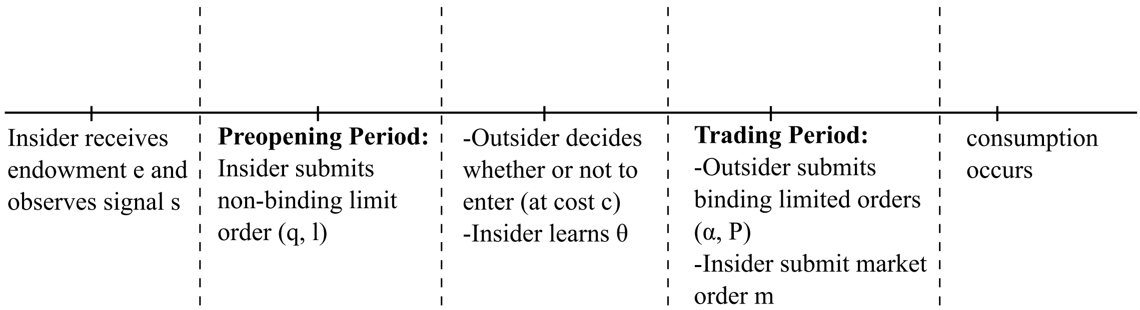

Figure 1: The timeline of the trading in the financial market

$$
\begin{aligned}
&prob(\tilde{s} = \theta_L | \tilde{\theta} = \theta_L) = prob(\tilde{s} = \theta_H | \tilde{\theta} = \theta_H) = p \\
&prob(\tilde{s} = \theta_H | \tilde{\theta} = \theta_L) = prob(\tilde{s} = \theta_L | \tilde{\theta} = \theta_H) = 1 - p,
\end{aligned}
\tag{1}
$$

where $p > \frac{1}{2}$. Equation (1) indicates that if $\tilde{\theta} = \theta_L$ ($\tilde{\theta} = \theta_H$), the insider observes a signal θ_L (θ_H) with probability p and a signal θ_H (θ_L)with probability $1 - p$. Since $p > \frac{1}{2}$, the signal is informative.

After the insider privately observes his endowment shock and the signal on the asset value, there is a preopening period where the insider can submit a non-binding limited order (q, l), where q represents a quantity and l is a limit price. After observing (q, l), the outsider can decide whether or not to enter the market with an entry cost c. As in Grossman and Miller (1988) and Admati and Pfleiderer (1991), if she decides to participate in the market, the outsider incurs a cost c. This cost can be interpreted as an order processing cost. It can also be thought of as an opportunity cost related to the time spent learning about market conditions or the cost of freeing up capital for trading. In the meantime, the insider perfectly observes the value of $\tilde{\theta}$. This assumption indicates that the information set of the insider can evolve during the preopening period. This assumption comes from the fact that traders can keep updating their information set from different sources during the preopening period.[1]

[1] This assumption also makes our setup more general since the case where the insider do not change his information set corresponds to a special scenario in our model that the signal received by the insider before the preopening period is perfectly informative. In addition, with this assumption, our model can generate some interesting results in Section 3.4 on how the informativeness of the insider's private signal

Given the outsider enters the market and pays the cost c, the game proceeds to the trading period. The outsider submits a menu of binding limit orders denoted by (α, P) where α is a vector of quantities and P is a vector of associated limit prices. The insider chooses to trade against one of the limit orders submitted by the outsider. This decision is denoted by m where $m = i$ represents that the insider chooses to execute the order (α_i, P_i). In our setup, the insider has four types since he has private information on both his endowment shock and asset value. The revelation principle allows us to restrict our attention to the case where the outsider submits 4 binding limit orders at the trading stage. Limit orders with 0 quantity represent no trading. Finally, the trading ends. The value of asset v becomes publicly observable and consumption occurs.

In this game, an insider strategy is a pair of mappings (q, l): $(\{0, 1\}, \{\theta_L, \theta_H\}) \rightarrow (R, R)$ and m: $(\{0, 1\}, \{\theta_L, \theta_H\}) \rightarrow \{1, 2, 3, 4\}$. The mapping (q, l) prescribes a non-binding limit order $(q, l)(e, s)$ at the preopening stage on the basis of his endowment shock e and private signal s. The mapping m prescribes a market order $m(e, \theta)$ at the trading stage to execute one of the outsider's limit orders on the basis of his endowment shock e and asset value θ.

An outsider strategy is a pair of mappings $d : (R, R) \rightarrow \{0, 1\}$ and $(\alpha, P) : (R, R) \rightarrow R^4 \times R^4$. The mapping d prescribes an entry decision $d(q, l)$ conditional on the insiders non-binding limit order, where $d = 1$ stands for entry while $d = 0$ stands for no entry. The mapping $(\alpha, P)(q, l)$ prescribes the limit orders the outsider submits conditional on the insider's non-binding limit order. We use the convention that positive numbers of q and α represent purchases. The conditional beliefs of the outsider are represented by a mapping that associates to each collection of limit orders (q, l) a probability function $Pr[\cdot|(q, l)]$ on $\{\tilde{e}, \tilde{\theta}\}$, where $Pr[\tilde{e} = e, \tilde{\theta} = \theta|(q, l)]$ is the probability that the outsider attaches to $\{\tilde{e} = e, \tilde{\theta} = \theta\}$ given the insider's limit order (q, l).

To sum up, the trading stage is modeled as a principal-agent game with the outsider as principal and the insider as agent, and the preopening period is modeled as a round

affects the parameter range of the credible information transmission regarding asset values during the preopening period.

of pre-play communication where the agent can transmit information to the principal by submitting a non-binding limit order.

3 Equilibrium Analysis

We first consider a benchmark case with no information asymmetry. If the insider does not own the asset, i.e., $e = 0$, no trade happens. However, if the insider owns the asset, i.e., $e = 1$, there are gains from trade. At the trading stage, the outsider proposes a price $P_i = \theta_i - \frac{1}{2}A\sigma^2$ to buy the asset from the insider when $\tilde{\theta} = \theta_i$, where $i = L, H$. Trading volume is always 1. The insider can sell his total asset to the outsider regardless of the realization of the asset value $\tilde{\theta}$. This allocation allows an optimal transfer of risk from the risk-averse insider to the risk-neutral outsider, and the pricing allows the outsider to extract all the gains from trade: she earns an expected profit equal to $\frac{1}{2}A\sigma^2$ while the insider has an expected utility equal to his outside option $\theta_i - \frac{1}{2}A\sigma^2$, where $i = L, H$. At the preopening stage, the outsider enters into the trading stage if and only if $\tilde{e} = 1$ and $c \leq \frac{1}{2}A\sigma^2$.

We now turn to the more interesting case with information asymmetry. In this case, the insider has two trading motives: hedging and informed speculation, which is in line with Bhattacharya and Spiegel (1991). In this section, we will solve our model backward analyzing first the trading period, and then the preopening period.

3.1 Trading Period

At the trading stage, the outsider has already made her entry decision. The cost of market participation is thus a sunk cost. We therefore ignore it for now and will reintroduce it when we explicitly consider the entry decision and the participation constraint of the outsider at the preopening stage. Given that the outsider decided to enter the market, she has to choose a menu of limit order (α, P) to maximize her expected trading profits given that the incentive and participation constraints of the insider are satisfied.

We denote α_i^j, P_i^j, U_i^j and V_i^j as the trading volume, price, utility of the insider and the utility of the outsider at the trading stage on type $\{\tilde{e} = j, \tilde{\theta} = \theta_i\}$, where $j = 0, 1$ and $i = L, H$. In addition, we denote by b_i^j the updated beliefs of the outsider on type $\{\tilde{e} = j, \tilde{\theta} = \theta_i\}$, where $j = 0, 1$ and $i = L, H$, i.e., $b_i^j = Pr[\tilde{e} = j, \tilde{\theta} = \theta_i | (q, l)]$. By solving the trading game at the trading stage, we obtain the following result.

Lemma 1. *Denote $K = \frac{A\sigma^2}{\theta_H - \theta_L}$. For the case where $K \geq 1$, the equilibrium trading strategies and utilities of both the outsider and the insider in the trading stage are shown in Table 1. For the case where $K < 1$, the results are in Table 2.*

The coefficient K represents the important risk sharing benefits, measured by $A\sigma^2$, relative to the adverse selection risk, measured by the difference $\theta_H - \theta_L$. Tables 1 and 2 characterize the second best equilibrium and show how the outsider's order placement strategy including prices and volumes, as well as how both agents' utilities are affected by adverse selection.

In Table 1, we consider the case where $K \geq 1$, i.e., $A\sigma^2 \geq \theta_H - \theta_L$. In this case, the insider without the asset will choose to stay out of the market rather than mimic the one with the asset. The limit orders proposed by the outsider for the insider without the asset always specify 0 trading volume. Both the insider and the outsider get their outside option values.

The limit orders for the insider with the asset, however, depends on the outsider's belief $\frac{b_L^1}{b_H^1}$, i.e., the likelihood of meeting type θ_L asset relative to type θ_H asset. There is a trade-off between efficiency and informational rent. To ensure that the insider with low quality asset θ_L will not mimic the one with high quality asset θ_H, the insider with asset θ_L must obtain an informational rent, which is an increasing function of the trading volume of type θ_H (α_H^1). Thus, a decrease in α_H^1 will reduce the informational rent if the insider owns asset θ_L, but it will simultaneously reduce the efficiency gain of risk sharing if the insider owns asset θ_H. In this case, the trade-off between the informational cost and the risk-sharing efficiency depends on the outsider's belief $\frac{b_L^1}{b_H^1}$.

If the outsider believes that it is more likely to meet the insider with asset θ_L, she cares more about the informational cost than the efficiency gain, thus α_H^1 decreases with $\frac{b_L^1}{b_H^1}$. Actually, if $\frac{b_L^1}{b_H^1}$ is sufficiently large, i.e., $\frac{b_L^1}{b_H^1} \geq K$, the outsider will shut down the trading with the insider holding asset θ_H ($\alpha_H^1 = 0$). If the asset value $\tilde{\theta}$ turns out to be θ_L, the insider sells the total asset to the outsider at a price greater than his outside option value. The outsider gets a revenue equal to total efficiency gain of risk sharing $\frac{1}{2}A\sigma^2$ minus the informational rent paid to the insider $\alpha_H^1(\theta_H - \theta_L)$. If the asset value $\tilde{\theta}$ turns out to be θ_H, the insider sells part or none of the asset to the outsider at a price lower than his outside option value. The insider always gets his outside option value. The outsider obtains a revenue equal to partial efficiency gain from risk sharing $\frac{1}{2}A\sigma^2(1-(1-\alpha_H^1)^2)$, which is 0 when $\alpha_H^1 = 0$.

In Table 2, we consider the case where $K < 1$, i.e., $A\sigma^2 < \theta_H - \theta_L$. In this case, the insider without the asset may want to mimic the one with the asset. When $\frac{b_L^1}{b_H^1}$ is sufficiently low, i.e., $\frac{b_L^1}{b_H^1} < K(1-K)$, the informational rent to the insider holding the type θ_L asset is very large. In this case, the insider without the asset but observing the asset value θ_L wants to pretend to have the liquidity needs and trade with the outsider to get the informational rent but at a cost of bearing risk. In this case, on the one hand, the outsider should reduce the trading volume for the insider holding the type θ_H asset to reduce the informational rent. On the other hand, the outsider can increase the trading volume for the insider holding type θ_L asset beyond 1 to increase the cost of risk bearing for the insider without the asset. When the outsider believes that the probability to meet the insider without the asset but observing θ_L is sufficiently large, i.e., $\frac{b_L^0}{b_L^1} > \frac{1}{K + \frac{b_L^1}{b_H^1}\frac{1}{K}} - 1$, she wants to distort the trading volume α_L^1 and α_H^1 for the insider with the asset further to shut down the participation of the insider without the asset. For the case where $\frac{b_L^1}{b_H^1}$ is large, i.e., $\frac{b_L^1}{b_H^1} \geq K(1-K)$, we come back to the case where the insider without the asset always chooses to stay out of the market. We will get exactly the same results as in Table 1. The utilities of the insider and the outsider are also displayed in the table.

