Strategic Noise Traders and Liquidity Pressure with a Physically Deliverable Futures Contract

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Abstract

Do physically deliverable futures contracts induce liquidity pressure in the underlying spot market? The answer is believed to be no since the asset is delivered sometimes after the expiration of the contract so that the futures trader's payoff does not clearly depend on the price of the underlying stock at expiration. We construct a rational expectations equilibrium model in which a strategic uninformed trader induces liquidity pressure in the underlying spot market at the expiration of a physically deliverable futures contract. Liquidity pressure is the

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result of a pure informational advantage: if it is known that futures traders hedge their position in the spot market then a strategic trader with no information about the fundamental value of the underlying has an incentive to create noise in the futures market in order to gain information on the composition of the spot order flow at future auctions.

We show that informed traders benefit from this form of strategic noise and that the efficiency of the prices remains unaffected.

JEL classification codes: D4, D44, G13, G18

1. Introduction

The recent development of trading in single-stock futures contracts (SSF) poses some theoretical and empirical challenges[1]. No arbitrage arguments suggest that a future price should correspond to the unbiased expectation of the spot price at settlement date. Therefore one should not expect to make any profits by trading in futures markets. So, why should investors trade futures? One of the answers to this question is that futures markets are more liquid with respect to spot markets and allow to pursue different trading strategies by hedging future risks more effectively. From the spot market regulator's perspective, however, one of the main concerns refers to the possibility of using this derivative market to manipulate the spot price of the underlying stock.

[1]SSF contracts started to trade in the US on November 9, 2002 at two newly created exchanges, NQLX and OneChicago, while the London International Forward and Futures Exchange (LIFFE) started on January 29, 2001 on a wide set of international stocks. For more details about SSF traded in the US and at LIFFE look at www.nqlx.com, www.onechicago.com and www.universal-stockfutures.com

Various forms of market manipulation depend on the settlement rules at exipiration, namely cash settlement or physical delivery[2]. For example for what concerns physically delivered contracts manipulation models such as Jarrow (1992), Jarrow and Chatterjea (1998) and Nyborg and Strebulaev (2001) deal with the static and dynamic analysis of short squeezes in the context of Treasuries auctions[3].

Both at LIFFE and at the US exchanges however the newly introduced single-stock futures are written on highly traded and liquid stocks so that the possibility of a short squeeze is reasonably extremely low. Kumar and Seppi (1992) and Capuano (2002), on the other hand, show that in the standard Kyle (1985) set up with a cash settled futures market an uninformed manipulator is able to make positive expected profits by creating liquidity pressure[4] in the spot market where an insider trades according to her private information.

In the market microstructure literature the liquidity of a financial market is its ability to absorb order flow without price impact and represents a determinant of the cost of trading. Investors naturally look for markets where their strategies can be cheaply implemented and as a consequence liquidity provision is a key element for the success of a market. Furthermore, liquidity represents one of the links between the market microstructure and the asset pricing literature since it enters as a determinant of stock returns, Pastor and Stambaugh (2003). It is then of no surprise that

[2]It is interesting to note that while SSF are settled for cash at LIFFE, they are physically delivered in the US exchanges.

[3]A short squeeze realizes when one or more manipulators, after having acquired a long position greater than the available asset's supply, force the short investors (those who sold the asset without having the property) to deliver. However the shorts will be charged a higher price (squeezed) since they can only buy the asset they promised to deliver from the long manipulators.

[4]In those models the manipulator succeeds in "cornering" the market, i.e., in artificially pushing the spot price up (down) in order to make profits on the previously aquired long (short) position in the futures market.

institutional rules giving rise to liquidity pressure are of great concern to regulators and market participants[5].

This paper analyzes the profitability of creating liquidity pressure at the expiration of a physically delivered contract. Since the asset is delivered some time after the expiration of the contract[6] this case is of interest becauses the futures trader's payoff does not clearly depend on the price of the underlying stock at expiration.

