Informed Trading, Short Sales Constraints, and Futures' Pricing*

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This version: February, 2000

*The authors would like to thank Markku Lanne, Peter Mikkelsen, Asani Sarkar, Patrik Säfvenblad and seminar participants at Insead, Stockholm School of Economics, CBOT Futures Research Symposium in Barcelona, FMA-EFMA Conference in Lisbon and AFFI conference in Aix-en-Provence for helpful comments. The usual caveat applies. The authors would also like to thank Karl Felixson and Antti Vauramo for data collection and Insead R&D funds for financial support. Financial support from Yrjö Jahnsson Foundation (Jokivuolle and Koskinen) and Finnish Cultural Foundation (Koskinen) is gratefully acknowledged.

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Abstract

The purpose of this paper is to provide an explanation for relative pricing of futures contracts with respect to underlying stocks based on short sales constraints and informational lags between the two markets. In this model stocks and futures are perfect substitutes, except that short sales are only allowed in futures markets. The futures price is more informative than the stock price, because the existence of short sales constraints in the stock market prohibits trading in some states of the world. If an informed trader with no initial endowment in stocks gets a negative signal about the common future value of stocks and futures, she is only able to sell futures. In addition uninformed traders also face similar short sales constraint in the stock market. As a result of the short sales constraint, the stock price is less informative than the futures price even if the informed trader has received positive information. Stocks can be under- and overpriced compared to futures, provided that market makers in stocks and futures only observe with a lag the order flow in the other market. Our theory implies that 1.) the basis is positively associated with the contemporaneous futures returns, 2.) the basis is negatively associated with the contemporaneous stock return, 3.) futures returns lead stock returns, 4.) stock returns also lead futures returns, but to a lesser extent and 5.) the trading volume in the stock market is positively associated with the contemporaneous stock return. The model is tested using daily data from the Finnish index futures markets. Finland provides a good environment for testing our theory, since short sales were not allowed during the time that we have data (May 27, 1988 - May 31, 1994). We find strong empirical support for our implications.

Keywords: futures pricing, lead-lag, short sales, informed trading, trading volume

JEL classification: G13, G14

1 Introduction

The purpose of this paper is to provide an explanation for some stylized facts regarding the pricing of futures contracts with respect to stocks and the trading volumes in the two markets. The well-known empirical observations that this model can account for are 1.) that futures' returns lead stock index returns even after the effects of non-synchronous trading are taken into account (Chan 1992), 2.) that there is a positive contemporaneous correlation between trading volumes and returns in the stock market (Karpoff 1987) and 3.) that the trading volume and returns are not related in the futures market (Kocagil and Shachmurove 1998). The model presented here is based on short sales constraints and informational lags between different markets. In this model stocks and futures are perfect substitutes, except that short sales are only allowed in futures markets. The futures price is more informative than the stock price, because the existence of short sales constraints in the stock market prohibits trading in some states of the world. If an informed trader with no initial endowment in stocks gets a negative signal about the common future value of stocks and futures, she is only able to sell futures. In addition uninformed traders also face short sales constraint in the stock market. These constraints can be binding irrespective of the information that the informed traders possess. As a result, the stock price is less informative than the futures price even if the informed trader has received positive information about the common value of the securities, because uninformed traders might not be able to trade.

In the model presented in this paper stocks can be under- and overpriced compared to futures, provided that market makers in stocks and futures only observe with a lag the prices in the other market. The model implies that 1.) the basis is positively associated with the contemporaneous futures returns, 2.) the basis is negatively associated with the contemporaneous stock return, 3.) futures returns lead stock returns, 4.) stock returns also lead futures returns, but to less extent and 5.) the trading volume in the stock market is positively associated with the contemporaneous stock return. The model is tested using daily data from the Finnish index futures markets. Finland provides a good environment for testing this theory, since short sales were not allowed during the time period studied in this paper (May 27, 1988 - May 31, 1994). The implications of the theory are well supported by the empirical evidence.

This model shares the feature of imperfect informational integration between different markets with Chan (1993) and Kumar and Seppi (1994). Chan models the observed positive cross-autocorrelation between different stocks with market makers, who price individual stocks based on signals pertaining to that specific stock without access to information in other markets. Stock returns become positively cross-autocorrelated when market makers update their prices after having seen the previous price information in other markets[1]. The issue in Kumar and Seppi is the evolution of futures basis in a dynamic learning game. Market makers receive a signal about the true value of futures or stocks without immediately being able to observe the developments in other markets. Arbitraguers are able to observe stock and futures prices across markets with less of a lag than market makers and thus benefit from their informational advantage. Subrahmanyam (1991) develops an adverse selection model for the existence and popularity of basket of securities like the futures contract based on a stock index. In his model, liquidity traders prefer to trade in the futures contract because of a smaller danger of being a counterparty to an informed trader.

Several other papers also deal with the interaction between futures and stock markets in an equilibrium setting, but emphasize the risk sharing aspects of the two markets. Holden (1995) explains the existence of arbitrage between stocks and futures in an equilibrium model as arising from the risk aversion of market makers and independent liquidity shocks to futures and stock markets. In Fremault (1991), different traders have unequal access to stock and futures markets. In her model, only arbitraguers have access to all markets. The role of arbitraguers is mainly based on reallocating risk, although she also briefly considers informational issues. Chen, Cuny, and Haugen (1995) have presented an equilibrium model of stock index futures basis behavior, where futures contracts are not perfect substitutes for stocks because they lack customization value of stock portfolios. In their model when market volatility increases current stock holders sell futures to hedge against the increasing risk of their customized stock portfolios decreasing the basis. As a result of increased hedging the futures open interest increases too.

Short sales constraints have for some reason been quite neglected area of research. The notable exception is of course Diamond and Verrechia (1987). Like in our model, prohibiting short sales reduces the informativeness of security prices, simply because some informative trades are not possible. Unlike in the model presented in this paper, in Diamond and Verrechia this effect is more pronounced for bad news. Diamond and Verrechia also show the positive association between trading volumes and returns.

The empirical literature on lead-lag relationship between futures and stock indices is quite large (see for example Kawaller et al. (1987), Stoll and Whaley (1990) and Chan (1992) for U.S. evidence and Yadav and Pope (1990) for international evidence). This model based on short sales constraints in the stock market also helps to explain why futures returns lead more stock returns than vice versa and why this relationship is robust even if the effects of non-synchronous trading are taken into account[2]. Harris (1989) studies the crash of 1987 and the behavior of futures basis around that time. He finds that non-synchronous trading in the stock market explains some, but not all, of the large negative futures basis and the lead-lag relationship between futures and stocks. This empirical evidence fits our argument well: in extreme situations like October 1987, short sales in stocks are difficult and costly to execute. This would imply that the order flow in futures markets is much more informative and as a result, futures returns would lead stock returns and the basis would be large.