	$\tilde{e}=0,\tilde{\theta}=\theta_L$	$\tilde{e}=0,\tilde{\theta}=\theta_H$	$\tilde{e}=1,\tilde{\theta}=\theta_L$	$\tilde{e}=1,\tilde{\theta}=\theta_H$
Senario 1: $0 \leq \frac{b_L^1}{b_H^1} < K$				
Trading Volume	$\alpha_L^0 = 0$	$\alpha_H^0 = 0$	$\alpha_L^1 = 1$	$\alpha_H^1 = 1 - \frac{b_L^1}{b_H^1}\frac{1}{K}$
Trading Prices	$P_L^0 = N/A$	$P_H^0 = N/A$	$P_L^1 = \theta_L - \frac{1}{2}A\sigma^2 + \alpha_H^1(\theta_H - \theta_L)$	$P_H^1 = \theta_H - \frac{1}{2}A\sigma^2 - \frac{1}{2}A\sigma^2(1-\alpha_H^1)$
Insider's Utility	$U_L^0 = 0$	$U_H^0 = 0$	$U_L^1 = \theta_L - \frac{1}{2}A\sigma^2 + \alpha_H^1(\theta_H - \theta_L)$	$U_H^1 = \theta_H - \frac{1}{2}A\sigma^2$
Outsider's Utility	$V_L^0 = 0$	$V_H^0 = 0$	$V_L^1 = \frac{1}{2}A\sigma^2 - \alpha_H^1(\theta_H - \theta_L)$	$V_H^1 = \frac{1}{2}A\sigma^2(1-(1-\alpha_H^1)^2)$
Senario 2: $\frac{b_L^1}{b_H^1} \geq K$				
Trading Volume	$\alpha_L^0 = 0$	$\alpha_H^0 = 0$	$\alpha_L^1 = 1$	$\alpha_H^1 = 0$
Trading Prices	$P_L^0 = N/A$	$P_H^0 = N/A$	$P_L^1 = \theta_L - \frac{1}{2}A\sigma^2$	$P_H^1 = N/A$
Insider's Utility	$U_L^0 = 0$	$U_H^0 = 0$	$U_L^1 = \theta_L - \frac{1}{2}A\sigma^2$	$U_H^1 = \theta_H - \frac{1}{2}A\sigma^2$
Outsider's Utility	$V_L^0 = 0$	$V_H^0 = 0$	$V_L^1 = \frac{1}{2}A\sigma^2$	$V_H^1 = 0$

Table 1: Trading Prices, Volumes and Utilities when $K \geq 1$ ($A\sigma^2 \geq \theta_H - \theta_L$)

	$\tilde{e}=0,\tilde{\theta}=\theta_L$	$\tilde{e}=0,\tilde{\theta}=\theta_H$	$\tilde{e}=1,\tilde{\theta}=\theta_L$	$\tilde{e}=1,\tilde{\theta}=\theta_H$
Senario 1: $0 \le \frac{b_L^1}{b_H^1} < K(1-K)$ and $\frac{b_L^0}{b_L^1} \le \frac{1}{K+\frac{b_L^1}{b_H^1}\frac{1}{K}} - 1$				
Trading Volume	$\alpha_L^0 = \alpha_H^1 - K\alpha_L^1$	$\alpha_H^0 = 0$	$\alpha_L^1 = 1 + \frac{b_L^0}{b_L^1}$	$\alpha_H^1 = 1 - \frac{b_L^0 + b_L^1}{b_H^1}\frac{1}{K}$
Trading Prices	$P_L^0 = \theta_H + \frac{1}{2}A\sigma^2\alpha_L^0$	$P_H^0 = N/A$	$P_L^1 = \theta_L - \frac{1}{2}A\sigma^2 + [\frac{\alpha_H^1}{\alpha_L^1} + \frac{1}{2}K(\alpha_L^1 - 1)](\theta_H - \theta_L)$	$P_H^1 = \theta_H - \frac{1}{2}A\sigma^2 - \frac{1}{2}A\sigma^2(1-\alpha_H^1)$
Insider's Utility	$U_L^0 = \alpha_L^0(\theta_H - \theta_L)$	$U_H^0 = 0$	$U_L^1 = \theta_L - \frac{1}{2}A\sigma^2 + \alpha_H^1(\theta_H - \theta_L)$	$U_H^1 = \theta_H - \frac{1}{2}A\sigma^2$
Outsider's Utility	$V_L^0 = -\frac{1}{2}A\sigma^2(\alpha_L^0)^2 - \alpha_L^0(\theta_H - \theta_L)$	$V_H^0 = 0$	$V_L^1 = \frac{1}{2}A\sigma^2(1-(1-\alpha_L^1)^2) - \alpha_H^1(\theta_H - \theta_L)$	$V_H^1 = \frac{1}{2}A\sigma^2(1-(1-\alpha_H^1)^2)$
Senario 2: $0 \le \frac{b_L^1}{b_H^1} < K(1-K)$ and $\frac{b_L^0}{b_L^1} > \frac{1}{K+\frac{b_L^1}{b_H^1}\frac{1}{K}} - 1$				
Trading Volume	$\alpha_L^0 = 0$	$\alpha_H^0 = 0$	$\alpha_L^1 = \frac{K}{\frac{b_L^1}{b_H^1} + K^2}$	$\alpha_H^1 = \frac{K^2}{\frac{b_L^1}{b_H^1} + K^2}$
Trading Prices	$P_L^0 = N/A$	$P_H^0 = N/A$	$P_L^1 = \theta_L - \frac{1}{2}A\sigma^2 + [\frac{\alpha_H^1}{\alpha_L^1} + \frac{1}{2}K(\alpha_L^1 - 1)](\theta_H - \theta_L)$	$P_H^1 = \theta_H - \frac{1}{2}A\sigma^2 - \frac{1}{2}A\sigma^2(1-\alpha_H^1)$
Insider's Utility	$U_L^0 = 0$	$U_H^0 = 0$	$U_L^1 = \theta_L - \frac{1}{2}A\sigma^2 + \alpha_H^1(\theta_H - \theta_L)$	$U_H^1 = \theta_H - \frac{1}{2}A\sigma^2$
Outsider's Utility	$V_L^0 = 0$	$V_H^0 = 0$	$V_L^1 = \frac{1}{2}A\sigma^2(1-(1-\alpha_L^1)^2) - \alpha_H^1(\theta_H - \theta_L)$	$V_H^1 = \frac{1}{2}A\sigma^2(1-(1-\alpha_H^1)^2)$
Senario 3: $K(1-K) \le \frac{b_L^1}{b_H^1} < K$			Trading profiles are the same as Scenario 1 in Table 1	
Senario 4: $\frac{b_L^1}{b_H^1} \ge K$			Trading profiles are the same as Scenario 2 in Table 1	

Table 2: Trading Prices, Volumes and Utilities when $K < 1$ ($A\sigma^2 < \theta_H - \theta_L$)

In summary, in the case where $K \geq 1$, if the insider does not own the asset, the outsider will not trade with the insider and no risk sharing is needed; if the insider owns the asset, the outsider buys all the endowment and the allocation of risk is optimal when the asset is of low quality. However, when the asset is of high quality, the trading volume is lower than the optimal risk sharing level 1 to ensure incentive compatibility. In the case where $K < 1$, if the insider does not own the asset, overtrading might exist since the insider without the asset may mimic the one with the asset; if the insider owns the asset, undertrading always happens and risk sharing is lower than optimal level when the asset is of high quality. When the asset is of low quality, overtrading might happen, in which case the allocation of risk is not optimal either.

In addition, we can see that the outsider's beliefs concerning the types of insiders, especially $\frac{b_L^1}{b_H^1}$, have a crucial impact on the limit orders she proposes to the insider at the trading stage. In the following, we will study whether the insider can transmit his private information on liquidity needs and (or) asset values to the outsider at the preopening stage in order to influence her belief, and thereby influence her order placement strategy at the trading stage.

3.2 Preopening Period

For the analysis of the preopening stage, the strategy profiles at the trading stage are omitted since it corresponds to the equilibrium situation. The four pure strategy profiles that are candidates for equilibrium at the preopening stage are listed below.

i) No preannouncement: the insider's non-binding limit order (q, l) does not depend on $\tilde{e}$ nor on $\tilde{s}$; the outsider's entry decision d and her trading profiles do not depend on (q, l) and are only based on her prior beliefs over both $\tilde{e}$ and $\tilde{\theta}$. This case is similar to the situation without preopening period.

ii) Preannouncement of liquidity needs: the insider submits a non-binding limit order (q, l) for a quantity q that depends on $\tilde{e}$: for example, he sets $q(\tilde{e}) = \tilde{e}$. The limit price l does not depend on $\tilde{s}$. The outsider updates her belief over $\tilde{e}$ according to q and keeps her prior belief over $\tilde{\theta}$. Based on this new belief, the outsider determines her entry decision d and subsequent trading strategies.

iii) Preannouncement of private signal: the insider submits a non-binding limit order (q, l) with a limit price l that depends on $\tilde{s}$: for example, he sets $l(\tilde{s}) = \tilde{s}$. The quantity q does not depend on $\tilde{e}$. The outsider keeps her belief over $\tilde{e}$ and updates her belief over $\tilde{\theta}$ according to l. Based on this new belief, the outsider determines her entry decision d and subsequent trading strategies.

iv) Preannouncement of both liquidity needs and private signal: the insider submits a non-binding limit order (q, l) which is a function of $\tilde{e}$ and $\tilde{s}$. For example, he sets $q(\tilde{e}) = \tilde{e}$ and $l(\tilde{s}) = \tilde{s}$. The outsider updates her beliefs over $\tilde{e}$ and $\tilde{\theta}$ according to q and l. Based on this new belief, the outsider determines her entry decision d and subsequent trading strategies.

To complete the characterization of the perfect Bayesian equilibrium, we specify the following out-of-equilibrium beliefs: if the outsider observes an action that is not part of the equilibrium path, she will not enter the market. Denote $V(\cdot, \cdot)$ as the expected payoff of the outsider at the preopening stage given no entry cost, where the first variable of V represents her belief concerning $\tilde{e} = 1$, and the second variable represents her belief concerning $\tilde{\theta} = \theta_L$.

Proposition 1. *No preannouncement is an equilibrium.*

In the case without preannouncement, the outsider chooses her optimal entry decisions and subsequent trading strategies based her prior belief over $\tilde{e}$ and $\tilde{\theta}$. Given the strategy of the outsider, the insider has no incentive to deviate from his no preannouncement strategy. Thus, no preannouncement is an equilibrium.

Proposition 2. *Preannouncement of liquidity needs is an equilibrium.*

In the case of preannouncing liquidity needs, the insider signals his liquidity trading motive by revealing his endowment shock to the outsider. The outsider updates her belief concerning $\tilde{e}$, while keeps her prior belief over $\tilde{\theta}$. Given the outsider's prior belief over $\tilde{\theta}$, i.e, $\frac{b_L^1}{b_1^2} = 1$, the equilibrium profiles proposed by the outsider in the trading stage given she enters is either as scenario 1 in Table 1 if $K \geq 1$ or scenario 4 in Table 2 if $K < 1$. In both cases, the insider without the asset ($\tilde{e} = 0$) will always get 0 regardless of his report. However, the insider with the asset ($\tilde{e} = 1$) can benefit from truthfully revealing his liquidity trade motive. This is because, if the insider truthfully reveals his liquidity trading motive, the outsider is able to make her entry decision contingent on this information, which saves her entry cost and leads to more entry into the trading stage. In this case, the insider with the asset is more likely to obtain the informational rent. Therefore, the insider has no incentive to lie about his liquidity shock, and preannouncement of liquidity needs is always an equilibrium.

Proposition 3. *Preannouncement of private signals is an equilibrium under any of the following three scenarios: i) if $K \leq \frac{1-p}{p}$; ii) if $\frac{1-p}{p} < K \leq \frac{p}{1-p}$ and $V(\lambda, 1-p) < c$; or iii) if $K > \frac{p}{1-p}$ and* $\max\{V(\lambda, 1-p), V(\lambda, p)\} < c$.

In the trading stage the insider holding the low quality asset θ_L rather than the high quality asset θ_H is likely to obtain positive rents, and the magnitude of the rent decreases with the outsider's belief $\frac{b_L^1}{b_H^1}$, therefore at the preopening stage the insider has an incentive to pretend to receive signal θ_H to reduce the outsider's belief $\frac{b_L^1}{b_H^1}$ and increase his future informational rent. In this case, we need to find conditions to make sure under which the insider receiving signal θ_L has no incentive to mimic signal θ_H.

Proposition 3 implies that preannouncing private signals can be an equilibrium, but its feasibility depends on the magnitude of K. First, in the case where K is sufficiently small, i.e., $K \leq \frac{1-p}{p}$, regardless of the insider's report of the signal, the likelihood $\frac{b_L^1}{b_H^1}$ is always larger than the threshold. Thus, the trading profiles at the trading stage are as Scenario 2 in Table 1 or Scenario 4 in Table 2. The insider will obtain no rent whatever the asset value. In this case, the insider has no incentive to lie about his private signal on asset value. Second, in the case where K is in the intermediate range, i.e., $\frac{1-p}{p} < K \leq \frac{p}{1-p}$, the insider observing signal θ_L has incentive to pretend to observe signal θ_H, since by doing this he can get more informational rent at the trading stage. The outsider will punish the lying behavior of the insider through staying out of the market if the signal report is θ_H. This punishment is credible when $c > V(\lambda, 1-p)$. Third, in the case where K is sufficiently large, i.e., $K > \frac{p}{1-p}$, and $\max\{V(\lambda, 1-p), V(\lambda, p)\} < c$, the outsider would never enter into the trading stage regardless of the insider communicates his signal, and the insider has no incentive to lie about his private signals. In this equilibrium, no real trading occurs since the entry cost is so high that the outsider always chooses to stay out of the market regardless of the insider's signal.

