FINANCIAL MARKET LINKAGES AND ORDERFLOW*

Jan-Magnus MOBERG[1] and Genaro SUCARRAT[2]

12 October 2006

Abstract

We study to what extent the returns of foreign financial markets and order-flow at the Oslo Stock Exchange (OSE) determine the value of an index of liquid stocks at the OSE. The foreign markets included in our study are the US stock market (measured by the NYSE Composite Index), the European stock markets (measured by the EuroFirst100 index) and the oilmarket (measured by the spot oilprice at the International Petroleum Exchange (IPE)). We study their impact both at the daily and intra-daily (15 minute intervals) levels and find that the return in the European stock markets have the strongest influence on the Oslo Stock Exchange of the foreign financial markets both on daily and intra-daily level. Surprisingly, neither contemporaneous nor lagged returns of the NYSE Composite Index have a significant impact on a daily level. A likely reason for this is that the impact of NYSE stocks works through the EURF100 index. Our results also suggest that the impact from oil price is stronger overnight than during trading hours. We also find that order flow affect market return in the most liquid Norwegian companies independent of how foreign markets move.

JEL Classification: C53, F31
Keywords: Order Flow, Oil Price, Oslo Stock Exchange

[1]Corresponding author. Norwegian School of Economics and Business Administration. Email:jan.moberg@nhh.no.

[2]Department of Economics, Universidad Carlos III de Madrid (Spain), CORE and Department of Economics, Université catolique de Louvain (Belgium). Email: sucarrat@core.ucl.ac.be.

*We are greatly indebted to various people for useful questions, comments or suggestions at different stages, including Jonas Andersson, Luc Bauwens, Randi Næs and David Veredas. A special thanks to Øyvind Skaar at the Oslo Stock Exchange for preparing our data and answering questions regarding them. Errors and interpretations being our own applies of course. Genaro Sucarrat acknowledges financial support by the European Community's Human Potential Programme under contract HPRN-CT-2002-00232, MICFINMA.

1 Introduction

On a global scale the OSE is comparatively small and the conventional view is that its value is determined by other stock exchanges, in particular the US and European, and the oil price due to its importance for the Norwegian economy. The aim of this project is to study to what extent this actually holds, paying particular attention to the impact of 1) OSE order flow, 2) stock exchanges abroad and 3) the oil price. We study their impacts both at daily and intra-daily (15 minute intervals) levels.

The literature of movements between financial markets may be divided into two strands. The first strand focuses on the links between returns across markets, whereas the second focuses on the relation between volatilities across markets. Our study is first and foremost a contribution to the first strand. Grubel (1968) focused on the comovements existing between different markets and examined correlations in order to determine the potential benefits from international diversification from a U.S. point of view. Later papers extended this approach and studied lagged dependencies between markets. This can be done examining lagged correlations or performing univariate regressions of a country index return on lagged foreign index returns as in Copeland and Copeland (1998). They find, using U.S. country and industry indexes, that the U.S. has statistically significant one-day leads over markets in Europe and Asia and that no significant leads extend beyond one day. In particular, they find that OSE has a contemporaneous and one-day lagged relationship with the U.S. index.

Eun and Shim (1989) estimate a VAR system in order to get for each market an impulse response function to past shocks stemming from other countries. More sophisticated approaches have been proposed by Malliaris and Urrutia (1992) who provide explicit causality tests to detect which market are leading the others. Arshanapali and Doukas (1993)) use cointegration tests to document the linkages and dynamic interactions existing between markets. Even though there are no systematic conclusions regarding the direction and magnitude of existing international links two findings have been frequently reported; the US market is the most influential market and the lead-lag relationships existing between different markets vanish beyond one day.

To test the price effect for a given trade it is necessary to study order flow. Microstructure models predict a positive relation between stock return and order imbalances because order flow communicates non-public information, and once communicated, it is reflected in price. Glosten and Milgrom (1985) and Huang and Stoll (1997) contribute to the uniform findings in the literature that prices are positively related to the sign and size of a trade. Two methodologies have generally been used to test whether order flow has a persistent price effect on securities. The first approach is to estimates a vector-autoregressive model (VAR) and test whether innovations in order flow have long-run effects on price. Hasbrouck (1991) pioneered this approach measuring information content in stock transactions and how they influenced subsequent quotes. His analysis is done on high frequency data in transactions time. In this model order flow is further simplified to an indicator variable with value +1 if the trade is buyer-initiated, -1 if seller-initiated and 0 if it is a undetermined trade. He concludes that the full impact of a trade on the security price is not felt instantaneously, but with a protracted lag. The second approach uses time-aggregated order flow to explain price movements in foreign exchange markets. In this context order flow can be defined as the net of buyer-initiated and seller-initiated orders. This time-aggregated order flow can be interpreted as a measure of net buying pressure. The idea behind this aggregation is that if single trades have only transitory effects on price, then order flow aggregated over the day will not be closely related to daily price movements. Dunne et al. (2005) obtain a structural relationship between equity returns, exchange rate returns and their relationships to home and foreign market order flow. They find that a high percentage of aggregate equity return variation is explained jointly by exchange rate returns and macroeconomic order flows.