In the Finnish context, short sales constraints and futures pricing have been previously dealt with in an informal way by Puttonen and Martikainen (1991) and Puttonen (1993). In their analysis, the short sales restrictions in the stock market are used to rationalize the underpricing of futures contracts with respect to underlying stocks. Contrary to that analysis, this paper shows that short sales constraints also explain the overpricing of futures contracts[3].

Section two presents a simple model of basis formation and trading volumes in stock and futures markets. Section three presents empirical evidence from the Finnish markets for the model presented here. Section four concludes.

2 The Model

2.1 The set-up

The structure of the market is like in Kyle (1985)[4]. There are three types of investors: informed speculators, market makers and noise traders. There are two risky securities that are perfect substitutes, except that short positions are allowed only in one of the securities. That security is called the futures contract. The security with no short sales is called the stock[5]. The risky securities have a value of either H or L. For simplicity we assume that $H = 1$ and $L = 0$. For clarity we maintain sometimes the H and L notation. There are three dates, 0, 1 and 2. At $t = 0$ the risk-neutral informed traders receive a perfect signal about the value of the risky securities. With probability $\frac{1}{2}$ the signal is H and with probability $\frac{1}{2}$ the signal is L. At $t = 1$, the informed and noise traders submit their orders to market makers and the two risky securities are traded for cash. There is only one round of trading. The interest rate in the cash market is assumed to be zero.

Noise traders trade only for exogenous reasons. One way of thinking about noise trading is that the trading takes place because of consumption (in the stock market) or hedging (in the futures market) reasons that are not explicitly modelled[6]. So at $t = 0$ before the trading starts the noise traders receive a consumption or hedging shock that can be either negative or positive. We assume that the shock is positive with probability $\frac{1}{2}$ and negative with probability $\frac{1}{2}$. The shock is assumed to be uncorrelated between the two markets and also uncorrelated with the information that the informed traders have. If the consumption or hedging shock is positive, the noise traders would like to buy risky securities and if the shock is negative, they would like to sell securities.

The market makers are assumed be risk-neutral and competitive. At $t = 1$ the market makers observe the orders in their respective markets: the market makers in the stock market observe the orders in the stock market and market makers in the futures market observe the orders at the futures market. Based on these orders, the market makers set their prices in their respective markets. At $t = 2$ the market makers observe the prices that were quoted in the other market and then they update their prices based on that new information. Note that no new trading takes place at $t = 2$. P_0 is the price of both stocks and futures at $t = 0$ before the trading starts. The prices in the stock and futures markets are denoted by P_s and P_f respectively at $t = 1$, and the trading volumes in the two markets are denoted by S and F. The prices at $t = 2$ are denoted by P_2 .

2.2 Trading at $t = 1$

Informed speculators trade both in the futures market and in the stock market. In the futures market they are able to trade with out any restrictions according to their information. In the stock market they might face a short sales constraint. So when the informed traders receive a negative signal, they can always sell futures contracts. In the stock market the informed traders are only able to sell if they own the stock. We assume that there are two kinds of informed traders: with probability λ they own the stock and hence can always sell in both markets, and with probability $1 - \lambda$ they don't own the stock and selling is impossible in the stock market. Naturally there is no difference in informed traders ability to buy either the stock or the futures contract.

The noise traders face the same problem as informed traders. In the futures market they can always trade according the their hedging needs, but in the stock market they can only sell if they own the stock. For simplicity it is assumed that the short sales constraint is binding for the noise traders with the same probability as with the informed traders: with probability $1 - \lambda$ the constraint is binding and with probability λ the noise traders own the stock and are able to sell if needed[7]. Noise traders orders are normalized to be of one unit in both markets. So noise traders always buy one stock or a futures contract when they receive a positive consumption or hedging shock. In the futures market, they always sell one contract after a negative shock. In the stock market they sell a stock after a negative shock with probability λ and with probability $1 - \lambda$ they don't trade at all.

There are separate market makers for both markets. It is assumed that market makers in both markets are able to observe only the buy and sell orders in their own markets at $t = 1$, so that the prices in the other market are initially unobservable to the market maker in the other market. The same structure is also in Chan (1993), where the purpose is to explain cross-autocorrelation between different stocks. This assumption of simultaneous unobservability of the other market's prices is crucial to the results of this paper. Without this assumption there wouldn't be any price differences between the two markets. In a dynamic setting this can be thought of as informational lag between the two markets: the market makers don't observe the present order flow in the other market, but could observe the past prices in the other market. In addition to observing the buy and sell orders separately in their own markets, the market makers know the probabilities of information signals, consumption shocks and binding short sales constraint, but they don't of course observe the realizations of these variables. The market makers update their beliefs in Bayesian fashion about the likelihood of high and low signals after receiving both buy and sell orders and then set prices. The prices are set so that on expected terms the market makers breaks even and that the markets clear.

Informed traders buy and sell using the same order sizes as noise traders. Informed traders are able to make limit orders. In most Kyle (1985) type models the informed traders are assumed to be able to make only market orders. Here the strategy space of informed traders is enlarged by enabling them to make orders conditional on the price that would prevail if they were to place a buy or sell order. Limit orders are a more realistic way of modelling informed traders' behavior. A convenient way of modelling limit orders is to use the results from Rochet and Vila (1994). They show that the Kyle (1989) model, where limit orders are possible for the informed trader, is equivalent to the Kyle (1985) model, where the informed trader only places market orders, if in the latter it is assumed that the informed trader observes the amount that noise traders are trading. Following Rochet and Vila (1994) it is assumed that the informed traders observe noise traders orders before buying or selling. However, it is important to emphasize that this assumption is merely a convenient way of modelling limit orders.

Placing an order with the market maker costs the an amount c in both markets. It is assumed that $\frac{1-\lambda}{3-2\lambda} > c > 0$. This cost is small enough to allow profitable trading whenever prices do not fully reflect the information that informed traders have, but prohibits orders when the profit form trading is zero.

2.3 Prices in the futures market at $t = 1$

When the informed trader has received a high signal, she has to make the decision whether to buy a futures contract or not. She is able to make a limit order: depending on noise trader demand, the informed trader will either buy one futures contract or do nothing. This is equivalent to placing an order conditional on a certain price. So if the noise trader buys one contract, the informed trader will not do anything. If she bought one contract as well, the market maker would know that informed trader is buying and hence the signal must have been high. As a result she would lose the amount c. This will happen with probability $\frac{1}{4}$. As a result, one buy order indicates that a high signal has occurred. Similarly, if the signal has been low and the noise traders sell one futures contract, the informed trader again will do nothing: two sell orders would indicate to the market maker that a negative signal has occurred with certainty. So one sell order indicates that a low signal has occurred. When the signal has been high, but the noise trader is selling, then the informed trader can buy. Conversely, in the case of a low signal and noise trader is buying, the informed trader can now sell. As a result, when ever the market maker sees one buy order and one sell order, he is not able to change his beliefs about the likelihood of a good signal, since both negative and positive signals are equally likely.