Contrary to what one would expect we construct a rational expectations model in which an uninformed noise trader profitably creates liquidity pressure in the underlying market at the expiration of a physically delivered futures contract.

The intuition we pursue is the following: if it is known that traders pursue correlated strategies between the futures and the underlying market then by trading derivatives, an uninformed strategic trader may be able to infer a component of the future spot order flow, exactly the "correlated" trade, and to use this information to profit from her subsequent spot trades[7].

Liquidity pressure, in this model, is the result of a pure informational advantage. In particular the privileged information is not about the fundamental value of the underlying asset, but on the composition of the spot order flow at future auctions.

Liquidity dries up in the spot market not as a result of manipulative strategies used by some experienced traders, but because the market makers, the agents whose institutional role is to supply liquidity to the incoming order, will have to face two

[5]Liquidity pressure realizes when it is difficult to find a trader willing to provide liquidity to the incoming order and as a consequence the market price abnormally overreacts.

[6]On both NQLX and OneChicago the delivery is due three business days after expiration.

[7]For example, as Kumar and Seppi (1992) note, if it is known that delivery is costly or if it is known that investors hedge their derivative positions, then for every acquired futures position an "offsetting" trade has to be expected.

types of informed traders: insiders with private information about the fundamental value of the risky asset and strategic noise traders with privileged information about the composition of the order flow.

Strategic liquidity traders have been analyzed in Admati and Pfleiderer (1991). They model "sunshine trading" as traders preannouncing their future orders to gain on the reduction of the associated transaction costs. More similarly to our set up Grossman (1988) shows that when trading in a real security (such as a put option) provides information about the future hedging demand of the investor then the first trade can affect the supply of liquidity to the market. Finally, the idea that information concerning the composition of the order flow results to be valuable in determining the price of an asset irrespectively of its fundamental value is also present in Gennotte and Leland (1990) as well as in Jacklin, Kleidon and Pfleiderer (1992).

Interestingly, we are able to show that this uniformed liquidity pressure does not affect the efficiency of the underlying spot price and is actually essential for the spot market to correctly function. On the other hand pure hedging traders suffer from it. Hence it is not clear whether the regulator should be concerned about episodes of liquidity pressure at the expiration of physically delivered derivative contracts.

The paper is organized as follows: section 2 presents the model with the main proposition, section 3 provides an analysis of the equilibrium and of its implications, section 4 develops a more general set up in which to observe liquidity pressure and section 5 concludes.

2. The Model

The structure of the model is based on the standard Kyle(1985) set up and is similar to Kumar and Seppi(1992) or Capuano(2002). Trading takes place over a risky asset whose payoff is $v \sim N(\mu, \sigma_v^2)$. There are three time periods: in period one a futures market is open, in period two the futures contract expires and at the same time a spot market is open. In period three the risky payoff is revealed and physical delivery takes place, the seller (the holder of a short position) delivers the asset underlying the futures contract to a respective buyer (the holder of a long position) who, in exchange, pays the agreed futures price multiplied by the quantity of the securities delivered.

There are three types of investors: a pure liquidity trader who trades $e \sim N(0, \sigma_e^2)$ in the futures market and then completely offsets her position in the spot market by trading $u = -e$ in period two, such that her total position in the risky asset $e + u = 0$. We do not try to rationalize the pure liquidity trader's behavior. The assumption of perfect offsetting trades is not necessary for our results. What is needed is some correlation between the two trades and the perfectly negative correlation assumption is simply made for tractability. This is consistent with an hedging component motive due to risk aversion or to excessive delivery costs[8].

The second type of trader is a risk neutral informed agent who knows v but can trade x only in the spot market in period two. Finally, there is a risk neutral strategic noise trader who is endowed with some random wealth $w \sim N(0, \sigma_w^2)$ and is not

[8] For example a pure liquidity short trader might fear that acquiring the asset at delivery might turn out to be extremely costly due to a potential short squeeze, hence she prefers to at least partially offsets her futures position at expiration.