Proposition 4. *Preannouncement of both liquidity needs and private signals is an equilibrium under any of the following three scenarios: i) if* $K \leq \frac{1-p}{p}$*; ii) if* $\frac{1-p}{p} < K \leq \frac{p}{1-p}$ *and* $V(1, 1-p) < c$*; or iii) if* $K > \frac{p}{1-p}$ *and* $\max\{V(1, 1-p), V(1, p)\} < c$*.*

In the case of preannouncing both liquidity needs and private signals, we find almost exactly the same result as Proposition 3 except that the expected utility of the outsider is $V(1, \cdot)$ rather than $V(\lambda, \cdot)$ since the outsider knows precisely the endowment shock given the report on liquidity shocks from the insider.

In our framework, the outsider must pay a cost c to enter into the trading stage. Our first impression would be the introduction of the entry cost is a bad thing for trading. However, in the following, we find that the introduction of the entry cost sometimes is a good thing for information transmission at the preopening stage. By comparing Propositions 3 and 4 in the case without the entry cost, we obtain an interesting result as follows.

Corollary 1. *With an entry cost* c*, the contingent entry decision made by the outsider based on the information at the preopening stage can work as a mechanism to punish the lying behavior of the insider and make the information transmission on private signals to be feasible in a wider parameter range. In order to make the punishment credible, the entry cost must be sufficiently high.*[2]

[2] In the equilibrium with preannouncement of private signals, if $\frac{1-p}{p} < K \leq \frac{p}{1-p}$, $c > V(\lambda, 1-p)$, and if $K > \frac{p}{1-p}$, $c > \max\{V(\lambda, 1-p), V(\lambda, p)\}$. In the equilibrium with preannouncement of both liquidity needs and private signals, if $\frac{1-p}{p} < K \leq \frac{p}{1-p}$, $c > V(1, 1-p)$ and if $K > \frac{p}{1-p}$, $c > \max\{V(1, 1-p), V(1, p)\}$.

Without an entry cost, the outsider always enters into the trading stage regardless of the insider's report. In this case, preannouncing private signals is an equilibrium only when K is sufficiently small, i.e., $K < \frac{1-p}{p}$. However, with an entry cost, the outsider not only designs her trading profiles but also makes her entry decision contingent on the information she receives from the insider at the preopening stage. This contingent entry decision can work as a mechanism to punish the lying behavior of the insider. For example, when K is in the intermediate range, the insider observing signal θ_L has an incentive to mimic θ_H, while the no entry decision of the outsider contingent on a signal θ_H works as a punishment mechanism to ensure that the insider has no incentive to lie. In this case, the entry cost makes the transmission on private signals to be feasible in a wider parameter range. But, the existence of the entry cost does not guarantee the credibility of the punishment. If the entry cost is lower than the expected utility in the trading stage, the outsider cannot promise to stay out of the market even if she receives a signal report θ_H. Thus, to make the punishment promise credible, the entry cost must be sufficiently high.

Corollary 1 also implies that social welfare can sometimes increase with the entry cost. When the entry cost is just below the threshold, preannouncing private signals is not incredible, but if the entry cost increases a little bit to ensure it is above the threshold, preannouncing private signals becomes credible. In this case, the benefit arising from credible communication on asset values can be greater than the very small increase in the entry cost.

3.3 Information Transmission, Liquidity Formation and Social Welfare

In the case without preopening stage (without preannouncement of information), the outsider decides to enter into the market if $c \leq V(\lambda, \frac{1}{2})$, otherwise, she chooses to stay out of the market. The following proposition states, compared with the market without the preopening stage, how the information transmission on liquidity needs at the preopening stage affects liquidity formation.

Proposition 5. *With the information transmission on liquidity needs ($\tilde{e}$) at the preopening stage, the outsider provides liquidity if and only if the endowment shock is preannounced, i.e., $\tilde{e} = 1$, allowing a better coordination of the demand and the supply of liquidity. This information communication is also able to avoid market breakdown when $c \in (V(\lambda, \frac{1}{2}), V(1, \frac{1}{2})]$.*

By communicating endowment shocks at the preopening stage, the outsider provides liquidity only when the liquidity need is preannounced by the insider. On the one hand, it saves the outsider's participation cost and allows a better coordination of the demand and the supply of liquidity, and on the other hand, it leads to more entry when the cost is relatively high, which avoids the market breakdown phenomenon observed in the case without preopening stage. Thus, the information transmission on liquidity needs at preopening stage always improves liquidity formation. It also yields the following result on social welfare.

Proposition 6. *Compared with no preannouncement, the information transmission on liquidity needs at the preopening stage improves social welfare.*

In the following, we discuss the impact of the information communication on the private signals of asset values ($\tilde{s}$) at the preopening stage on liquidity formation. From now on, we mainly focus on the case where $V(1, 1-p) < V(1, p)$ and $V(\lambda, 1-p) < V(\lambda, p)$, which ensures that real trading also happens in the equilibrium with preannouncement of private signals when K is in intermediate range.

Proposition 7. *Compared with the case of no preannouncement, preannouncing private signals ($\tilde{s}$) at the preopening stage improves liquidity provision, except on the occasion where $V(\lambda, 1-p) < V(\lambda, \frac{1}{2}) < V(\lambda, p)$, in which case the outsider will provide less liquidity when $c \in (V(\lambda, 1-p), V(\lambda, \frac{1}{2})]$.*

The above proposition tells us that most of the time, the preannouncement of private signals can help avoid market breakdown phenomena that would occur in the absence of a preopening period. Also, this proposition shows that preannouncing private signals can increase liquidity provision. Such an increase is however not guaranteed because the outsider's entry decision is less in phase with liquidity needs. In the case where $V(\lambda, 1-p) < V(\lambda, \frac{1}{2}) < V(\lambda, p)$, without preopening stage, the outsider always enters into the trading game as long as $c \in [0, V(\lambda, \frac{1}{2})]$. With preannouncing private signals, the outsider only enters if the signal report is θ_L and stays out of the market if the signal report is θ_H when $c \in (V(\lambda, 1-p), V(\lambda, p)]$ to reduce the adverse selection risk she faces. Thus, the outsider will provide less liquidity when $c \in (V(\lambda, 1-p), V(\lambda, \frac{1}{2})]$.

In addition to the effect of preannouncing private signals on liquidity formation, we also interested in its impact on social welfare.

Proposition 8. *In terms of social welfare, information transmission on asset values at preopening stage dominates no preannouncement except on the case where* $V(\lambda, 1-p) < V(\lambda, \frac{1}{2}) < V(\lambda, p)$, $1 < K \leq \frac{p}{1-p}$ *and* $c \in (V(\lambda, 1-p), V(\lambda, \frac{1}{2})]$.

Preannouncing private signals dominate no preannouncement in terms of social welfare because information transmission on asset values can save the entry cost and reduce the adverse selection risk of the outsider investor. She is able to make better entry and trading decisions. However, in the case where case where $V(\lambda, 1-p) < V(\lambda, \frac{1}{2}) < V(\lambda, p)$, $1 < K \leq \frac{p}{1-p}$ and $c \in (V(\lambda, 1-p), V(\lambda, \frac{1}{2})]$, with preannouncing private signals, though the outsider still benefits from a reduction in the entry cost and the adverse selection risk, the insider will lose informational rent. Whether preannouncing private signals improves social welfare or not depending on the magnitude of the benefit relative to the cost.

3.4 Selection of Equilibrium

Now, we consider the selection of equilibrium. Since the insider is active at the preopening stage, we assume that he decides which equilibrium to play based on the following rule: at the preopening stage, the insider selects the equilibrium that maximizes his expected utility subject to the participation constraint of the outsider, and in the case where he obtains exactly the same maximum utility at different equilibria, he chooses the one which maximizes the expected payoff of the outsider.

Lemma 2. *The outsider benefits from entry decisions and trading profiles being contingent on the preannouncement of liquidity needs and/or private signals.*

Lemma 2 tells us that the more information is being preannounced, the better is the outsider. In other words, the outsider will be better off from making entry decisions and proposing trading profiles based on more accurate information communicated at the preopening stage. Based on this lemma, we can obtain the following proposition.

Proposition 9. *At the preopening stage,*

- *If $K \leq \frac{1-p}{p}$, the insider chooses to preannounce both liquidity needs and private signals.*
- *If $\frac{1-p}{p} < K \leq \frac{p}{1-p}$, there exists c_1 and c_2, where $0 < c_1 \leq c_2$. The insider chooses to preannounce liquidity needs when $c \in [0, c_1]$, preannounce private signals when $c \in (c_1, c_2]$, and preannounce both liquidity needs and private signals when $c \in (c_2, +\infty)$.*[3]
- *If $K > \frac{p}{1-p}$, the insider chooses to preannounce liquidity needs.*

The result of Proposition 9 is depicted in Figure 2: the insider chooses the equilibrium with preannouncement of liquidity needs when K is large, while the equilibrium with preannouncement of both liquidity needs and private signals when K is small. With intermediate K, as the entry cost increases, the insider switches from preannouncing liquidity needs, to preannouncing private signals, and then to preannouncing both liquidity needs and private signals.

[3] Please see in Appendix how the exact values of c_1 and c_2 are determined.

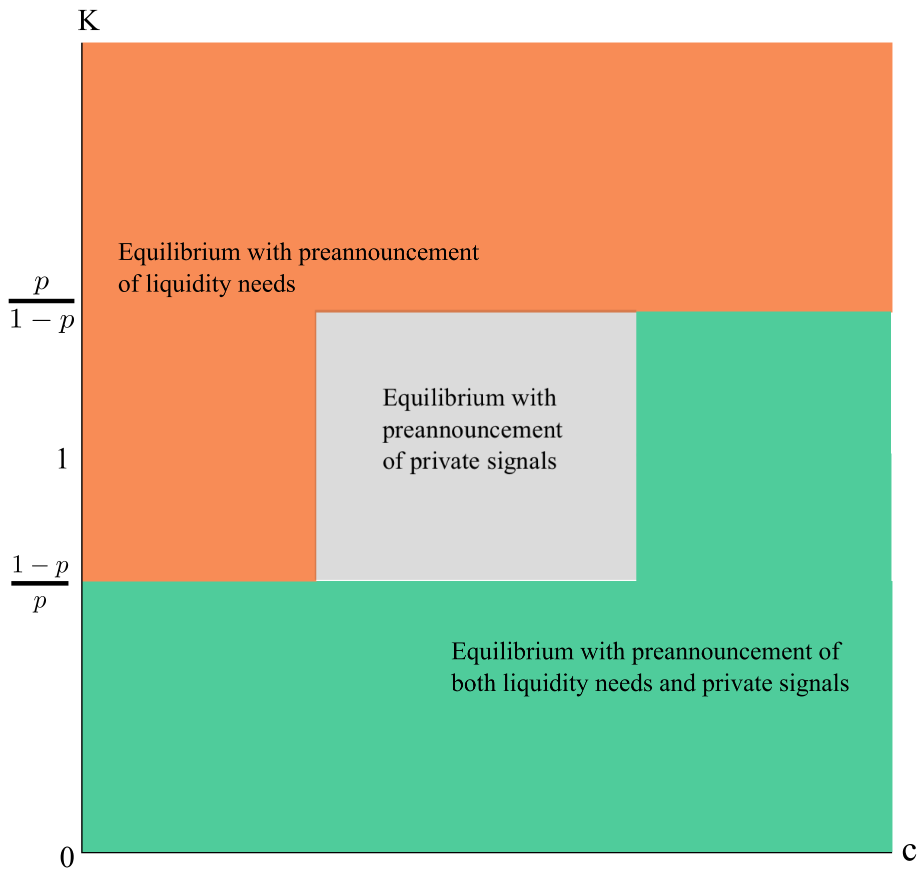

Figure 2: The yellow area represents the equilibrium with preannouncement of liquidity needs, the grey area represents the equilibrium with preannouncement of private signals and the green area represents the equilibrium with preannouncement of both liquidity needs and private signals.

In the case where $K \leq \frac{1-p}{p}$, the equilibrium trading profiles always correspond to Scenario 1 in Table 1 and Scenario 4 in Table 2, thus the insider obtains no informational rent no matter what information is communicated at the preopening stage. But the communication on both liquidity needs and private signals at the preopening stage benefits the outsider and is always feasible according to Proposition 3 and 4 when $K \leq \frac{1-p}{p}$. Therefore, the insider chooses to preannounce both liquidity needs and private signals.