Signal received	**Noise trader demand**	**Informed trader demand**	**Joint probability**
High	+1	0	$\frac{1}{4}$
High	-1	+1	$\frac{1}{4}$
Low	+1	-1	$\frac{1}{4}$
Low	-1	0	$\frac{1}{4}$

Now the prices for futures contracts, keeping in mind that a high signal is normalized to be one and a low signal is normalized to be zero, can be simply stated as the conditional probability that the high signal has occurred given the observed orders:

$$
\begin{aligned}
P_f(H \mid +1, 0) &= 1 \\
P_f(H \mid +1, -1) &= \frac{1}{2} \\
P_f(H \mid -1, 0) &= 0
\end{aligned}
\tag{1}
$$

2.4 Prices in the stock market at $t = 1$

Pricing of the stock is more complicated than the pricing of the futures contract because of the potentially binding short sales constraint that either the informed or the noise trader faces. First the case when the signal is positive is considered.. When the noise trader demand is positive, the informed trader can either buy one stock or do nothing. If she bought a stock, then the market maker would know that the signal has been positive with certainty. Then the informed trader would loose the cost c. So she is better off doing nothing. If the noise trader sells one stock, the informed trader can potentially buy one stock, because this order flow might occur also with a negative signal. Finally, if the noise trader is unable to trade because of the short sales constraint, the informed trader might be able to buy a stock profitably depending on what happens when the signal is negative.

As a summary the demands from the informed and noise traders together with the joint probability of the event occurring can be summarized as follows:

Short sales constraint binding	**Noise trader demand**	**Informed trader demand**	**Joint probability**
No	+1	0	$\frac{\lambda}{4}$
No	-1	+1	$\frac{\lambda}{4}$
Yes for NT	+1	0	$\frac{1-\lambda}{4}$
Yes for NT	0	+1	$\frac{1-\lambda}{4}$

When the information received by the informed traders is negative and the short sales constraint is not binding, the demands of the traders are exactly like in the futures market: if the noise trader buys, the informed traders will sell one stock and if the noise trader sells, then the informed trader is better off by doing nothing. If the informed trader cannot trade because of the short sales constraint, the order flow is determined by the noise trading activity: either one buy or one sell order is observed by the market maker. If the noise trader is constrained by the binding short sales constraint, the informed trader will sell one stock if the noise trader buys and will do nothing if the noise trader does nothing. In the latter case if the informed trader tried to sell, the market maker would know with certainty that the signal has been low. When the short sales constraint is binding for both sides, then the informed trader cannot do anything and market maker sees only the orders of the noise trader.

This can be summarized as follows:

Short sales constraint binding	**Noise trader demand**	**Informed trader demand**	**Joint probability**
No	+1	-1	$\frac{\lambda^2}{4}$
No	-1	0	$\frac{\lambda^2}{4}$
Yes for IT	+1	0	$\frac{(1-\lambda)\lambda}{4}$
Yes for IT	-1	0	$\frac{(1-\lambda)\lambda}{4}$
Yes for NT	+1	-1	$\frac{(1-\lambda)\lambda}{4}$
Yes for NT	0	0	$\frac{(1-\lambda)\lambda}{4}$
Yes for both	+1	0	$\frac{(1-\lambda)^2}{4}$
Yes for both	0	0	$\frac{(1-\lambda)^2}{4}$

Now we are able to calculate the prices for the stock given the order flow. Bayesian updating yields the following prices for the stock:

$$
\begin{aligned}
P_s(H \mid +1, 0) &= \frac{2-\lambda}{3-2\lambda} \qquad (2)\\
P_s(H \mid +1, -1) &= \frac{1}{2}\\
P_s(H \mid 0, 0) &= 0\\
P_s(H \mid -1, 0) &= 0
\end{aligned}
$$

It is worth noting that no trading is bad news for the stock's price. In this simple model no trading leads to full revelation: no trading means that a good signal hasn't occurred, otherwise somebody would have placed a buy order.

2.5 Implications for prices and trading volumes

Now it is possible to calculate the reactions in both markets when informed traders receive either the high or low signals. The prices given by the equations 1 and 2 are multiplied by the probability of observing that order flow given the signal. The expected price for the futures contract given the high or low signal is thus:

$$\begin{aligned} E\left(P_f \mid H\right) &= \frac{3}{4} \\ E\left(P_f \mid L\right) &= \frac{1}{4} \end{aligned} \tag{3}$$

Similarly the expected prices in the stock market are calculated given either the high or low signal:

$$\begin{aligned} E\left(P_s \mid H\right) &= \frac{\lambda}{4} + \left(1 - \frac{\lambda}{2}\right) \frac{2-\lambda}{3-2\lambda} \\ E\left(P_s \mid L\right) &= \frac{\lambda}{4} + \left(\frac{1-\lambda}{2}\right) \frac{2-\lambda}{3-2\lambda} \end{aligned} \tag{4}$$

Now it is possible to state the following two results that establish that the futures prices are more informative than the stock prices:

Proposition 1 *Given the low signal, the expected price of the futures contract is lower than the expected price of the stock. The difference* $E\left(P_f \mid L\right) - E\left(P_s \mid L\right)$ *is an increasing function of* λ. *If the short sales are allowed, the expected prices are equal.*

Proof. First note that if $\lambda = 0$, then $E\left(P_s \mid L\right) = \frac{1}{3}$ .Also if $\lambda = 1$, then $E\left(P_s \mid L\right) = \frac{1}{4}$. Now it suffices to show that $\frac{dE(P_s|H)}{d\lambda} < 0$ for $\forall$ λ. The derivative is $\frac{dE(P_s|H)}{d\lambda} = \frac{-1}{4(3-2\lambda)^2}$, which is always negative. ■

This result is very intuitive, since a short sales constraint diminishes the opportunities for trading in the stock market, but not in the futures market after the informed trader has received negative information. Note that the short sales constraint doesn't actually have to be binding, it is enough that the constraint is expected to be binding for some traders. The next result is less intuitive at a first glance:

Proposition 2 *Given the high signal, the expected price of the futures contract is higher than the expected price of the stock. The difference $E(P_f \mid H) - E(P_s \mid H)$ is a decreasing function of λ. If the short sales are allowed, the expected prices are equal.*

Proof. First note that if $\lambda = 0$, then $E(P_s \mid H) = \frac{2}{3}$ .Also if $\lambda = 1$, then $E(P_s \mid H) = \frac{3}{4}$. Now it suffices to show that $\frac{dE(P_s|H)}{d\lambda} > 0$ for $\forall\ \lambda$. The derivative is $\frac{dE(P_s|H)}{d\lambda} = \frac{1}{4(3-2\lambda)^2}$, which is always positive. ■

The reason behind this result is that the short sales constraints the informed and noise traders face after a low signal create less information revelation in the stock market even after a good signal. Of course the short sales constraint is not binding for an informed trader after a positive signal: she is always able to buy a stock just like she is always able to buy a futures contract. However, the order flow is now less informative in the stock market than in the futures market. If the market maker observes one buy order in the stock market, he doesn't know whether that resulted from a good signal or simply from the inability of the informed trader to sell after a low signal.