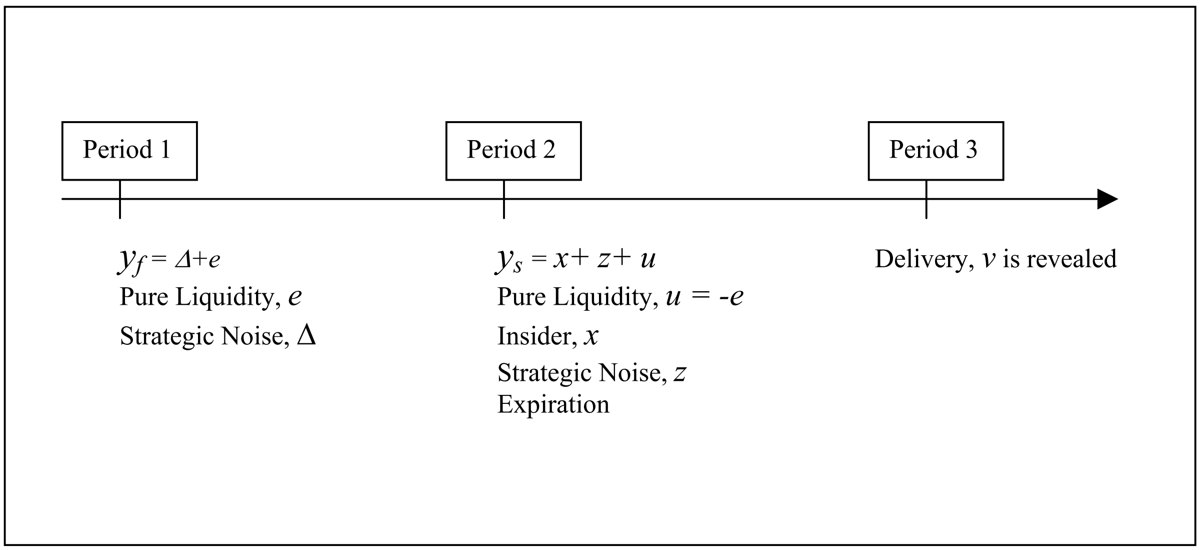
Period 1
Period 2
Period 3
$y_f = \Delta + e$
Pure Liquidity, e
Strategic Noise, Δ
$y_s = x + z + u$
Pure Liquidity, $u = -e$
Insider, x
Strategic Noise, z
Expiration
Delivery, v is revealed

Figure 1

informed about v, but can trade Δ in the futures market and z in the spot market[9]. Liquidity is supplied by two competitive market makers: one in the spot and the other in the futures market who set the market prices efficiently and make zero expected profits. The time line of the events is presented in figure 1.

In any period the market maker sees the overall order flow that is realized in her own market as well as the past prices and order flows realized in the other market. Based on her current and past information and facing competition from other liquidity suppliers she sets the price making zero expected profits.

Let $\mathcal{F}^{IF} = \{v, y_f)$ indicate the informed trader's information set in period two where

$$y_f = \Delta + e$$

is the futures order flow realized in period one. Similarly one can define $\mathcal{F}^{SL} = (y_f, e)$, $\mathcal{F}^{S} = (y_s, y_f)$, $\mathcal{F}^{F} = (y_f)$ respectively as the strategic noise trader[10], spot market maker and futures market maker's information sets, where

$$y_s = x + z + u$$

is the spot order flow in period two.

In order to obtain an equilibrium we need to endow the strategic noise trader with some random wealth $|w|$, where $w \sim N(0, \sigma_w^2)$ and then assume that $|\Delta| \leq |w|$.

[9] While it seems restrictive to prevent the informed trader from trading in the futures market, one should consider that if allowed to trade in period one the informed trader would behave as a strategic noise trader.

[10] This is her information set in period two, i.e., before she has to decide how much to trade in the spot market. While in period one she is completely uninformed.

As in Kumar and Seppi(1992) this delivers a normally distributed futures position in period one, which allows us to use linear projections in computing the prices. One can interpret this assumption as a position limit requirement for the derivative trade.