In the case where $\frac{1-p}{p} < K \leq \frac{p}{1-p}$, preannouncing liquidity needs is always an equilibrium regardless of the level of the entry cost, but preannouncing private signals is an equilibrium only when the entry cost is sufficiently high, in which case the outsider can punish the insider who observes θ_L but mimics θ_H by staying out of the market when she receives signal report θ_H. The insider first chooses to preannounce liquidity needs to maximize his informational rent when the entry cost is relatively low. When the cost is relatively high, the market will be shut down if only communicating liquidity needs at the preopening stage. In this case, the insider chooses to first preannounce private signals and then preannounce both information to maximize the profit of the outsider.

From Proposition 3 and 4, in the case where $K > \frac{p}{1-p}$, communication on private signals is not feasible at the preopening stage except for the case where this communication leads to complete shut down of trading. Thus, the insider only chooses to preannounce liquidity needs to coordinate liquidity shocks.

In summary, the economic intuition is that if K is large, i.e., the gains from trade $A\sigma^2$ is large or the adverse risk faced by the outsider is not a main concern with a small $\theta_H - \theta_L$, the insider and the outsider only communicate the liquidity needs. However, if K is small, i.e., the gains from trade $A\sigma^2$ is small and the adverse risk becomes a main issue with a large $\theta_H - \theta_L$, the insider prefers to communicate not only liquidity needs but also private signals. With intermediate K, the equilibrium depends on the magnitude of the entry cost. With a larger c, the outsider is more able to use the contingent entry decision to punish the lying behavior of the insider by staying out of the market. In this case, preannouncing private signals become a more feasible tool at the preopening stage.

4 Conclusion

This paper studies the role of preopening periods in financial markets. We propose a theoretical model where a preopening period is instrumental in the liquidity formation process. In our setting, liquidity is latent because of the cost of market participation and because of information asymmetries. At equilibrium, risk averse insiders use the preopening period to communicate liquidity needs and/or their private information concerning asset valuation. This communication mitigates the influence of market imperfections. Welfare can be enhanced thanks to the savings on the cost of market participation, and thanks to a reduction in the adverse selection risk borne by liquidity providers. In addition, the introduction of a preopening period is expected to reduce the likelihood of market breakdowns.

This paper has implications for portfolio management. It suggests that preopening periods can be used to attract latent liquidity. As a result, the actual market liquidity can be higher than what is indicated by the average state of the order book. Indeed trading sessions where preannouncement has been made during the preopening period display a high liquidity. On the contrary, trading sessions where no preannouncement has occurred display a low liquidity. Overall, the time series averages of liquidity measures do not reflect the latent liquidity and thus underestimate the quality of the market. Portfolio managers can thus benefit from realizing that liquidity is endogenous and responds positively to the implementation of trading strategies based on preannouncements. This is in line with empirical findings of Dia and Pouget (2011).

This paper has also implications for the design of financial markets. It shows that introducing a preopening period may trigger welfare improvements. Market organizers may thus have an interest in providing traders with pre-trade communication platforms such as preopening periods as a way to disseminate information regarding both liquidity needs and asset valuation.

In our analysis, trading is modeled as a principal-agent game where the uninformed trader (the principal) submits limit orders that can be executed by the informed trader (the agent). This raises two questions. What would happen if the informed trader was submitting limit orders, and what would be the impact of competition? The case where the informed trader submits limit orders corresponds to a signaling game. In the signaling game, at the trading stage, the uninformed trader has no bargaining power and obtains nothing. Thus, she would choose to stay out of the market. Our analysis shows that, to incentivize an uninformed trader to provide liquidity to the informed trader, she must have some bargaining power during the trading process to secure a positive payoff to cover the entry cost. One possible solution is that, in a dynamic signaling game, the uninformed trader could credibly threaten to not participate in the future trading games if she gets no rent at the current trading stage. The analysis of such a dynamic game is left for future research.

Competition between traders would not alter our results but would open the scope for interesting analysis. On the one hand, increasing the number of insiders would increase the likelihood of endowment shocks and would thus enhance the amount and frequency of liquidity needs. This would reduce but not eliminate the usefulness of the preopening period. In addition, there would be a coordination problem among insiders regarding who should make the preannouncements (and thus partly loose informational advantages). Since the most risk-averse insiders highly value liquidity, one could argue that they would be the promptest to make a preannouncement. On the other hand, introducing competition on the liquidity provision side would create another coordination problem at the entry decision stage because of the cost of market participation. Entry coordination could be achieved through preannouncements made during the preopening period. We conjecture that those liquidity providers with the lowest cost of participation would be the most likely to enter the market. These avenues of research are left for future inquiry.

A Proof of Lemma 1

Because the utility function of the insider is a CARA utility function and the distribution of $\tilde{v}$ conditional on $\tilde{\theta} = \theta_i$ is a normal random variable with mean θ_i and variance σ^2, the incentive compatibility constraints ensuring that the insider observing $\tilde{\theta} = \theta_L$ has no incentive to lie about his endowment shock are as follows.

$$\alpha_L^0 P_L^0 - \alpha_L^0 \theta_L - \frac{1}{2} A\sigma^2 (-\alpha_L^0)^2 \geq \alpha_L^1 P_L^1 - \alpha_L^1 \theta_L - \frac{1}{2} A\sigma^2 (-\alpha_L^1)^2, \tag{2}$$

and

$$\alpha_L^1 P_L^1 + (1-\alpha_L^1)\theta_L - \frac{1}{2} A\sigma^2 (1-\alpha_L^1)^2 \geq \alpha_L^0 P_L^0 + (1-\alpha_L^0)\theta_L - \frac{1}{2} A\sigma^2 (1-\alpha_L^0)^2, \tag{3}$$

where condition (2) implies that given observing $\tilde{\theta} = \theta_L$, the insider without the asset does not want to mimic the one with the asset, and condition (3) indicates that the insider has the asset does not want to pretend that he does not.

Similarly, we obtain the incentive compatibility constraints which guarantee that the insider observing $\tilde{\theta} = \theta_H$ has no incentive to lie about his endowment shock:

$$\alpha_H^0 P_H^0 - \alpha_H^0 \theta_H - \frac{1}{2} A\sigma^2 (-\alpha_H^0)^2 \geq \alpha_H^1 P_H^1 - \alpha_H^1 \theta_H - \frac{1}{2} A\sigma^2 (-\alpha_H^1)^2, \tag{4}$$

and

$$\alpha_H^1 P_H^1 + (1-\alpha_H^1)\theta_H - \frac{1}{2} A\sigma^2 (1-\alpha_H^1)^2 \geq \alpha_H^0 P_H^0 + (1-\alpha_H^0)\theta_H - \frac{1}{2} A\sigma^2 (1-\alpha_H^0)^2. \tag{5}$$

In addition, we also need to make sure that the insider does not want to lie about his private information of asset value. The incentive compatibility constraints ensuring that the insider without the asset does not lie about his observation of $\tilde{\theta}$ are

$$\alpha_L^0 P_L^0 - \alpha_L^0 \theta_L - \frac{1}{2} A\sigma^2 (-\alpha_L^0)^2 \geq \alpha_H^0 P_H^0 - \alpha_H^0 \theta_L - \frac{1}{2} A\sigma^2 (-\alpha_H^0)^2, \tag{6}$$

and

$$\alpha_H^0 P_H^0 - \alpha_H^0 \theta_H - \frac{1}{2} A\sigma^2 (-\alpha_H^0)^2 \geq \alpha_L^0 P_L^0 - \alpha_L^0 \theta_H - \frac{1}{2} A\sigma^2 (-\alpha_L^0)^2, \tag{7}$$

where condition (6) guarantees that given no endowment shock, the insider observing θ_L does not want to mimic θ_H, and condition (7) ensures that the insider observing θ_H does not pretend to observe θ_L.

Similarly, the incentive constraints where the insider with the asset does not lie about his observation on $\tilde{\theta}$ are

$$\alpha_L^1 P_L^1 + (1-\alpha_L^1)\theta_L - \frac{1}{2} A\sigma^2 (1-\alpha_L^1)^2 \geq \alpha_H^1 P_H^1 + (1-\alpha_H^1)\theta_L - \frac{1}{2} A\sigma^2 (1-\alpha_H^1)^2, \tag{8}$$

and

$$\alpha_H^1 P_H^1 + (1-\alpha_H^1)\theta_H - \frac{1}{2} A\sigma^2 (1-\alpha_H^1)^2 \geq \alpha_L^1 P_L^1 + (1-\alpha_L^1)\theta_H - \frac{1}{2} A\sigma^2 (1-\alpha_L^1)^2. \tag{9}$$

In addition to the incentive compatibility constraints, we also need to consider participation constraints of the insider with four different types.

$$\alpha_L^0 P_L^0 - \alpha_L^0 \theta_L - \frac{1}{2} A\sigma^2 (-\alpha_L^0)^2 \geq 0, \tag{10}$$

$$\alpha_H^0 P_H^0 - \alpha_H^0 \theta_H - \frac{1}{2} A\sigma^2 (-\alpha_H^0)^2 \geq 0, \tag{11}$$

$$\alpha_L^1 P_L^1 + (1-\alpha_L^1)\theta_L - \frac{1}{2} A\sigma^2 (1-\alpha_L^1)^2 \geq \theta_L - \frac{1}{2} A\sigma^2, \tag{12}$$

and

$$\alpha_H^1 P_H^1 + (1-\alpha_H^1)\theta_H - \frac{1}{2} A\sigma^2 (1-\alpha_H^1)^2 \geq \theta_H - \frac{1}{2} A\sigma^2. \tag{13}$$

Conditions (10), (11), (12), and (13) ensure that the insider will at least get his outside option value.

The outsider proposes a menu of limit orders to maximize his own profit subject to all the incentive and participation constraints. Thus the program of the outsider is

$$\begin{aligned}
\max_{\alpha_i^j, P_i^j} \quad & b_L^0 \alpha_L^0 (\theta_L - P_L^0) + b_H^0 \alpha_H^0 (\theta_H - P_H^0) + b_L^1 \alpha_L^1 (\theta_L - P_L^1) + b_H^1 \alpha_H^1 (\theta_H - P_H^1) \\
s.t. \quad & Conditions(2) - (13).
\end{aligned} \tag{14}$$

Denote

$$\begin{aligned}
U_L^0 &= \alpha_L^0 P_L^0 - \alpha_L^0 \theta_L - \frac{1}{2} A\sigma^2 (-\alpha_L^0)^2 \\
U_H^0 &= \alpha_H^0 P_H^0 - \alpha_H^0 \theta_H - \frac{1}{2} A\sigma^2 (-\alpha_H^0)^2 \\
U_L^1 &= \alpha_L^1 P_L^1 + (1 - \alpha_L^1)\theta_L - \frac{1}{2} A\sigma^2 (1 - \alpha_L^1)^2 \\
U_H^1 &= \alpha_H^1 P_H^1 + (1 - \alpha_H^1)\theta_H - \frac{1}{2} A\sigma^2 (1 - \alpha_H^1)^2,
\end{aligned} \tag{15}$$

Thus, Program (14) can be rewritten as

$$\begin{aligned}
\max_{(\alpha_i^j, U_i^j)_{i=0,1; j=1,2}} \quad & b_L^1 \theta_L + b_H^1 \theta_H - \frac{1}{2} A\sigma^2 \left[b_L^0 (\alpha_L^0)^2 + b_H^0 (\alpha_H^0)^2 + b_L^1 (1 - \alpha_L^1)^2 + b_H^1 (1 - \alpha_H^1)^2 \right] \\
& - \left[b_L^0 U_L^0 + b_H^0 U_H^0 + b_L^1 U_L^1 + b_H^1 U_H^1 \right] \\
& U_L^0 \geq U_L^1 - \theta_L + \frac{1}{2} A\sigma^2 (1 - 2\alpha_L^1) \quad (IC_1) \\
& U_L^1 \geq U_L^0 + \theta_L - \frac{1}{2} A\sigma^2 (1 - 2\alpha_L^0) \quad (IC_2) \\
& U_H^0 \geq U_H^1 - \theta_H + \frac{1}{2} A\sigma^2 (1 - 2\alpha_H^1) \quad (IC_3) \\
& U_H^1 \geq U_H^0 + \theta_H - \frac{1}{2} A\sigma^2 (1 - 2\alpha_H^0) \quad (IC_4) \\
& U_L^0 \geq U_H^0 + \alpha_H^0 (\theta_H - \theta_L) \quad (IC_5) \\
& U_H^0 \geq U_L^0 - \alpha_L^0 (\theta_H - \theta_L) \quad (IC_6) \\
& U_L^1 \geq U_H^1 - (1 - \alpha_H^1)(\theta_H - \theta_L) \quad (IC_7) \\
& U_H^1 \geq U_L^1 + (1 - \alpha_L^1)(\theta_H - \theta_L) \quad (IC_8) \\
& U_L^0 \geq 0 (PC_1), U_H^0 \geq 0 (PC_2), U_L^1 \geq \theta_L - \frac{1}{2} A\sigma^2 (PC_3), U_H^1 \geq \theta_H - \frac{1}{2} A\sigma^2 (PC_4).
\end{aligned} \tag{16}$$

First, we obtain the first-best case by maximizing the program subject to only participation constraints. It yields that $U_L^0 = U_H^0 = 0$, $U_L^1 = \theta_L - \frac{1}{2}A\sigma^2$, $U_H^1 = \theta_H - \frac{1}{2}A\sigma^2$, $\alpha_L^0 = \alpha_H^0 = 0$ and $\alpha_L^1 = \alpha_H^1 = 1$. Check whether the first-best solutions satisfy the IC constraints. By plugging the solutions into the constraints, we find that IC_7 constraint does not hold. In other words, given the first best results, the insider holding low quality asset θ_L would like to pretend to hold high quality asset θ_H.