The two above results concerning the informativeness of futures and stock prices are not directly empirically testable. Hence, we establish the following relationships that can be directly tested.

Proposition 3 *The expected basis $E(P_f - P_s)$ is positively related to the contemporaneous futures return $E(P_f - P_0)$.*

Proof. The covariance can be written as $E[(P_f - P_s)(P_f - P_0)]$, since the expected futures return is zero. Using that definition, the covariance can be written as

$\frac{1}{16}\left[\frac{1-\lambda}{3-2\lambda}(2-\lambda) + \frac{2-\lambda}{3-2\lambda}(1-\lambda) + \lambda\right]$, which simplifies to be $\frac{1}{16}\frac{4-3\lambda}{3-2\lambda} > 0$ ■

This proposition establishes that when the futures price changes, the stock price changes to the same direction, but by less of an amount.

Proposition 4 *The expected basis $E(P_f - P_s)$ is negatively related to the contemporaneous stock return $E(P_s - P_0)$*

Proof. The covariance can be written as $E\left[\left(P_f - P_s\right)\left(P_s - P_0\right)\right]$, since the expected stock return is zero. Using that definition, the covariance can be written as $\frac{1}{8}\left[\frac{1-\lambda}{3-2\lambda}\frac{2-\lambda}{2(3-2\lambda)} - \left(\frac{1}{2(3-2\lambda)}\right)^2(3-2\lambda) - \frac{2-\lambda}{3-2\lambda}\frac{1-\lambda}{2(3-2\lambda)} - \frac{1}{4}\right]$, which simplifies to be $-\frac{1}{32}\frac{4-2\lambda}{3-2\lambda} < 0$ ■

According to this proposition when the stock price changes, the futures price changes to the same direction, but by a smaller amount. Note, however, that the basis is more strongly related to the contemporaneous futures returns than to the contemporaneous stock return, since $\frac{1}{16}\frac{4-3\lambda}{3-2\lambda} > \frac{1}{32}\frac{4-2\lambda}{3-2\lambda}$ for $1 > \lambda$. Only if the short sales constraint is never binding there is no difference in magnitude.

Not only the expected prices, but also the expected trading volumes should differ in the stock market depending on the information that the informed traders receive. If the signal is negative and if the short sales constraint is binding for the informed trader, then naturally the expected trading volume should be lower compared to the volume if the signal is positive.

Proposition 5 *The expected stock trading volume $E(S)$ is positively related to the contemporaneous stock return $E(P_S - P_0)$*

Proof. The covariance can be written as $E\left[S\left(P_s - P_0\right)\right]$, since the expected stock return is zero. Using that definition, the covariance can be written as $\frac{1}{8} - \frac{\lambda}{8} = \frac{1-\lambda}{8} > 0$ ■

The two empirical implications about the pricing error and futures and stock returns could be results of a learning process between two markets that have informational lags between them (see Chan (1993)), but without short sales constraints there wouldn't be any relationship between the trading volume and returns.

Proposition 6 *The futures trading volume $E(F)$ is not related to the contemporaneous futures return $E(P_F - P_0)$*

Proof. It is straightforward to show that the covariance is always zero ■

2.6 Prices at $t = 2$

At $t = 1$ the marker makers observed the order flow in their own markets. After the trading has taken place, the market makers are able to observe what has happened in the other market. Based on the prices at $t = 1$ in the two markets, the market makers update their quotes using the Bayes rule. The following prices prevail at $t = 2$:

$$\begin{aligned} P_2\left(H \mid P_f = 1, P_s = \frac{2-\lambda}{3-2\lambda}\right) = P_2\left(H \mid P_f = 1, P_s = \frac{1}{2}\right) = 1 \\ P_2\left(H \mid P_f = \frac{1}{2}, P_s = \frac{2-\lambda}{3-2\lambda}\right) = \frac{2-\lambda}{3-2\lambda} \\ P_2\left(H \mid P_f = 0, P_s = \frac{2-\lambda}{3-2\lambda}\right) = P_2\left(H \mid P_f = 0, P_s = \frac{1}{2}\right) = 0 \\ P_2\left(H \mid P_f = 0, P_s = 0\right) = P_2\left(H \mid P_f = \frac{1}{2}, P_s = 0\right) = 0 \end{aligned} \tag{5}$$

Note that no new trading is needed to achieve this updating to new prices. It is also worth observing that both markets contribute to this learning process: the common price the prevails at $t = 2$ is always the same as the price that deviated the most from $P_0 = \frac{1}{2}$, irrespective of the market. In particular, if either one of the prices is fully revealing at $t = 1$, then both of the prices are fully revealing at $t = 2$.

2.7 Implications for lead-lag

Now it is possible to calculate the lead-lag relationships between the two markets. The following two propositions can be established:

Proposition 7 *The lagged futures return $P_f - P_0$ leads the expected stock return $E\left(P_2 - P_s\right)$.*

Proof. The covariance between second period stock return and first period futures return can be written as $E\left[\left(P_2 - P_s\right)\left(P_f - P_0\right)\right]$, since the expected futures return is zero. Using that definition, the covariance can be written as $\frac{1}{16}\left[\frac{1-\lambda}{3-2\lambda}\left(2-\lambda\right) + \frac{2-\lambda}{3-2\lambda}\left(1-\lambda\right) + \lambda\right]$, which simplifies to $\frac{1}{16}\frac{4-3\lambda}{3-2\lambda} > 0$ ■

Proposition 8 *The lagged stock return $P_s - P_0$ leads the expected futures return $E\left(P_2 - P_f\right)$*

Proof. The covariance between second period futures return and first period stock return can be written as $E\left[\left(P_f - P_s\right)\left(P_s - P_0\right)\right]$, since the expected stock return is zero. Using that definition, the covariance can be written as $\frac{1}{8}\left[\left(\frac{1}{2(3-2\lambda)}\right)^2(3-2\lambda)+\frac{1}{4}\right]$, which simplifies to $\frac{1}{32}\frac{4-2\lambda}{3-2\lambda} > 0$ ■

These two propositions are essentially the same as the propositions between the basis and the contemporaneous futures return and basis and the contemporaneous stock return. It can be also stated that the futures return leads the stock return more than the other way around, since $\frac{1}{16}\frac{4-3\lambda}{3-2\lambda} > \frac{1}{32}\frac{4-2\lambda}{3-2\lambda}$ for all $1 > \lambda$. Only if there is no short sales constraints the lead-lag relationship is equally significant both ways.