Proposition 2.1. *There exists a linear equilibrium in which*

- the strategic noise trader trades

$$\Delta \sim N(0, \sigma_w^2)$$

in the futures market in period one and

$$z = \frac{e}{2} - \frac{k}{2} y_f \tag{2.1}$$

in the spot market in period two where $y_f = \Delta + e$ *is the realized futures order flow in period one and*

$$k = \frac{\sigma_e^2}{\sigma_e^2 + \sigma_w^2}$$

- the insider trades

$$x = \frac{1}{2\lambda} (v - \mu) \tag{2.2}$$

in the spot market in period two.

- the futures price in period one is given by

$$F = E(v \mid F^F) = E(v) = \mu$$

- the spot price in period two is given by

$$S = E(v \mid \digamma^S) = \frac{1}{2}(v+\mu) + \lambda\left[\frac{k}{2}y_f - \frac{e}{2}\right] \tag{2.3}$$

where

$$\lambda = \frac{\sigma_v}{2\left[Var(z \mid y_f)\right]^{\frac{1}{2}}} \tag{2.4}$$

and

$$Var\left(z \mid y_f\right) = \frac{k^2}{4}\sigma_w^2 + \left(\frac{1-k}{2}\right)^2 \sigma_e^2 \tag{2.5}$$

Proof. :

Few steps are needed to show the results.

Step 1: strategic noise trader problem in period two

First consider that market efficiency and the distributional assumptions imply that

$$\begin{aligned} S &= E(v \mid \digamma^S) = E(v \mid y_s, y_f) = E(v \mid y_s, y_f) = \mu + \lambda\left[y_s - E(y_s \mid y_f)\right] \quad (2.6) \\ F &= E(v \mid \digamma^F) = E(v) = \mu \end{aligned}$$

By backward induction we start by solving the strategic noise trader problem in period two, given her future position Δ in period one, the insider trade x, and the linear structure of the prices. Her program is:

$$\max_z E(\pi^{SL} \mid \digamma^{SL}) = E(\Delta(v-F) + z(v-S) \mid \digamma^{SL}) \tag{2.7}$$

which reduces to:

$$\max_{z} E(\pi^{SL} \mid F^{SL}) = \Delta(\mu - F) + z\left[-\lambda\left(z - e - E(z - e \mid y_f)\right)\right]$$

The first order conditions deliver:

$$z = \frac{e}{2} - \frac{E(e \mid y_f)}{2} + \frac{E(z \mid y_f)}{2}$$

while the second order conditions are satisfied for $\lambda > 0$. Taking expectations on both sides conditional on y_f one can find:

$$\frac{E(z \mid y_f)}{2} = 0$$

So that:

$$z = \frac{e}{2} - \frac{E(e \mid y_f)}{2} = \frac{e}{2} - \frac{k}{2}(\Delta + e) \tag{2.8}$$

where the last equality comes from the convenient normal distributional assumptions

$$E(e \mid y_f) = k y_f$$

and $0 < k < 1$ is the slope coefficient in this linear projection which shows (2.1).

Step 2: strategic noise trader problem in period one

In order to solve her period one program plug (2.8) in (2.7). She now has to solve:

$$\max_{\Delta} E(\pi^{SL}) \quad = \quad E\left\{\Delta(\mu - F) + \left[\frac{e}{2} - \frac{k}{2}(\Delta + e)\right](v - S)\right\}$$

$$s.t. \ \ |\Delta| \leq |w|$$

which, after substitution of the spot and futures prices from (2.6), simplifies into:

$$\max_{\Delta} \frac{\lambda}{4} \left[(1-k)^2 \sigma_e^2 + k^2 \Delta^2 \right]$$

$$s.t. \ \ |\Delta| \leq |w|$$

Note that the objective is increasing in Δ^2 so that the strategic noise trader is indifferent between going long $|w|$ or short $-|w|$ futures contracts in period one. Therefore she will be willing to randomize with equal probability, which implies that $\Delta \sim N(0, \sigma_w^2)$ and also confirms the expression for k given in the proposition.