In this case, we guess that IC_7 should be binding, i.e., $U_L^1 = U_H^1 - (1-\alpha_H^1)(\theta_H - \theta_L)$. Given IC_7 is binding, PC_3 cannot be binding. In this case, we maximize the expected utility of the outsider subject to IC_7, PC_1, PC_2 and PC_4, while ignoring other IC and PC constraints (we will check whether other constraints hold afterwards).

The solutions are: $U_L^0 = U_H^0 = 0$, $U_L^1 = \theta_L - \frac{1}{2}A\sigma^2 + \alpha_H^1(\theta_H - \theta_L)$, $U_H^1 = \theta_H - \frac{1}{2}A\sigma^2$, $\alpha_L^0 = \alpha_H^0 = 0$, $\alpha_L^1 = 1$ and $\alpha_H^1 = 1 - \frac{b_L^1}{b_H^1}\frac{\theta_H - \theta_L}{A\sigma^2}$. Given the solutions, we find all PCs and ICs are satisfied if $0 \leq \alpha_H^1 \leq \frac{A\sigma^2}{\theta_H - \theta_L}$. In other words, the solutions satisfy all the constraints if $K(1-K) \leq \frac{b_L^1}{b_H^1} \leq K$. We consider two different cases where $K < 1$ and $K \geq 1$.

<u>CASE: $K < 1$</u>

In this case, $K(1-K) > 0$.

Thus, if $K(1-K) \leq \frac{b_L^1}{b_H^1} \leq K$, we obtain that $U_L^0 = U_H^0 = 0$, $U_L^1 = \theta_L - \frac{1}{2}A\sigma^2 + \alpha_H^1(\theta_H - \theta_L)$, $U_H^1 = \theta_H - \frac{1}{2}A\sigma^2$, $\alpha_L^0 = \alpha_H^0 = 0$, $\alpha_L^1 = 1$ and $\alpha_H^1 = 1 - \frac{b_L^1}{b_H^1}\frac{1}{K}$. In other words, we obtain Scenario 3 in Table 2.

However, if $\frac{b_L^1}{b_H^1} > K$, IC_2, IC_3 and PC_3 are not satisfied, and if $0 \leq \frac{b_L^1}{b_H^1} < K(1-K)$, IC_1 is not satisfied.

In the case where $\frac{b_L^1}{b_H^1} > K$, the outsider believes that the probability to meet an insider who holds low quality asset is sufficiently high. In this case, we guess that she would like to shut down the trading with the insider holding high quality asset to reduce the informational rent to the insider who holds the low quality asset. Thus, we guess IC_7, PC_1, PC_2, PC_3 and PC_4 should be binding. By solving the program, we obtain that $U_L^0 = U_H^0 = 0$, $U_L^1 = \theta_L - \frac{1}{2}A\sigma^2$, $U_H^1 = \theta_H - \frac{1}{2}A\sigma^2$, $\alpha_L^0 = \alpha_H^0 = 0$, $\alpha_L^1 = 1$ and $\alpha_H^1 = 0$.

Given the results, all constraints are satisfied. Thus, we obtain Scenario 4 in Table 2.

In the case where $0 \leq \frac{b_L^1}{b_H^1} < K(1-K)$, the outsider investor believes that the probability to meet an insider who holds low quality is very low, so the informational rent gained by the low quality asset is very high. In this case, the outsider who observes θ_L but without any endowment would like to mimic the one who holds the asset. Thus, we guess that both IC_7 and IC_1 should be binding. Given IC_1 binding, PC_1 cannot be binding. Thus, we maximize the program subject to IC_1, IC_7, PC_2 and PC_4.

The solutions are $U_L^0 = \alpha_H^1(\theta_H - \theta_L) - A\sigma^2\alpha_L^1$, $U_H^0 = 0$, $U_L^1 = \theta_L - \frac{1}{2}A\sigma^2 + \alpha_H^1(\theta_H - \theta_L)$, $U_H^1 = \theta_H - \frac{1}{2}A\sigma^2$, $\alpha_L^0 = 0$, $\alpha_H^0 = 0$, $\alpha_L^1 = 1 + \frac{b_L^0}{b_L^1}$ and $\alpha_H^1 = 1 - \frac{b_L^0 + b_L^1}{b_H^1}\frac{1}{K}$. We find that IC_6 does not hold given the solutions. Thus, we further guess IC_7, IC_1 and IC_6 are binding. By using the same procedure by ignoring other constraints to solve the program, we find that the solutions PC_2 is not satisfied.

In this case, we guess IC_7, IC_1, IC_6, PC_2 and PC_4 are binding. In this case, we maximize the utility of the outsider subject to constraints IC_7, IC_1, IC_6, PC_2 and PC_4. The solutions are $U_L^0 = \alpha_H^1(\theta_H - \theta_L) - A\sigma^2\alpha_L^1$, $U_H^0 = 0$, $U_L^1 = \theta_L - \frac{1}{2}A\sigma^2 + \alpha_H^1(\theta_H - \theta_L)$, $U_H^1 = \theta_H - \frac{1}{2}A\sigma^2$, $\alpha_L^0 = \alpha_H^1 - K\alpha_L^1$, $\alpha_H^0 = 0$, $\alpha_L^1 = 1 + \frac{b_L^0}{b_L^1}$ and $\alpha_H^1 = 1 - \frac{b_L^0 + b_L^1}{b_H^1}\frac{1}{K}$. Given the solutions, ICs and PCs are satisfied if $\frac{b_L^0}{b_L^1} \leq \frac{1}{K + \frac{b_L^1}{b_H^1}\frac{1}{K}} - 1$. Thus, we obtain Scenario 1 in Table 2.

Now we turn to the situation where $\frac{b_0^1}{b_L^1} > \frac{1}{K + \frac{b_L^1}{b_H^1}\frac{1}{K}} - 1$. PC_1 and IC_5 do not hold. Thus, we guess IC_7, IC_1, IC_6, PC_1, PC_2 and PC_4 are binding. we maximize the utility of the outsider subject to constraints IC_7, IC_1, IC_6, PC_1, PC_2 and PC_4.

The solutions are $U_L^0 = U_H^0 = 0$, $U_L^1 = \theta_L - \frac{1}{2}A\sigma^2 + \alpha_H^1(\theta_H - \theta_L)$, $U_H^1 = \theta_H - \frac{1}{2}A\sigma^2$, $\alpha_L^0 = \alpha_H^0 = 0$, $\alpha_L^1 = \frac{K}{\frac{b_L^1}{b_H^1} + K^2}$, and $\alpha_H^1 = \frac{K^2}{\frac{b_L^1}{b_H^1} + K^2}$. In this case, all ICs and PCs are satisfied. Thus, we obtain the results as Scenario 2 in Table 2.

<u>CASE: $K \geq 1$</u>

In this case, $K(1-K) \leq 0$. Thus, if $0 \leq \frac{b_L^1}{b_H^1} \leq K$, we obtain that $U_L^0 = U_H^0 = 0$, $U_L^1 = \theta_L - \frac{1}{2}A\sigma^2 + \alpha_H^1(\theta_H - \theta_L)$, $U_H^1 = \theta_H - \frac{1}{2}A\sigma^2$, $\alpha_L^0 = \alpha_H^0 = 0$, $\alpha_L^1 = 1$ and $\alpha_H^1 = 1 - \frac{b_L^1}{b_H^1}\frac{1}{K}$.

This represents Scenario 1 in Table 1.

However, if $\frac{b_L^1}{b_H^1} > K$, IC_2, IC_3 and PC_3 are not satisfied. By taking the same procedure as in the case where $K < 1$, we obtain the results as Scenario 2 in Table 1. Q.E.D.

B Proof of Proposition 3

In the case of preannouncing private signals, the outsider updates her beliefs concerning $\tilde{\theta}$ in a Bayesian manner using the information included in the preopening order, while keeps her prior belief concerning $\tilde{e}$.

At the preopening stage, if the insider reports $\tilde{s} = \theta_L$ to the outsider, the outsider's beliefs over four types are $b_L^0 = (1-\lambda)p$, $b_H^0 = (1-\lambda)(1-p)$, $b_L^1 = \lambda p$ and $b_H^1 = \lambda(1-p)$, thus $\frac{b_L^1}{b_H^1} = \frac{p}{1-p}$. If the insider reports $\tilde{s} = \theta_H$ to the outsider, her beliefs now become $b_L^0 = (1-\lambda)(1-p)$, $b_H^0 = (1-\lambda)p$, $b_L^1 = \lambda(1-p)$ and $b_H^1 = \lambda p$, therefore, $\frac{b_L^1}{b_H^1} = \frac{1-p}{p}$. Since $\frac{1}{2} < p \leq 1$, $\frac{1-p}{p} < 1 < \frac{p}{1-p}$.

First, we consider the case where $K \leq \frac{1-p}{p}$. In this case, $\frac{p}{1-p} > \frac{1-p}{p} \geq K$, the outsider's belief of meeting θ_L relative to θ_H, i.e., $\frac{b_L^1}{b_H^1}$, cannot be smaller than K regardless of the insider's signal report. Thus, the trading profiles would be as Scenario 2 in Table 1 or Scenario 4 in Table 2. The insider would not obtain any informational rent at the trading stage regardless of his report. In this case, the insider has no incentive to lie on his private signals. Thus, preannouncing private signals is an equilibrium.

Second, we consider the case where $\frac{1-p}{p} < K \leq \frac{p}{1-p}$ and $V(\lambda, 1-p) < c$. That is, if the insider reports signal θ_L, the trading profiles would be as Scenario 2 in Table 1 or Scenario 4 in Table 2. The insider would not obtain any informational rent. However, if the insider reports θ_H, the trading profiles would be as Scenario 1 in Table 1, or Scenario 1, 2 or 3 in Table 2. The insider would obtain positive informational rent. In this case, the insider observing signal θ_L has incentive to mimic signal θ_H. If $V(\lambda, 1-p) < c$, the outsider would stay out of the market given signal θ_H since the expected utility is lower than her entry cost. Given the no entry decision, the insider would not obtain any positive informational rent if he reports signal θ_H. Thus, the outsider use her no entry decision given signal θ_H as a mechanism to punish the lying behavior of the insider. In this case, the insider has no incentive to lie on his private signals. Thus, preannouncing private signals is an equilibrium.

Third, we consider the case where $K > \frac{p}{1-p}$ and $\max\{V(\lambda, 1-p), V(\lambda, p) < c\}$. That is, if the insider reports signal θ_L or θ_H, the trading profiles would be as Scenario 1 in Table 1, or Scenario 1, 2 or 3 in Table 2. The insider obtains positive informational rent regardless of his report. But since the informational rent decreases with $\frac{b_L^1}{b_H^1}$, the insider will obtain more informational rent if he reports signal θ_H than θ_L, and thereby the insider observing signal θ_L has incentive to mimic θ_H. If $\max\{V(\lambda, 1-p), V(\lambda, p) < c\}$, the outsider stays out of the market regardless of the insider's report since the participation cost is too high. In this case, the insider always obtain his outside option value and has no incentive to lie on his private signals. Thus, preannouncing private signals is an equilibrium, but which involves no trading between the insider and the outsider. Q.E.D.

C Proof of Proposition 5

In the equilibrium with preannouncement of liquidity needs ($\tilde{e}$), if the insider reports $\tilde{e} = 0$, the outsider stays out of the market due to no gains from trade. If the insider reports $\tilde{e} = 1$, the expected utility obtained by the outsider at the trading stage is $V(1, \frac{1}{2})$. She enters if and only if $V(1, \frac{1}{2}) \geq c$. Thus, compared with the case without preopening stage, the outsider provides liquidity only if the endowment shock is announced, which better coordinates the supply and demand of liquidity. In addition, without preopening stage, the outsider would not enter if $c > V(\lambda, \frac{1}{2})$. Therefore, preannouncement of liquidity needs avoids market breakdown when $c \in (V(\lambda, \frac{1}{2}), V(1, \frac{1}{2})]$.[4] Q.E.D.