3 Empirical results[8]

Daily closing values are used for both the futures contract and the underlying stock index, called the FOX index, from the Finnish Options Market (FOM) to test the implications of this model. The sample contains data virtually from the start of the Finnish index futures market, May 27, 1988, until May 31, 1994 [9]. The Finnish market provides a good environment for testing our theory, since short sales were not allowed during the time of study. Moreover, there have been large deviations between stock and futures prices (see Figure 1).

Since we test a model of asymmetric information using a stock index and index futures prices, a crucial question is whether there really is asymmetric information among the investors concerning the value of an entire stock index. It can be argued that private information is mostly firm-specific, the effect of which should be largely diversified away in an index. We argue, however, that this is not the case with the FOX index. It consists of the 25 most actively traded stocks in the Helsinki Stock Exchange. As a value-weighted index only the few largest stocks dominate it in practise [10]. Hence private information regarding these few stocks should also be reflected in the whole index. Therefore the implications of our model of informed speculative trading should also be relevant to the derivatives market based on the FOX index.

Another interesting feature of the Finnish market is that in the stock market a broker has to identify herself when doing trades, whereas in the index futures and options market she does not have to. This readily gives another motive for better informed traders in Finland to use the derivatives' market.

On a thin market like Finland there is a potential problem of infrequent trading of stocks that would induce spurious positive autocorrelation into the stock index returns. Indeed, the daily logdifferences of the FOX index do exhibit large positive autocorrelation (see Table I)[11]. The index futures prices could thus "lead" the stock index value merely by taking into account the positive autocorrelation exhibited by the observed index returns. Therefore it is necessary to first purge the index returns from the autocorrelation, for otherwise it is impossible to tell whether a lead-lag relationship between the futures and the stock market is really due to the short sales constraints or due to the spurious autocorrelation. For this purpose we use the method of Jokivuolle (1995) that allows the computation of the *true* stock index value - in levels as well as in returns - based on an ARMA(p,q) specification of the observed index return process[12]. Then the true index value and returns are used to control for the autocorrelation of the FOX index in our empirical tests. Hereafter, whenever we refer to an index value, return, or the futures basis (involving the index value), we mean the true index value, if not noted otherwise[13].

Of the two futures contracts that were simultaneously available in the Finnish market during our sample period, we use the one with the shorter time-to-maturity. The longer contract always has a time-to-maturity of two months plus the maturity of the shorter contract. A new contract replaces the old one a week before the expiration day. The main reason for using the shorter contract for the empirical analysis is its higher liquidity.

The futures basis is computed as the percentage difference between the futures market price and its theoretical benchmark value according to the cost-of-carry relationship [14] That in turn is computed using the 3-month Helsinki Interbank Offered Rate (Helibor), and the actual dividends paid on the underlying stock portfolio during the futures' remaining time-to-maturity. That is

$$Basis_t = (I_t^{f,o} - I_t^{f,m})/I_t^{f,m}, \tag{6}$$

where $I_t^{f,o}$is the observed index futures price at time t, and $I_t^{f,m} = (I_t^* - D_t^T)\exp[r(T-t)]$ is the theoretical index futures price at time t. $I_t^*$is the true index value at time t, T is the expiration period of the futures contract, and D_t^T is the present value at time t of the dividends between t and T. The risk free rate is denoted by r.

The futures return is computed as the index return implied by the futures prices assuming that the cost-of-carry relationship holds; i.e.

$$Futuresreturn_t = \ln(I_t^{*,i}/I_{t-1}^{*,i}), \tag{7}$$

where $I_t^{*,i} = I_t^{f,o}\exp[-r(T-t)] + D_t^T$.This is done in order to control for the deterministic cost-of-carry component of the futures price changes.

The futures trading volume is measured as the number of contracts traded daily. It does not show any trend during our period of investigation, although there is variation in the daily volume. The sample average number of contracts traded daily is 162. There is a significant number of days when there was no futures trading at all. Because of these zero observations in the futures volume series we analyze the series in levels as such, and do not use logarithmic transformations.

Trading volume of the FOX index on day t is measured according to the following formula:

$$volume_t = \sum_{i=1}^{25} \frac{High_{i,t} + Low_{i,t}}{2} N_{i,t}, \tag{8}$$

where $High_{i,t}$ is the maximum transaction price during day t of stock i, $Low_{i,t}$ is the minimum transaction price during day t of stock i, $N_{i,t}$ is the number of shares of stock i traded during day t, and 25 is the number of FOX index stocks. The average of the daily maximum and minimum transaction price of each stock was used as the best available proxy of the daily average price. The variable to be used in the regressions is the above FOX index trading volume scaled by the daily closing index value in order to control for changes in the overall price level. The scaled index trading volume exhibits a more cyclical pattern over the period under investigation than the futures trading volume. A period of high trading volume in 1988-89 was followed by a period of low volume in 1990-92. Then in 1993-94 the volume rapidly reached new heights exceeding those experienced in 1988-89.

We test the following five hypotheses that are implied by the model developed in section 2[15]:

1. the futures basis is positively related to the contemporaneous futures return,
2. the futures basis is negatively related to the contemporaneous index return,
3. the lagged futures return leads the contemporaneous observed index return,
4. the lagged observed stock return leads the contemporaneous futures return,
5. the stock index trading volume is positively related to the contemporaneous index return, and
6. the futures trading volume has no relationship with the contemporaneous futures return.

Table IIa presents the results of the OLS regression testing the first hypothesis. As the basis is rather persistent three first lags of the endogenous variable are included. The contemporaneous futures return obtains a highly significant coefficient with the correct positive sign. The lagged futures return also obtains a significant coefficient with a positive sign. These results are very stable throughout the five subperiods of equal length not reported here. Hence, the data clearly supports our first hypothesis.

Table IIb contains the results of the OLS regression testing the second hypothesis. As in table IIa three first lags of the endogenous variable are included. The contemporaneous index return obtains a highly significant coefficient with the correct negative sign. The lagged index return is positive and significant. This could be evidence of that there is a flow of information also from the stock market to the futures market. We return to this subject in testing the fourth hypothesis below.