Step 3: period two informed trader strategy

Given v and y_f her problem is:

$$\max_{x} E(\pi^{IF} \mid F^{IF}) = E(x\,(v - S) \mid F^{IF}) \tag{2.9}$$

Note that the informed trader knows that the predictable component of the spot order flow will be filtered out by the spot market maker, hence (2.9) reduces to

$$\max_{x} x\,[v - \mu - \lambda\,(x - E(x \mid y_f))]$$

the first order conditions are:

$$x = \frac{1}{2\lambda}\,(v - \mu) + \frac{1}{2} E(x \mid y_f)$$

and as before the second order conditions are satisfied when $\lambda > 0$. Taking expectations on both sides one can find:

$$x = \frac{1}{2\lambda}(v - \mu)$$

which corresponds to (2.2).

Step 4: market liquidity, spot and futures prices

Plugging our strategic noise trader and insider strategies in (2.6) we obtain

$$\begin{aligned} S &= E(v \mid \digamma^S) = \frac{1}{2}(v + \mu) + \lambda \left[\frac{k}{2} y_f - \frac{e}{2} \right] \\ F &= E(v \mid \digamma^F) = \mu \end{aligned}$$

which confirms (2.3). Now market efficiency and the normality of the random variables imply that λ is nothing more than the slope coefficient of a linear projection. In particular:

$$\lambda = \frac{Cov\,(v - \mu; y_s \mid y_f)}{Var\,(y_s \mid y_f)} \tag{2.10}$$

One can easily substitute to obtain:

$$Cov\,(v - \mu; y_s \mid y_f) = \frac{1}{2\lambda}\sigma_v^2$$

$$Var\,(y_s \mid y_f) = \frac{1}{4\lambda^2}\sigma_v^2 + Var\,(z \mid y_f)$$

where

$$Var\left(z \mid y_f\right) = \frac{k^2}{4}\sigma_w^2 + \left(\frac{1-k}{2}\right)^2 \sigma_e^2$$

which is (2.5). Plugging back into (2.10) one can find a quadratic equation in λ whose solution is

$$\lambda = \frac{\sigma_v}{2\left[Var(z \mid y_f)\right]^{\frac{1}{2}}}$$

which is (2.4) in the proposition ■

3. Comments on the Equilibrium

The equilibrium we have presented is intriguing: the strategic noise trader optimally creates noise in period one in order to gain information on the noise component of the order flow that will be realized in the future auction. This acquired information is the origin of the strategic noise trader's profits. Note that, with respect to similar analysis of concurrent spot and futures markets like Kumar and Seppi(1992) or Capuano(2002), no manipulation of the underlying asset price is involved.

Several results can be derived from this equilibrium.

(i) *the strategic noise is essential in order for the spot market to open in period two*

This follows by observing that if it is known that $\Delta = 0$ in period one then

$$E(u \mid y_f) = -y_f = -e$$

and the only unpredictable component of the spot order flow in period two will be given by the insider trade. Hence the well known "no trade theorem" of Milgrom and Stockey(1982) will apply and no market maker will be willing to open the spot market[11].

(ii) *The informed trader expected profits are an increasing function of the existing strategic noise*

As an implication of the previous result, by substituting (2.2) and (2.4) in the expected profits of the insider one obtains:

$$E(\pi^{IF} \mid F^{IF}) = \frac{\sigma_v \left[Var(z \mid y_f)\right]^{\frac{1}{2}}}{2}$$

therefore when the strategic noise increases the insider is better off[12].

(iii) *Liquidity traders bear the losses of the strategic traders profits*

This can be seen by computing their expected profits:

$$E\left\{e\left[v-F\right]+u\left[v-S\right]\right\}=E\left\{-e\left[v-S\right]\right\}=\frac{\lambda}{2}\left(k-1\right)\sigma_e^2<0$$

since $0 < k < 1$ and $\lambda > 0$.