[4] $V(1, \frac{1}{2}) > V(\lambda, \frac{1}{2})$ always holds. Please see details in the Proof of Lemma 2.

D Proof of Proposition 7

In the equilibrium with preannouncement of private signals, if the insider reports $\tilde{s} = \theta_L$, the expected utility for the outsider obtained at the trading stage is $V(\lambda, p)$. The outsider enters into the market if $c \leq V(\lambda, p)$, otherwise, she stays out of the market. If the insider reports $\tilde{s} = \theta_H$, the expected utility for the outsider is $V(\lambda, 1-p)$. Thus, she enters into the market if $c \leq V(\lambda, 1-p)$, otherwise, she stays out of the market.

In the case where $K \leq \frac{1-p}{p}$, preannouncing private signals is always an equilibrium. When $c \leq V(\lambda, 1-p)$, the outsider always enters into the market; when $V(\lambda, 1-p) < c \leq V(\lambda, p)$, she enters only if $\tilde{s} = \theta_L$; when $c > V(\lambda, p)$, she stays out of the market. Without preopening, we know that the outsider enters into the market when $c \leq V(\lambda, \frac{1}{2})$. Thus, if $V(\lambda, \frac{1}{2}) \leq V(\lambda, 1-p)$, compared with the case without preopening, preannouncing private signals allows the outsider to provide more liquidity and avoids market breakdown when $c \in (V(\lambda, \frac{1}{2}), V(\lambda, p)]$. If $V(\lambda, \frac{1}{2}) > V(\lambda, 1-p)$, the outsider provides less liquidity when $c \in (V(\lambda, 1-p), V(\lambda, \frac{1}{2})]$, since without preopening, the outsider always enters into the market while with preannouncing private signals, the outsider only enters if $\tilde{s} = \theta_L$. But the outsider provides more liquidity and avoids market breakdown when $c \in (V(\lambda, \frac{1}{2}), V(\lambda, p)]$.[5]

In the case where $\frac{1-p}{p} < K \leq \frac{p}{1-p}$ and $c > V(\lambda, 1-p)$, preannouncing private signals is an equilibrium. In the equilibrium, the outsider enters if $\tilde{s} = \theta_L$ when $V(\lambda, 1-p) < c \leq V(\lambda, p)$, and stays out of the market when $c > V(\lambda, p)$. Compared with the case without preopening, we find that, if $V(\lambda, \frac{1}{2}) \leq V(\lambda, 1-p)$, preannouncing private signals allows the outsider to provide more liquidity and avoids market breakdown when $c \in (V(\lambda, 1-p), V(\lambda, p)]$. If $V(\lambda, \frac{1}{2}) > V(\lambda, 1-p)$, the outsider provides less liquidity when $c \in (V(\lambda, 1-p), V(\lambda, \frac{1}{2})]$ while provides more liquidity and avoids market breakdown when $c \in (V(\lambda, \frac{1}{2}), V(\lambda, p)]$ as in the case where $K \leq \frac{1-p}{p}$.

In the case where $p > \frac{p}{1-p}$ and $c > \max\{V(\lambda, 1-p), V(\lambda, p)\}$, preannouncing private signals is an equilibrium. But in this case, no trading occurs both in the equilibrium

[5] $V(\lambda, p) > V(\lambda, \frac{1}{2})$ always holds. Please see details in the Proof of Lemma 2.

without preannouncement and in the equilibrium with preannouncing signals. Q.E.D.

E Proof of Proposition 8

From Proposition 3, we know that preannouncing private signals on asset value is an equilibrium only in three difference cases. In the following, we want to compare the social welfare in the case without preannouncement and with preannouncing private signals in these three scenarios to see how preannouncing private signals can affect social welfare.

First, in the case where $K \leq \frac{1-p}{p}$, preannouncing private signals is always an equilibrium. When $c \leq V(\lambda, 1-p)$, the outsider always enters into the market. When $V(\lambda, 1-p) < c \leq V(\lambda, p)$, the outsider enters into the market only if $\tilde{s} = \theta_L$. When $c > V(\lambda, p)$, the outsider always stays out of the market. Without preannouncement, when $c \leq V(\lambda, \frac{1}{2})$, the outsider always enters into the market. When $c > V(\lambda, \frac{1}{2})$, the outsider always stays out of the market.

If $V(\lambda, \frac{1}{2}) \leq V(\lambda, 1-p)$, in the case where $c \leq V(\lambda, \frac{1}{2})$, in both equilibria, the outsider always enters into the market and given entry full trading occurs if the insider owns the low value asset, while no trading occurs if the insider owns high value asset. Therefore, both equilibria generate exactly the same social welfare. In the case where $V(\lambda, \frac{1}{2}) < c \leq V(\lambda, p)$, trading completely shut down in the case without preannouncement but preannouncing private signals allow trading happen with positive probability, thus preannouncing private signals generate larger social welfare. In the case where $c > V(\lambda, p)$, trading completely shuts down in both equilibria.

If $V(\lambda, \frac{1}{2}) > V(\lambda, 1-p)$, in the case where $c \leq V(\lambda, 1-p)$, in both equilibria, the outsider always enters into the market and given entry, full trading occurs if the insider owns the low value asset, while no trading occurs if the insider owns high value asset. Thus, both equilibria generate the same welfare. In the case where $V(\lambda, 1-p) < c \leq V(\lambda, \frac{1}{2})$, without preannouncement the outsider always enters into the market, while with preannouncing private signals she enters only if $\tilde{s} = \theta_L$. In both equilibria, given entry, full trading occurs if the insider owns the low value asset, while no trading occurs if the insider owns high value asset. In both equilibria, the insider obtains outside option value. The outsider obtains all gains of trade, i.e., $V(\lambda, \frac{1}{2}) - c$ and $\frac{1}{2}(V(\lambda, p) - c)$ in the case without preannouncement and with preannouncing private signals respectively.

$$V(\lambda, \frac{1}{2}) - c = \frac{1}{4}A\sigma^2 - c. \tag{17}$$

and

$$\frac{1}{2}(V(\lambda, p) - c) = \frac{1}{2}(p\frac{1}{2}A\sigma^2 - c). \tag{18}$$

In addition, we also can obtain that

$$V(\lambda, 1-p) = (1-p)\frac{1}{2}A\sigma^2. \tag{19}$$

Since $c > V(\lambda, 1-p) = (1-p)\frac{1}{2}A\sigma^2$, we obtain that $\frac{1}{2}(V(\lambda, p) - c) > V(\lambda, \frac{1}{2}) - c$. Thus preannouncing private signals dominate. In the case where $V(\lambda, \frac{1}{2}) < c \leq V(\lambda, p)$, trading completely shut down in the case without preannouncement but preannouncing private signals allow trading happen with positive probability, thus preannouncing private signals generate larger social welfare. In the case where $c > V(\lambda, p)$, trading completely shuts down in both equilibria.

Second, in the case where $\frac{1-p}{p} < K \leq \frac{p}{1-p}$ and $V(\lambda, 1-p) < c$, preannouncing private signals is an equilibrium. If $V(\lambda, \frac{1}{2}) \leq V(\lambda, 1-p)$, in the case where $V(\lambda, 1-p) < c \leq V(\lambda, p)$, no preannouncement completely shuts down the trading while preannouncing private signals allow entry if the signal is θ_1. Thus, preannouncing private signals dominates no preannouncement. In the case where $c > V(\lambda, p)$, trading completely shuts down in both equilibria.

If $V(\lambda, \frac{1}{2}) > V(\lambda, 1-p)$, in the case where $V(\lambda, 1-p) < c \leq V(\lambda, \frac{1}{2})$, the outsider always enter without preannouncement while enters only if $\tilde{\theta} = \theta_L$ with preannouncing private signals. Given entry, without preannouncement, partial trading occurs if the asset turns out to be high value when $K > 1$ while no trading when $K \leq 1$. With preannouncing private signals, no trading occurs if the asset turns out to be high value. If $K \leq 1$, the insider obtains the outside option value in both equilibria. The outsider obtains $V(\lambda, \frac{1}{2}) - c$ and $\frac{1}{2}(V(\lambda, p) - c)$ in the case without preannouncement and with preannouncing private signals respectively. Similarly, we obtain that $\frac{1}{2}(V(\lambda, p) - c) > V(\lambda, \frac{1}{2}) - c$. Thus preannouncing private signals dominate. In the following, we restrict our attention to the case where $K > 1$. Without preannouncement, with probability $\frac{1}{2}$, full trading happens if the insider owns an low quality asset, therefore gains from trade is $\frac{1}{2}A\sigma^2$. With probability $\frac{1}{2}$, partial trading occurs (α_H^1) if the insider owns a high quality asset, therefore gains from trade is $\frac{1}{2}A\sigma^2(1 - (1 - \alpha_H^1)^2)$. The total social welfare in the case without preannouncement is

$$\begin{aligned} &\frac{1}{2} * \frac{1}{2}A\sigma^2 + \frac{1}{2} * \frac{1}{2}A\sigma^2(1 - (1 - \alpha_H^1)^2) - c \\ &= \frac{1}{4}A\sigma^2 + \frac{1}{4}A\sigma^2 * (1 - \frac{1}{K^2}) - c \\ &= \frac{1}{2}A\sigma^2 - \frac{1}{4}A\sigma^2\frac{1}{K^2} - c. \end{aligned} \tag{20}$$

With preannouncing private signals, with probability $\frac{1}{2}$, the insider receives a bad signal and report at the preopening stage. The outsider enters. In the trading stage, with probability p, the asset turns out to be low quality and full trading occurs. Gains of trade is $\frac{1}{2}A\sigma^2$. With probability $1 - p$, the asset turns out to be high quality and no trading occurs. In this case, the total social welfare is

$$\frac{1}{2}(p * \frac{1}{2}A\sigma^2 - c). \tag{21}$$

In addition, we can obtain the expected utility of the outsider investor

$$\begin{aligned} V(\lambda, \frac{1}{2}) &= \frac{1}{2}(\frac{1}{2}A\sigma^2 - \alpha_H^1(\theta_H - \theta_L)) + \frac{1}{2} * \frac{1}{2}A\sigma^2(1 - (1 - \alpha_H^1)^2) \\ &= \frac{1 + K^2}{4K^2}A\sigma^2. \end{aligned} \tag{22}$$

and

$$V(\lambda, 1-p) = (1-p)(\frac{1}{2}A\sigma^2 - \alpha_H^1(\theta_H - \theta_L)) + p\frac{1}{2}A\sigma^2(1-(1-\alpha_H^1)^2)$$
$$= \frac{(1-p)(1-(1-K^2)p)}{2pK^2}A\sigma^2. \tag{23}$$

Therefore, c must satisfy the following condition $\frac{(1-p)(1-(1-K^2)p)}{2pK^2}A\sigma^2 < c \leq \frac{1+K^2}{4K^2}A\sigma^2$.

We compare the welfare in the two equilibria:

$$\frac{1}{2}A\sigma^2 - \frac{1}{4}A\sigma^2\frac{1}{K^2} - c - \frac{1}{2}(\frac{1}{2}pA\sigma^2 - c)$$
$$= \frac{(2-p)K^2-1}{4K^2}A\sigma^2 - \frac{1}{2}c. \tag{24}$$

We can see that this can either a positive or negative number. Thus, preannouncing private signals can generate greater or smaller social welfare than no preannouncement.

In the case where $V(\lambda, \frac{1}{2}) < c < V(\lambda, p)$, no preannouncement completely shuts down the trading while preannouncing private signals allow entry if the signal is θ_1. Thus, preannouncing private signals dominates. In the case where $c > V(\lambda, p)$, trading completely shuts down in both equilibria.

Third, in the case where $K > \frac{p}{1-p}$ and $\max\{V(\lambda, 1-p), V(\lambda, p)\} < c$, trading completely shuts down in both equilibria. Q.E.D.

F Proof of Lemma 2

Tables 3 and 4 display the expected utilities of both the outsider and the insider at the preopening stage given different equilibria. There are two things to notice: first, the expected utility of the insider in the two tables is the expected informational rent he expects to obtain at the trading stage; second, we only give the parameter range for each equilibrium which involves trading, i.e., the outsider enters into game. For other parameter ranges, they either involve no trading, i.e., the outsider stays out of the market, or are not on the equilibrium path at all.