Given the results of Table IIa it is not surprising that the results of the "lead-lag" regression, presented in Table IIIa, support the third hypothesis which is basically the dynamic version of the same effect driving the first hypothesis. An error-correction term is included in the regression to account for the apparent co-integration of the stock index and the index futures (see Engle and Granger, 1987). Note that, quite in accordance with the theory, the lagged futures return subsumes all explanatory power with respect to the current observed index return, leaving nothing to the lagged observed index return. Also notice that here the observed index returns are used instead of the true index returns, as the lead-lag setup based on a test of Granger-causality involve the lagged observed index returns which readily serve as a control for the observed index return autocorrelation. To complete the analysis the lead-lag relationship was also tested in the opposite direction, as presented in Table IIIb. The observed index return predicts the current futures return only in its third lag. Therefore the flow of information between the two markets mainly appears to go in one direction; from the futures market to the stock market. This is inconsistent with the result in Table IIb. If the basis is negatively related to the contemporaneous stock returns, then the lagged stock returns should lead futures returns.

Test results of the fifth hypothesis are presented in Table IV where IVa presents a version using the logdifference of the index trading volume as the endogenous variable, whereas IVb uses a version where the log level of the volume is the endogenous variable. In each case the contemporaneous index return obtains a highly significant positive sign, as is consistent with the theory. The time series of the index trading volume, both in log levels and the log difference form, contains occasional very large observations in absolute value. As these are fairly evenly distributed over time we tend to interpret them as occasional heteroscedasticity in the series. The overall OLS estimation strategy of using White's heteroscedasticity-consistent covariance matrix should readily account for this (White, 1980). As a second check, although not reported here, the index trading volume regressions using robust estimation, that is, the least-absolute-errors method (LAE, see Judge et al., 1988), were carried out. The coefficient estimates turned out to be very similar as in the OLS regressions. However, analysis of the OLS regressions with five subperiods of equal length revealed that the contemporaneous index return obtains a significant coefficient only in the last two subperiods, whereas in the third subperiod it is barely marginally significant (with a p-value of 13%). Nevertheless, the sign of the coefficient is correct (positive) throughout all the subperiods, although clearly not significant in the first two subperiods. Overall we conclude that the fifth empirical hypothesis also gets supported by the data.

The final hypothesis of no relationship between the futures trading volume and the contemporaneous futures return is studied in Table V. Consistent with the theory the coefficient of the futures return is not significant. However, it should be born in mind that in this case the theory's prediction coincides with the null hypothesis, so the fact that the null is not rejected should not be taken too strongly as evidence in favor of the new theory we propose.

In conclusion, the overall empirical results support quite well the predictions of the theory. Thus, the theory of the futures basis behavior and trading volumes based on asymmetric information in conjunction with short sales constraints appear to provide a reasonable explanation of the facts in the Finnish index futures market during the period of the study.

4 Conclusions

A primary motivation for this paper is to try to understand the large deviations of the stock index futures price from its arbitrage based cost-of-carry relationship in Finland. It is not satisfactory to refer only to the apparently large transactions costs in the Finnish market inhibiting efficient arbitrage, but it is also important to understand the futures basis dynamics inside any arbitrage-free band induced by transactions costs. A model which is based on short-selling restrictions of stocks and speculative futures buying and selling demand of an informed investor is proposed as an explanation of the observed phenomena. In the model short sales constraint decreases the possibilities for the informed trader to profit from negative information. Moreover, short sales constraint also makes the stock prices less informative even if the informed trader has received positive information. Using the a history of six years of daily data from the Finnish index futures market from May 27, 1988 until May 31, 1994, we find strong support for the model's prediction that the level of basis is positively related to the contemporaneous futures return and negatively related to contemporaneous stock returns, that the futures returns lead stock returns and that the trading volume in the stock market is positively related to the contemporaneous stock returns.

5 Endnotes

1. Similar issues are also deal with in Säfvenblad (1997).

2. Our model assumes that short sales are prohibited. This is not the case in the U.S. markets. However, short sales are still more costly than other types of trades and, moreover, short sales are not allowed on a down tick.

3. Puttonen (1993) also claims that futures lead stocks more when there are bad news. However, Martikainen and Puttonen (1994) find no statistically significant evidence for this, once heteroscedasticity is taken into account.

4. A similar binary Kyle-type model has previously been used by Dow and Gorton (1997). The classic example of a binary structure in a trading game is Glosten and Milgrom (1985).

5. In the empirical part we test our theory with an index futures contract and a stock index.

6. For the equivalence of consumption and hedging based models, see Sarkar (1994).

7. The assumption that informed and noise traders have the same probability of facing a short sales constraint doesn't affect our qualitative results at all. This assumption simplifies the calculations considerably.

8. See appendix for all the tables containing the empirical results.

9. Trading in index derivatives based on the FOX-index started in FOM on May 2, 1998.

10. Before the 1990's commercial banks had a large weight in the index, but since the economic depression in Finland in the early 1990's and the subsequent banking crises their market value dropped dramatically. In the last half of our data sample Nokia Corporation has been the largest company measured by market capitalization. Other important companies are mainly pulp and paper producers.

11. Alternatively, even in the absence of infrequent trading there can be positive autocorrelation in stock index returns as a result of differential information among stock specific market makers, as shown by the model of Chan (1993).

12. See Kempf and Korn (1998) for an empirical application of the Jokivuolle (1995) procedure in a similar context.

13. The computation of the true index value and returns, done in an ex post manner, was based on an AR(4) specification of the FOX index daily logdifferences (see Jokivuolle, 1995, for details). A Chow test, splitting the entire FOX index sample in two halfs, did not indicate a structural break in the series, thereby giving some justification for the short-cut of using ex post analysis.

14. Note that the terminology here deviates from the standard one where the basis is defined as the difference between the current futures and the spot price. When the riskless interest rate is zero and there are no interim dividends, as in our model, then the standard definition of the basis and the futures pricing error relative to the cost-of-carry relationship are the same.

15. Throughout our empirical analysis we are often forced to use several lags of the endogenous variable as explanatory variables to purge the models from residual autocorrelation. An expositionally "lighter" alternative might have been to use the autocorrelation consistent estimation method of Newey and West (1987). However, we do believe the approach we have adopted is econometrically at least as reliable as theirs.

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Appendix A: Tables and Figures

Figure 1.The futures percentage pricing error with respect to the cost-of-carry value, i.e., the basis, on 88/05/27-94/05/31.