(iv) *Strategic noise trader's profits are a decreasing function of the spot liquidity in period two*

[11] This is one way to see that if an opportunity to trade in period one were given to the insider, she would behave exactly as the strategic noise trader.

[12] This is similar to Kyle (1985) where an increase in noise leads to a more complex inference problem for the market maker and, as a consequence, to a more valuable private information.

The liquidity of the spot market is given by the inverse of λ. Since

$$E(\pi^{SL}) = \frac{\lambda}{4}\left[(1-k)^2\sigma_e^2 + k^2\Delta^2\right]$$

when spot liquidity increases (λ decreases) strategic noise traders are worse off. When the spot market is very liquid unexpected order flow does not have a big price impact and the information acquired on the futures market is not so valuable anymore.

(v) *The efficiency of the spot price is not affected by the strategic noise*

Spot price efficiency is given by

$$Var(S) = E\left[S - E(S)\right]^2$$

The comparison we want to make is with the case in which there is no futures market, the Kyle model[13]. It is known that in that case

$$y_s = x + e = \mu + \frac{v-\mu}{2} + \lambda e$$

$$\lambda = \frac{\sigma_v}{2\sigma_e}$$

$$Var\left(S\right)_k = \frac{\sigma_v^2}{2}$$

Now in our model from (2.3)

$$Var\left(S\right)_n = \frac{\sigma_v^2}{4} + \left[\frac{\sigma_v}{2Var(z \mid y_f)}\right]^2\left[\frac{k^2}{4}\left(\sigma_w^2 + \sigma_e^2\right) + \frac{1}{4}\sigma_e^2 - \frac{k}{2}\sigma_e^2\right]$$

[13]We will use the subscript k to describe the Kyle model and n to indicate our strategic noise.

which reduces to

$$Var(S)_n = Var(S)_k = \frac{\sigma_v^2}{2}$$

The result is driven by the fact that the insider optimal strategy in period two is not affected by the strategic noise trader.

(vi) *Liquidity Pressure*

This is the main motivation of the paper. Strategic noise trading induces liquidity pressure in the spot market in period two[14]. We experience liquidity pressure if and only if

$$\left(\frac{1}{\lambda_k}\right) > \left(\frac{1}{\lambda_n}\right)$$

which is the same as

$$Var(z \mid y_f) < \sigma_e^2$$

And after substitution to

$$\frac{\sigma_e^2}{4}\left[k\left(1-2\right)-3\right] + \frac{\sigma_w^2}{4}k^2 < 0 \tag{3.1}$$

which is always satisfied for $\sigma_e^2 > 0$ and $\sigma_w^2 > 0$.

Liquidity dries up in the spot market because the market maker knows that she is now facing two types of informed traders: insiders with private information about the fundamental value of the asset and strategic traders with an informational advantage over the composition of the order flow.

[14] We will again compare our results with Kyle (1985).

4. General Liquidity Pressure

In the previous section we have imposed that once the pure liquidity trader has acquired a position in the futures market in period one she then completely offsets her initial trade in the spot market in period two. We have argued that this assumption is not essential to obtain liquidity pressure as described in proposition 2.1. We now want to provide a general argument for this claim.

Proposition 4.1. *As long as the pure liquidity trader's spot position in period two depends on her futures position in period one we will observe liquidity pressure at expiration*

Proof. :

The result follows if we show that the strategic noise trader's expected profits are positive because the spot market maker will then realize that she has to face two types of informed traders and liquidity will dry up.

From proposition 2.1 we know that the strategic noise trader does not make profit on her futures position, but instead profits from her knowledge of the demand structure in the spot market in period two.