Equilibrium	Parameter Range of c	Entry Decision	Outsider's Expected Utility	Insider's Expected Utility			
				$\{\tilde{e}=1, \tilde{s}=\theta_L\}$	$\{\tilde{e}=1, \tilde{s}=\theta_H\}$	$\{\tilde{e}=0, \tilde{s}=\theta_L\}$	$\{\tilde{e}=0, \tilde{s}=\theta_H\}$
No Preannouncement	$[0, V(\lambda, \frac{1}{2})]$	Always Enter	$V(\lambda, \frac{1}{2}) - c$	$p(1-\frac{1}{K})(\theta_H-\theta_L)$	$(1-p)(1-\frac{1}{K})(\theta_H-\theta_L)$	0	0
Preannouncement of $\tilde{e}$	$[0, V(1, \frac{1}{2})]$	Enter if $q=1$	$\lambda[V(1, \frac{1}{2}) - c]$	$p(1-\frac{1}{K})(\theta_H-\theta_L)$	$(1-p)(1-\frac{1}{K})(\theta_H-\theta_L)$	0	0
Preannouncement of $\tilde{s}$ when $1 \leq K \leq \frac{p}{1-p}$	$(V(\lambda, 1-p), V(\lambda, p)]$	Enter if $l=\theta_L$	$\frac{1}{2}[V(\lambda, p) - c]$	0	0	0	0
Preannouncement of $\tilde{e}$ and $\tilde{s}$ when $1 \leq K \leq \frac{p}{1-p}$	$(V(1, 1-p), V(1, p)]$	Enter if $q=1$ and $l=\theta_L$	$\frac{1}{2}\lambda[V(1, p) - c]$	0	0	0	0

Table 3: Insider's and Outsider's Expected Utilities for Different Equilibrium at Preopening Stage when $K \geq 1$

Equilibrium	Parameter Range of c	Entry Decision	Outsider's Expected Utility	Insider's Expected Utility			
				$\{\tilde{e}=1, \tilde{s}=\theta_L\}$	$\{\tilde{e}=1, \tilde{s}=\theta_H\}$	$\{\tilde{e}=0, \tilde{s}=\theta_L\}$	$\{\tilde{e}=0, \tilde{s}=\theta_H\}$
No Preannouncement	$[0, V(\lambda, \frac{1}{2})]$	Always Enter	$V(\lambda, \frac{1}{2}) - c$	0	0	0	0
Preannouncement of $\tilde{e}$	$[0, V(1, \frac{1}{2})]$	Enter if $q = 1$	$\lambda[V(1, \frac{1}{2}) - c]$	0	0	0	0
Preannouncement of $\tilde{s}$ when $K \leq \frac{1-p}{p}$	$[0, V(\lambda, 1-p)]$	Always Enter	$\frac{1}{2}[V(\lambda, 1-p) + V(\lambda, p)] - c$	0	0	0	0
Preannouncement of $\tilde{s}$ when $K < 1$	$(V(\lambda, 1-p), V(\lambda, p)]$	Enter if $l = \theta_L$	$\frac{1}{2}[V(\lambda, p) - c]$	0	0	0	0
Preannouncement of $\tilde{e}$ and $\tilde{s}$ when $K \leq \frac{1-p}{p}$	$[0, V(1, 1-p)]$	Enter if $q = 1$	$\lambda[\frac{1}{2}(V(1, 1-p) + V(1, p)) - c]$	0	0	0	0
Preannouncement of $\tilde{e}$ and $\tilde{s}$ when $K < 1$	$(V(1, 1-p), V(1, p)]$	Enter if $q = 1$ and $l = \theta_L$	$\frac{1}{2}\lambda[V(1, p) - c]$	0	0	0	0

Table 4: Insider's and Outsider's Expected Utilities for Different Equilibrium at Preopening Stage when $K < 1$

First, we consider the case where $K < 1$.

In the equilibrium of no preannouncement, the outsider's expected utility is $\max\{V(\lambda, \frac{1}{2}) - c, 0\}$. Since the outsider's beliefs are $b_L^0 = \frac{1}{2}(1-\lambda)$, $b_H^0 = \frac{1}{2}(1-\lambda)$, $b_L^1 = \frac{1}{2}\lambda$, and $b_H^1 = \frac{1}{2}\lambda$. Thus, $\frac{b_L^1}{b_H^1} = 1 > K$, the limit orders proposed by the outsider in the trading stage corresponds to Scenario 4 in Table 2, and we obtain that

$$\begin{aligned} V(\lambda, \frac{1}{2}) =& b_L^0 V_L^0 + b_H^0 V_H^0 + b_L^1 V_L^1 + b_H^1 V_H^1 \\ =& \frac{1}{4}\lambda A \sigma^2. \end{aligned} \tag{25}$$

Thus, the expected utility of the outsider is $\max\{V(\lambda, \frac{1}{2}) - c, 0\} = \max\{\frac{1}{4}\lambda A\sigma^2 - c, 0\}$.

In the equilibrium of preannouncing liquidity needs, the outsider's expected utility is $\lambda \max\{V(1, \frac{1}{2}) - c, 0\}$. With probability $1 - \lambda$, the insider does not own the asset and reports his liquidity needs. In this case, the outsider will stay out of the market and obtain 0. With probability λ, the insider owns the asset and reports his liquidity needs. The outsider's beliefs are $b_L^0 = 0$, $b_H^0 = 0$, $b_L^1 = \frac{1}{2}$, and $b_H^1 = \frac{1}{2}$. So, $\frac{b_L^1}{b_H^1} = 1 > K$, indicating that the limit orders proposed by the outsider in the trading stage still corresponds to Scenario 4 in Table 2. We obtain that

$$\begin{aligned} V(1, \frac{1}{2}) =& b_L^0 V_L^0 + b_H^0 V_H^0 + b_L^1 V_L^1 + b_H^1 V_H^1 \\ =& \frac{1}{4} A \sigma^2. \end{aligned} \tag{26}$$

Thus, the expected utility of the outsider is $\lambda \max\{V(1, \frac{1}{2}) - c, 0\} = \lambda \max\{\frac{1}{4}A\sigma^2 - c, 0\}$.

In the equilibrium of preannouncing private signals, if $K \leq \frac{1-p}{p}$, the outsider's expected utility is $\frac{1}{2}\max\{V(\lambda, 1-p) - c, 0\} + \frac{1}{2}\max\{V(\lambda, p) - c, 0\}$. With probability $\frac{1}{2}$, the insider observes signal θ_L and reports his signal. The outsider's beliefs become $b_L^0 = (1-\lambda)p$, $b_H^0 = (1-\lambda)(1-p)$, $b_L^1 = \lambda p$ and $b_H^1 = \lambda(1-p)$, thus $\frac{b_L^1}{b_H^1} = \frac{p}{1-p} > 1 > K$. The limit orders proposed by the outsider corresponds to Scenario 4 in Table 2. In this case, we obtain that

$$\begin{aligned} V(\lambda, p) =& b_L^0 V_L^0 + b_H^0 V_H^0 + b_L^1 V_L^1 + b_H^1 V_H^1 \\ =& \lambda p \frac{1}{2} A\sigma^2. \end{aligned} \tag{27}$$

With probability $\frac{1}{2}$, the insider observes signal θ_H and reports his signal. In this case, the outsider's beliefs are $b_L^0 = (1-\lambda)(1-p)$, $b_H^0 = (1-\lambda)p$, $b_L^1 = \lambda(1-p)$ and $b_H^1 = \lambda p$, thus $\frac{b_L^1}{b_H^1} = \frac{1-p}{p} \geq K$. In this case, the trading profiles proposed by the insider still correspond to Scenario 4 in Table 2, and we obtain that

$$\begin{aligned} V(\lambda, 1-p) =& b_L^0 V_L^0 + b_H^0 V_H^0 + b_L^1 V_L^1 + b_H^1 V_H^1 \\ =& \lambda(1-p) \frac{1}{2} A\sigma^2. \end{aligned} \tag{28}$$

Thus, the expected utility of the outsider in the case where $K \leq \frac{1-p}{p}$ is $\frac{1}{2}\max\{V(\lambda, 1-p) - c, 0\} + \frac{1}{2}\max\{V(\lambda, p) - c, 0\} = \frac{1}{2}\max\{\lambda(1-p)\frac{1}{2}A\sigma^2 - c, 0\} + \frac{1}{2}\max\{\lambda p \frac{1}{2}A\sigma^2 - c, 0\}$.

If $\frac{1-p}{p} < K < 1$, preannouncing private signals can be an equilibrium only when $c \in (V(\lambda, 1-p), +\infty)$. In this case, the expected utility of the outsider becomes $\frac{1}{2}\max\{V(\lambda, p) - c, 0\} = \frac{1}{2}\max\{\lambda p \frac{1}{2}A\sigma^2 - c, 0\}$.

In the equilibrium of preannouncing both liquidity needs and private signals, if $K \leq \frac{1-p}{p}$, the outsider's expected utility is $\frac{1}{2}\lambda\max\{V(1, 1-p) - c, 0\} + \frac{1}{2}\lambda\max\{V(1, p) - c, 0\}$. With probability $1-\lambda$, the insider has no endowment. In this case, the outsider stays out of the market and obtains 0. With probability λ, the insider has endowment. In this case, similarly with probability $\frac{1}{2}$, the insider observes and reports θ_L, we obtain that $V(1, p) = p\frac{1}{2}A\sigma^2$. With probability $\frac{1}{2}$, the insider observes and reports θ_H, we obtain that $V(1, 1-p) = (1-p)\frac{1}{2}A\sigma^2$. Thus, the expected utility of the outsider is $\frac{1}{2}\lambda\max\{V(1, 1-p) - c, 0\} + \frac{1}{2}\lambda\max\{V(1, p) - c, 0\} = \frac{1}{2}\lambda\max\{(1-p)\frac{1}{2}A\sigma^2 - c, 0\} + \frac{1}{2}\lambda\max\{p\frac{1}{2}A\sigma^2 - c, 0\}$.

In the case when $\frac{1-p}{p} < K < 1$ and $c \in (V(1, 1-p), +\infty)$, the expected utility of the outsider is $\frac{1}{2}\lambda\max\{V(1, p) - c, 0\} = \frac{1}{2}\lambda\max\{p\frac{1}{2}A\sigma^2 - c, 0\}$.

In the following, we compare the utilities of the outsider for different equilibrium, and obtain:

1) Since $\lambda \max\{\frac{1}{4}A\sigma^2 - c, 0\} \geq \max\{\frac{1}{4}\lambda A\sigma^2 - c, 0\}$ holds, the outsider obtains higher utility in the equilibrium of preannouncing liquidity needs than in the equilibrium of no preannouncement.

2) Since $\frac{1}{2}\max\{\lambda(1-p)\frac{1}{2}A\sigma^2-c, 0\}+\frac{1}{2}\max\{\lambda p\frac{1}{2}A\sigma^2-c, 0\} \geq \max\{\frac{1}{4}\lambda A\sigma^2-c, 0\}$ hold when $K \leq \frac{1-p}{p}$ and $\frac{1}{2}\max\{\lambda p\frac{1}{2}A\sigma^2-c, 0\} \geq \max\{\frac{1}{4}\lambda A\sigma^2-c, 0\}$ holds when $\frac{1-p}{p} < K < 1$, the outsider obtains higher utility in the equilibrium of preannouncing private signals than in the equilibrium of no preannouncement.

3) Since $\frac{1}{2}\lambda \max\{(1-p)\frac{1}{2}A\sigma^2 - c, 0\} + \frac{1}{2}\lambda \max\{p\frac{1}{2}A\sigma^2 - c, 0\} \geq \lambda \max\{\frac{1}{4}A\sigma^2 - c, 0\}$ when $K \leq \frac{1-p}{p}$ holds and $\frac{1}{2}\lambda \max\{p\frac{1}{2}A\sigma^2 - c, 0\} \geq \lambda \max\{\frac{1}{4}A\sigma^2 - c, 0\}$ holds when $\frac{1-p}{p} < K < 1$ and $c \in (V(1, 1-p), +\infty)$, the outsider obtains higher utility in the equilibrium of preannouncing both private signals and liquidity needs than in the equilibrium of preannouncing private signals.

4) Since $\frac{1}{2}\lambda \max\{(1-p)\frac{1}{2}A\sigma^2-c, 0\}+\frac{1}{2}\lambda \max\{p\frac{1}{2}A\sigma^2-c, 0\} \geq \frac{1}{2}\max\{\lambda(1-p)\frac{1}{2}A\sigma^2 - c, 0\}+\frac{1}{2}\max\{\lambda p\frac{1}{2}A\sigma^2-c, 0\}$ when $K \leq \frac{1-p}{p}$ holds and $\frac{1}{2}\lambda \max\{p\frac{1}{2}A\sigma^2-c, 0\} \geq \frac{1}{2}\max\{\lambda p \frac{1}{2}A\sigma^2 - c, 0\}$ holds when $\frac{1-p}{p} < K < 1$ and $c \in (V(1, 1-p), +\infty)$, the outsider obtains higher utility in the equilibrium of preannouncing both private signals and liquidity needs than in the equilibrium of preannouncing liquidity needs.