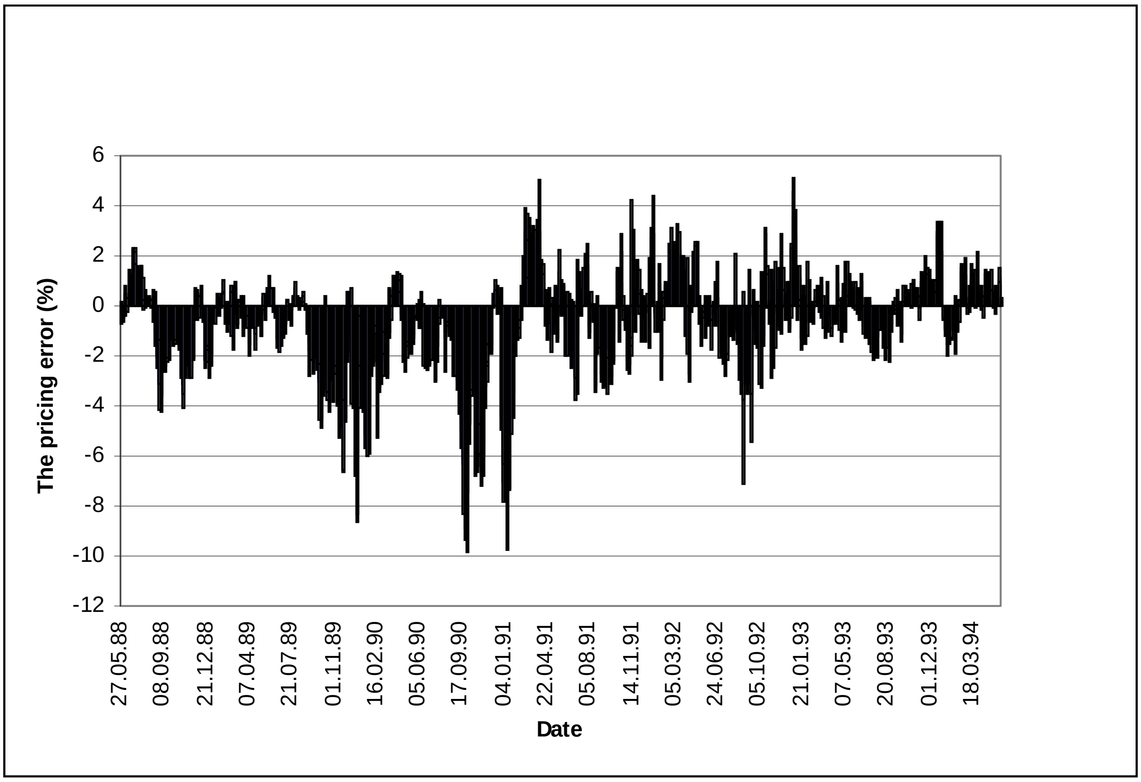

Table I. Summary statistics of selected variables on 88/05/27-94/05/31; the futures trading volume and open interest on 89/08/08-94/05/31. Figures in parentheses are coefficients of partial autocorrelation. "*" indicates statistical significance of an individual autocorrelation coefficient at 5% level.

	Basis	Observed index return	Futures return	Ln Stock trading vol.
#obs.	1508	1508	1508	1508
Mean	-.69	-.000004	.000003	11.34
St.dev.	1.92	.19 p.a.	.25 p.a.	1.05
Min	-10.11	-.049	-.09	8.37
Max	4.96	.068	.11	15.09
ρ_1	.85* (.85*)	.27* (.27*)	.09* (.09*)	.78* (.78*)
ρ_2	.80* (.30*)	-.02 (-.10*)	-.03 (-.04)	.75* (.34*)
ρ_3	.75* (.08*)	.03 (.07*)	.02 (.03)	.74* (.25*)
ρ_4	.70* (.02)	.10* (.07*)	.04 (.04)	.72* (.16*)
ρ_5	.66* (.01)	.09* (.05*)	.07* (.07*)	.71* (.12*)
ρ_6	.62* (.00)	.03 (.00)	-.01 (-.02)	.70* (.06*)
ρ_7	.59* (.05*)	.03 (.02)	.05* (.05*)	.70* (.09*)
ρ_8	.55* (-.03)	.06* (.03)	.05* (.03)	.69* (.06*)
ρ_9	.52* (.01)	.02 (-.01)	-.01 (-.02)	.69* (.08*)
ρ_{10}	.48* (-.03)	.05* (.05*)	.01 (.00)	.70* (.11*)

	Dln Stock trading vol.	Futures trading vol.	Open interest
#obs.	1508	1205	1205
Mean	-.00003	162	1386
St.dev.	.69	191	884
Min	-4.06	0	374
Max	3.21	1610	5427
ρ_1	-.41* (-.41*)	.46* (.46*)	.97* (.97*)
ρ_2	-.07* (.29*)	.35* (.17*)	.94* (-.02)
ρ_3	.01 (-.19*)	.33* (.15*)	.91* (-.04)
ρ_4	-.01 (-.15*)	.27* (.06*)	.88* (-.01)
ρ_5	.02 (-.08*)	.30* (.14*)	.85* (-.02)
ρ_6	-.04 (-.11*)	.26* (.04)	.82* (.03)
ρ_7	.02 (-.07*)	.24* (.05*)	.79* (-.03)
ρ_8	-.02 (.09*)	.27* (.08*)	.76* (-.03)
ρ_9	-.03 (-.12*)	.24* (.03)	.74* (.02)
ρ_{10}	.07* (-.02)	.18* (-.04)	.71* (-.01)

Table IIa. The futures pricing error with respect to the cost-of-carry-value (the basis) regressed on the contemporaneous and lagged futures returns, measured as the logdifference of the index implied by the futures price during 88/05/27-94/05/31; daily observations. Q-rejections indicate the residual lags at which the cumulative Q-test for residual autocorrelation up to 15 lags rejects at the 5% significance level. I.e., the results displayed in the table below are from the model

$$Basis_t = \alpha_0 + \sum_{i=1}^{4} \alpha_i Basis_{t-i} + \sum_{i=0}^{1} \beta_{i+1} Futures\ return_{t-i} + \varepsilon_t \,.$$

	Basis(t-1)	Basis(t-2)	Basis(t-3)	Basis(t-4)	Futures return(t)	Futures return(t-1)	Const.
coeff.	.54	.25	.09	.02	25.33	5.23	-.06
p-value	(.000)	(.000)	(.003)	(.315)	(.000)	(.015)	(.010)
R^2 adj.	.79						
Q-rej's	None						

Table IIb. The futures pricing error with respect to the cost-of-carry-value (the basis) regressed on the contemporaneous and lagged logdifference of the index (index return) during 88/05/27-94/05/31; daily observations. Q-rejections indicate the residual lags at which the cumulative Q-test for residual autocorrelation up to 15 lags rejects at the 5% significance level. I.e., the results displayed in the table below are from the model

$$Basis_t = \delta_0 + \sum_{i=1}^{3} \delta_i Basis_{t-i} + \sum_{i=0}^{2} \gamma_{i+1} Index\ return_{t-i} + \varepsilon_t .$$