Her period two problem is:

$$\max_{z} E(\pi^{SL} \mid F^{SL})$$

The first order conditions deliver:

$$z = \frac{E(z \mid F^S)}{2} - \frac{1}{2}\left[E(u \mid F^{SL}) - E(u \mid F^S)\right]$$

while the second order conditions are satisfied for $\lambda > 0$. Taking expectations on both sides conditional on F^S one can find:

$$\frac{E(z \mid F^S)}{2} = 0$$

Plugging back into the expected profits:

$$E(\pi^{SL} \mid F^{SL}) = E(z\,(v - S) \mid F^{SL}) = \frac{\lambda}{4}\left[E(u \mid F^{SL}) - E(u \mid F^S)\right]^2 > 0$$

■

The source of the strategic noise trader's profits is given by her informational advantage:

$$\left[E(u \mid F^{SL}) - E(u \mid F^S)\right]$$

If the spot position of the pure liquidity trader does not depend on her futures position then knowing e would not be informative about u and trading in the futures market would not give any informational advantage to the strategic noise trader. If this were the case

$$E(u \mid F^{SL}) = E(u \mid F^S) \Rightarrow z = 0$$

and we would not experience liquidity pressure.

It should now be clear that the perfect hedge example of the previous section represents a simplification of a more general result. To provide a further example let's suppose

$$u = -\alpha e + \varepsilon$$

where $0 < \alpha < 1$ and $\varepsilon \sim N(0, \sigma_\varepsilon^2)$ independent of e. Now u is not a deterministic function of e anymore. In particular

$$Cov(u, e) = -\alpha \sigma_e^2$$

$$Corr(u, e) = -\frac{\alpha \sigma_e}{(\alpha^2 \sigma_e^2 + \sigma_\varepsilon^2)^{\frac{1}{2}}} < 0$$

and conditional on e, $u \sim N(-\alpha e, \sigma_\varepsilon^2)$. Since $\sigma_\varepsilon^2 > 0$, $Corr(u, e) > -1$, and we do not have the perfect correlation assumption of the previous section. Now:

$$E(u \mid \digamma^{SL}) = E(u \mid e) = -\alpha e \neq -\alpha k y_f = E(-\alpha e \mid \digamma^{S}) = E(u \mid \digamma^{S})$$

and from proposition 4.1 we expect liquidity pressure.

This is indeed what happens since following the steps of proposition 2.1 it is easy to show that the strategic noise trader's period one problem reduces to

$$\max_{\Delta} \frac{\lambda \alpha^2}{4} \left[(1-k)^2 \sigma_e^2 + k^2 \Delta^2 \right]$$

$$s.t. \; |\Delta| \leq |w|$$

which delivers the same solution as the one described in proposition 2.1.

5. Concluding Remarks

An important feature for a financial market structure is its ability to provide high liquidity during critical days. Typically, expiration days of derivative contracts are considered to be risky because of tentative manipulation strategies. This is true for cash settled contracts because the manipulator cashes the difference between the price of the underlying at expiration and the price at which she entered the contract[15].

On the contrary physical delivery is believed to be sufficient to discourage manipulative strategies at expiration because the futures trader's payoff does not clearly depend on the price of the underlying stock at expiration.

We succeeded in presenting a rational expectations equilibrium model in which, at the expiration of a physically deliverable futures contract, a strategic uninformed trader induces liquidity pressure in the underlying spot market where an insider trades according to her private information.

Liquidity pressure is the result of a pure informational advantage: if it is known that futures traders positions across markets are correlated then a strategic trader with no information about the fundamental value of the underlying has an incentive to create noise in the futures market in order to gain information about the composition of the spot order flow at future auctions.

Liquidity dries up with respect to the situation in which there was no derivative market because the liquidity suppliers are facing two types of informed traders: in-

[15] See, for example, Kumar and Seppi (1992) or Capuano(2002).

siders who have private information about the fundamental value of the risky asset and strategic traders who have privileged information about the composition of the order flow.

In this example however the strategic noise is essential to the functioning of the spot market. Without it the spot market will be shut. Therefore, from an institutional design point of view, if this model represents at least partially the behavior of actual markets it is not clear that the regulator should be concerned about liquidity pressure episodes at expiration of physically delivered derivative contracts.

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