For the second case where $K \geq 1$, we take the same procedure, it is easy to show that the outsider benefits from the entry decisions and trading profiles contingent on liquidity needs or/and private signals. Q.E.D.

G Proof of Proposition 9

The values of c_1 and c_2 are determined as follows:

- When $\frac{1-p}{p} < K < 1$,

1. in the case where $\lambda[V(1,\frac{1}{2})-c] \geq \frac{1}{2}[V(\lambda,p)-c]$, the outsider benefits more from the equilibrium of preannouncing liquidity needs than preannouncing private signals. If $V(1,\frac{1}{2}) \geq \min\{V(1,1-p), V(\lambda,p)\}$, $c_1 = c_2 = V(1,1-p)$; If $V(1,\frac{1}{2}) < \min\{V(1,1-p), V(\lambda,p)\}$, $c_1 = \max\{V(1,\frac{1}{2}), V(\lambda,1-p)\}$ and $c_2 = V(1,1-p)$.
2. in the case where $\lambda[V(1,\frac{1}{2})-c] < \frac{1}{2}[V(\lambda,p)-c]$, the outsider benefits more from the equilibrium of preannouncing private signals than preannouncing liquidity needs. $c_1 = V(\lambda,1-p)$ and $c_2 = V(1,1-p)$.

- When $1 \leq K \leq \frac{p}{1-p}$,
  1. if $V(1,\frac{1}{2}) \geq \min\{V(1,1-p), V(\lambda,p)\}$, $c_1 = c_2 = \max\{V(1,\frac{1}{2}), V(1,1-p)\}$.
  2. if $V(1,\frac{1}{2}) < \min\{V(1,1-p), V(\lambda,p)\}$, $c_1 = \max\{V(\lambda,1-p), V(1,\frac{1}{2})\}$, and $c_2 = V(1,1-p)$.

If $K < 1$, according to Table 4, the insider obtains no informational rent in any of the four equilibria and thus will choose the equilibrium which maximize the utility of the outsider. In addition, we also obtain that the equilibrium with preannouncement of both information dominates all the three other equilibria, and the equilibrium with preannouncement of liquidity needs (private signals) dominates the equilibrium without preannouncement.

First, in the case where $K \leq \frac{1-p}{p}$, preannouncing private signals, and preannouncing both information are always equilbria. In this case, the insider will choose to preannounce both liquidity needs and private signals to maximize the utility of the outsider.

Second, in the case where $\frac{1-p}{p} < K < 1$, preannouncing private signals is an equilibrium if $c > V(\lambda,1-p)$ and preannouncing both information is an equilibrium if $c > V(1,1-p)$.

In the case where $\lambda[V(1,\frac{1}{2})-c] \geq \frac{1}{2}[V(\lambda,p)-c]$, the outsider obtains higher utility in the equilibrium with preannouncement of liquidity needs than with that with preannouncement of private signals. If $V(1,\frac{1}{2}) \geq \min\{V(1,1-p), V(\lambda,p)\}$, $V(1,\frac{1}{2}) \geq$

$V(1,1-p)$ when $V(1,1-p) \leq V(\lambda,p)$ and $V(1,\frac{1}{2}) \geq V(\lambda,p)$ when $V(1,1-p) > V(\lambda,p)$. Now we consider the case where $V(1,1-p) \leq V(\lambda,p)$, $V(1,\frac{1}{2}) \geq V(1,1-p)$. The equilibrium with preannouncement of both information and the equilibrium of preannouncement of liquidity needs share some overlapping parameter range. We turn to the other case where $V(1,1-p) > V(\lambda,p)$, $V(1,\frac{1}{2}) \geq V(\lambda,p)$. The parameter range for the equilibrium with preannouncement of private signals which involves trading is within the parameter range for the equilibrium with preannouncement of liquidity shocks. In both cases, to maximize the utility of the outsider, the insider chooses to preannounce liquidity shocks when $c \in [0, V(1,1-p)]$ and preannounce both information when $c \in (V(1,1-p),+\infty)$. Thus, $c_1 = c_2 = V(1,1-p)$.

If $V(1,\frac{1}{2}) < \min\{V(1,1-p), V(\lambda,p)\}$, $V(1,\frac{1}{2}) < V(1,1-p)$ and $V(1,\frac{1}{2}) < V(\lambda,p)$. In the case where $V(1,\frac{1}{2}) \leq V(\lambda,1-p)$, the insider chooses to preannounce liquidity needs when $c \in [0, V(\lambda,1-p)]$, preannounce private signals when $c \in (V(\lambda,1-p), V(1,1-p)]$, and preannounce both information when $c \in (V(1,1-p),+\infty)$. In the case where $V(1,\frac{1}{2}) > V(\lambda,1-p)$, the insider chooses to preannounce liquidity needs when $c \in [0, V(1,\frac{1}{2})]$, preannounce private signals when $c \in (V(1,\frac{1}{2}), V(1,1-p)]$ and preannounce both information when $c \in (V(1,1-p),+\infty)$. In short, the insider chooses to preannounce liquidity needs when $c \in [0, \max\{V(1,\frac{1}{2}), V(\lambda,1-p)\}]$, preannounce private signals when $c \in (\max\{V(1,\frac{1}{2}), V(\lambda,1-p)\}, V(1,1-p)]$ and preannounce both information when $c \in (V(1,1-p),+\infty)$. Thus, $c_1 = \max\{V(1,\frac{1}{2}), V(\lambda,1-p)\}$ and $c_2 = V(1,1-p)$.

In the case where $\lambda[V(1,\frac{1}{2}) - c] < \frac{1}{2}[V(\lambda,p) - c]$, the outsider obtains higher utility in the equilibrium with preannouncement of private signals than with that with preannouncement of liquidity needs. The insider chooses to preannounce both information when $c \in (V(1,1-p),+\infty)$, and private signals when $c \in (V(\lambda,1-p), V(1,1-p)]$. However, when $c \in [0, V(\lambda,1-p)]$, preannouncing private signals (may together with liquidity needs) cannot be an equilibrium. Thus, the insider chooses to preannounce liquidity needs when $c \in [0, V(\lambda,1-p)]$. Thus, $c_1 = V(\lambda,1-p)$ and $c_2 = V(1,1-p)$.

Third, in the case where $1 \leq K \leq \frac{p}{1-p}$, preannouncement of private signals is an equilibrium if $c > V(\lambda, 1-p)$, while preannouncement of both liquidity needs and private signals is an equilibrium if $c > V(1, 1-p)$. According to Table 3, the equilibrium with preannouncement of liquidity needs always dominates the equilibrium without preannouncement.

If $V(1, \frac{1}{2}) \geq \min\{V(1, 1-p), V(\lambda, p)\}$, $V(1, \frac{1}{2}) \geq V(\lambda, p)$ when $V(1, 1-p) \geq V(\lambda, p)$, and $V(1, \frac{1}{2}) \geq V(1, 1-p)$ when $V(\lambda, p) > V(1, 1-p)$. Now we consider the case where $V(1, 1-p) \geq V(\lambda, p)$, we know that $V(1, \frac{1}{2}) \geq V(\lambda, p)$, which indicates that preannouncement of private signals would never be chosen by the insider. This is because, according to Table 3, the insider can obtain positive informational rent by preannouncing liquidity needs when $c \leq V(1, \frac{1}{2})$, while preannouncement of private signals is an equilibrium which involves trading only when $V(\lambda, 1-p) < c \leq V(\lambda, p)$. Therefore, if $V(1, \frac{1}{2}) \geq V(1, 1-p)$, the insider chooses to preannounce liquidity needs when $c \in [0, V(1, \frac{1}{2})]$ to obtain the informational rent, and switch to preannounce both information when $c \in (V(1, \frac{1}{2}), +\infty)$ to maximize the expected utility of the outsider. If $V(1, \frac{1}{2}) < V(1, 1-p)$, the insider chooses to preannounce liquidity needs when $c \in [0, V(1, 1-p)]$ to obtain the informational rent, and switch to preannounce both information when $c \in (V(1, 1-p), +\infty)$ to maximize the expected utility of the outsider. We turn to the case where $V(\lambda, p) > V(1, 1-p)$, we know that $V(1, \frac{1}{2}) \geq V(1, 1-p)$. The insider would like to choose to preannounce liquidity needs to obtain informational rent when $c \in [0, V(1, \frac{1}{2}]]$, and switches to preannounce both information to maximize the utility of the outsider when $c \in (V(1, \frac{1}{2}), +\infty)$. In short, the insider chooses to preannounce liquidity needs when $c \in [0, \max\{V(1, \frac{1}{2}), V(1, 1-p)\}]$, and switch to preannounce both information when $c \in (\max\{V(1, \frac{1}{2}), V(1, 1-p)\}, +\infty)$. Thus, $c_1 = c_2 = \max\{V(1, \frac{1}{2}), V(1, 1-p)\}$.

Now we turn to the case where $V(1, \frac{1}{2}) < \min\{V(1, 1-p), V(\lambda, p)\}$. If $V(1, \frac{1}{2}) \geq V(\lambda, 1-p)$, the insider chooses to preannounce liquidity needs to maximize his informational rent when $c \in [0, V(1, \frac{1}{2})]$, and switches to preannounce private signals when $c \in (V(1, \frac{1}{2}, V(1, 1-p)]$, and then to preannounce both information when $c \in (V(1, 1-p), +\infty)$ to maximize the expected utility of the outsider. If $V(1, \frac{1}{2}) < V(\lambda, 1-p)$, the insider chooses to preannounce liquidity needs to maximize his informational rent when $c \in [0, V(\lambda, 1-p)]$, and switches to preannounce private signals when $c \in (V(\lambda, 1-p), V(1, 1-p)]$, and then to preannounce both information when $c \in (V(1, 1-p), +\infty)$ to maximize the expected utility. Thus, $c_1 = \max\{V(1, \frac{1}{2}), V(\lambda, 1-p)\}$ and $c_2 = V(1, 1-p)$.

Last, in the case where $K > \frac{1-p}{p}$, preannouncement of private signals, and preannouncement of both information cannot be an equilibrium which involves trading. In this case, the insider chooses the equilibrium with preannouncement of liquidity needs because it dominates the equilibrium without preannouncement. Q.E.D.

References

Admati, Anat R., and Paul Pfleiderer, 1991, Sunshine trading and financial market equilibrium, *Review of Financial Studies* 4, 443–481.

Barclay, Michael J., and Terrence Hendershott, 2003, Price discovery and trading after hours, *Review of Financial Studies* 16, 1041–1073.

———, 2008, A comparison of trading and non-trading mechanisms for price discovery, *Journal of Empirical Finance* 15, 839–849.

Baruch, Shmuel, 2005, Who benefits from an open limit-order book?, *Journal of Business* 78.

Bhattacharya, Utpal, and Matthew Spiegel, 1991, Insiders, outsiders, and market breakdowns, *Review of Financial Studies* 4, 255–282.

Biais, Bruno, Pierre Hillion, and Chester Spatt, 1999, Price discovery and learning during the preopening period in the paris bourse, *Journal of Political Economy* 107, 1218–1248.

Cao, Charles, Eric Ghysels, and Frank Hatheway, 2000, Price discovery without trading: Evidence from the nasdaq preopening, *Journal of Finance* 55.

Dia, Magueye, and Sebastien Pouget, 2011, Sunshine trading in an african stock market, *Managerial Finance* 37, 257–274.

Grossman, Sanford J., and Merton H. Miller, 1988, Liquidity and market structure, *Journal of Finance* 43.

Jiang, Christine X., Tanakorn Likitapiwat, and Thomas H. McInish, 2012, Information content of earnings announcements: Evidence from after-hours trading, *Journal of Financial and Quantitative Analysis* 47, 1303–1330.

Laffont, Jean-Jacques, and Eric S. Maskin, 1990, The efficient market hypothesis and insider trading on the stock market, *Journal of Political Economy* 98, 70–93.

Medrano, Luis A., and Xavier Vives, 2001, Strategic behavior and price discovery, *Rand Journal of Economics* 32, 221–248.

Pagano, Michael S., Lin Peng, and Robert A. Schwartz, 2013, A call auction's impact on price formation and order routing: Evidence from the nasdaq stock market, *Journal of Financial Markets* 16, 331–361.

Spatt, Chester, and Sanjay Srivastava, 1991, Preplay communication, participation restrictions, and efficiency in initial public offerings, *Review of Financial Studies* 4, 709–726.

Vives, Xavier, 1995, The speed of information revelation in a financial market mechanism, *Journal of Economic Theory* 67, 178–204.