	Basis(t-1)	Basis(t-2)	Basis(t-3)	Index return(t)	Index return(t-1)	Index return(t-2)	Const.
coeff.	.65	.17	.08	-13.56	8.80	-.80	-.06
p-value	(.000)	(.000)	(.011)	(.000)	(.000)	(.706)	(.012)
R^2 adj.	.76						
Q-rej's	None						

Table IIIa. The logdifference of the *observed* index regressed on the lagged futures returns, measured as the logdifference of the index implied by the futures price, during 88/05/27-94/05/31; daily observations. Q-rejections indicate the residual lags at which the cumulative Q-test for residual autocorrelation up to 15 lags rejects at the 5% significance level. I.e., the results displayed in the table below are from the model

$$Observed\ index\ return_t = \phi_0 + \phi_1 Error\ Correction_{t-1} + \sum_{i=1}^{3} \varphi_i Observed\ index\ return_{t-i} + \sum_{i=1}^{3} \eta_{i+1} Futures\ return_{t-i} + \varepsilon_t$$

where the error correction variable is the residual from regressing the log of the observed index on the log of the futures price.

	EC(t-1)	Observed index return(t-1)	Observed index return (t-2)	Observed index return (t-3)	Futures return(t-1)
Coefficient	-.07	-.002	-.16	.08	.26
p-value	(.001)	(.977)	(.002)	(.090)	(.000)
	Futures return (t-2)	Futures return (t-3)	Constant		
Coefficient	.08	-.010	-.00002		
p-value	(.036)	(.787)	(.954)		
R^2 adj.	.15				
Q-rejections	None				

Table IIIb. The futures return, measured as the logdifference of the index implied by the futures price, regressed on the lagged logdifferences of the *observed* index during 88/05/27-94/05/31; daily observations. Q-rejections indicate the residual lags at which the cumulative Q-test for residual autocorrelation up to 15 lags rejects at the 5% significance level. I.e., the results displayed in the table below are from the model

$$Futures\ return_t = \kappa_0 + \kappa_1 Error\ Correction_{t-1} + \sum_{i=1}^{3} \lambda_i Futures\ return_{t-i} +$$

$$\sum_{i=1}^{3} \eta_{i+1} Observed\ index\ return_{t-i} + \varepsilon_t$$

where the error correction variable is the residual from regressing the log of the observed index on the log of the futures price.

	EC(t-1)	Futures return (t-1)	Futures return (t-2)	Futures return (t-3)	Observed index return (t-1)
Coefficient	-.04	.05	-.008	-.02	.12
p-value	(.190)	(.433)	(.897)	(.724)	(.137)
	Observed index return (t-2)	Observed index return (t-3)	Constant		
Coefficient	-.10	.13	-.9-E5		
p-value	(.192)	(.042)	(.982)		
R^2 adj.	.02				
Q-rejections	11				

Table IVa. The *logdifference* of the trading volume of the index stock basket regressed on its own lags and the index return during 88/05/27-94/05/31; daily observations. Q-rejections indicate the residual lags at which the cumulative Q-test for residual autocorrelation up to 15 lags rejects at the 5% significance level. I.e., the results displayed in the table below are from the model

$$volume_t \equiv \ln(\Delta Volume_t) = \mu_0 + \sum_{i=1}^{9} \mu_i volume_{t-i} + \sum_{i=0}^{1} \nu_{i+1} Index\ return_{t-i} + \varepsilon_t$$

	volume (t-1)	volume (t-2)	volume (t-3)	volume (t-4)	volume (t-5)	volume (t-6)
Coefficient	-.67	-.53	-.41	-.32	-.25	-.24
p-value	(.000)	(.000)	(.000)	(.000)	(.000)	(.000)
	volume (t-7)	volume (t-8)	volume (t-9)	Index return(t)	Index return(t-1)	Constant
Coefficient	-.18	-.17	-.12	6.66	3.53	.001
p-value	(.000)	(.000)	(.000)	(.000)	(.000)	(.932)
R^2 adj.	.34					
Q-rejections	None					

Table IVb. The log of the trading volume of the index stock basket regressed on its own lags and the index return during 88/05/27-94/05/31; daily observations. Q-rejections indicate the residual lags at which the cumulative Q-test for residual autocorrelation up to 15 lags rejects at the 5% significance level. I.e., the results displayed in the table below are from the model $Volume_t = \varpi_0 + \sum_{i=1}^{15} \varpi_i Volume_{t-i} + \theta_1 Index\ return_t + \varepsilon_t$.

	Volume(t-1)	Volume(t-2)	Volume(t-3)	Volume(t-4)	Volume(t-5)	Volume(t-6)
Coefficient	.33	.12	.12	.08	.06	.008
p-value	(.000)	(.000)	(.000)	(.014)	(.036)	(.748)
	Volume(t-7)	Volume(t-8)	Volume(t-9)	Volume(t-10)	Volume(t-11)	Volume(t-12)
Coefficient	.04	.01	.04	.09	-.007	.01
p-value	(.210)	(.734)	(.173)	(.000)	(.800)	(.584)
	Volume(t-13)	Volume(t-14)	Volume(t-15)	Index return(t)	Constant	
Coefficient	.02	-.03	.04	6.94	4.04	
p-value	(.503)	(.181)	(.035)	(.000)	(.000)	
R^2 adj.	.72					
Q-rejections	None					

Table V. The level of the futures trading volume regressed on its own lags and the futures return during 88/05/27-94/05/31; daily observations. Q-rejections indicate the residual lags at which the cumulative Q-test for residual autocorrelation up to 15 lags rejects at the 5% significance level. I.e., the results displayed in the table below are from the model $Futures\,Volume_t = \vartheta_0 + \sum_{i=1}^{8} \vartheta_i Futures\,Volume_{t-i} + \varsigma_1 \text{Futures}\; return_t + \varepsilon_t$.

	Futures Volume (t-1)	Futures Volume (t-2)	Futures Volume (t-3)	Futures Volume (t-4)	Futures Volume (t-5)
Coefficient	.34	.09	.10	.005	.12
p-value	(.000)	(.036)	(.018)	(.899)	(.010)
	Futures Volume (t-6)	Futures Volume (t-7)	Futures Volume (t-8)	Futures return(t)	Constant
Coefficient	.02	.03	.08	-466.05	25.23
p-value	(.567)	(.411)	(.018)	(.157)	(.000)
R^2 adj.	.36				
Q-rejections	None				