Most existing studies analyse order imbalances around specific events or over short periods of times. In the market microstructure literature the observations are usually in transaction time, hence very short time intervals for liquid securities. Lauterbach and Ben-Zion (1993) and Blume et al. (1989) analyse order-imbalances around the October 1987 crash while Lee (1992) does the same around earnings announcements. Chordia et al. (2002) analyse the S&P500 index and finds that order imbalances are strongly related to contemporaneous absolute returns after controlling for market volume and market liquidity and that it is imperative to account for order imbalance in addition to volume in order to explain volatility. To calculate the order flow for each stock they infer trade direction according to the algorithm proposed by Lee and Ready (1991).

The remainder of the paper is structured as follows. In section 2 we introduce the data we use in this study. We also give a brief introduction to the OSE, the concept of order flow as well as the other foreign markets in this study. in Section we present and discuss the results. This section has three subsections. The first one looks at the relation between OBX-returns and order flow and tries to explain whether order flow aggregated over a trading day determines daily returns for a stock index. The second and third subsection analyse whether foreign financial markets and order flow determines the returns at the OSE on a daily and high-frequency interval respectively. In section 4 we conclude.

2 Data

2.1 The Oslo stock exchange

Norway is a small and open economy with only four and a half million inhabitants, and has one of the highest ratios of export plus import to gross domestic product (GDP) in the world. The petroleum sector plays a major role in the Norwegian economy. In 2004 oil and gas accounted for 50 percent of exports, and worldwide Norway is the third biggest oil exporter after Saudi Arabia and Russia. The OSE is the only regulated market place for securities trading in Norway. It is part of the NOREX-alliance, which is a strategic alliance between the Iceland Stock Exchange, the OSE and OMX. OMX own and operate the exchanges in Stockholm, Copenhagen, Helsinki, Tallinn, Riga and Vilnius. The market value of all companies listed on the OSE totaled NOK 996 billion by the end of 2004. The three largest companies measured in market value, Norsk Hydro, Statoil, and Telenor, attracted alone a turnover in total of NOK 410 billion. This represents 45 percent of the year's turnover.

In terms of size, listed companies range from a market capitalization of NOK 25 million to NOK 200 billion. At the end of 2004 there where 208 companies listed on OSE, of which 20 were foreign companies and 20 were Norwegian savings banks issuing primary capital certificates.

Table 1: Descriptive statistics of the OSE

	2004	**2003**
OSE Benchmark Index (OSEBX)	236.7	170.97
Percentage change OSEBX	38.4	48.4
Market capitalization all companies (NOK billion)	996	689.7
Total turnover (NOK billion)	906	552.5
Average turnover per day (NOK billion)	3.6	2.21
Number of transactions	3 407 688	2 348 085
Average value per transaction (NOK)	265 000	235 000
Turnover velocity	108.77	97.73
Number of listed companies	188	178
Number of foreign companies	20	21

Trading volume in the equity market at the OSE went up 60 percent from 2003 to 2004. The increased interest in the Norwegian stock market was largely due to foreign investors. NOREX has encouraged a number of foreign investment firms to start trading on the OSE in their own name over the last years. Over the two last years foreign investment firms have increased their market share from under 10 percent to 25 percent. It does not seem that this increase has been achieved at the expense of Norwegian investment firms, and it is rather the case that it reflects greater trading activity and better liquidity for Norwegian stocks in general. Foreign investors account for between 60 and 70 percent of daily share trading. This is reflected in the ownership structure of listed companies in that foreigners now hold 33 percent of the total market capitalization of companies listed on the OSE.

208 securities where listed at the OSE by the end of 2004. A large portion of these securities are traded infrequently, some not even every day. Our analysis relies on liquid securities only. We therefore use the OBX-index as a proxy for the value of the OSE. The OBX Index consists of the 25 most liquid securities at the OSE, and comprised 80 percent of the total market value at the OSE at the end of 2004. The constituents are selected on the basis of a six months turnover rating. It is a semiannually revised free float adjusted price index (not dividend adjusted) with composition changes implemented on the third Friday in December and June. In the period between the composition review dates the number of shares for each constituent is fixed with exception of continuous adjustments for corporate actions with priority for excisting shareholders. The four largest companies, measured in market capitalization at the end of 2004, were partially owned by the government. This government ownership is not accounted for in the free-float index.

The OSE is an order-driven market without any specialist or market maker providing liquidity to the security. Investors place orders through brokers registered as members at the exchange. An investor can submit limit orders at any price on a pre specified pricing grid, called tick size. Tick sizes vary according to the price of the security. For prices below NOK 10 the tick size is NOK 0.01; for prices between NOK 10 and NOK 50 the tick size is NOK 0.10; for prices between NOK 50 and NOK 150 the tick size is NOK 0.25; for prices between NOK 150 and NOK 1000 the tick size is NOK 0.50; and for prices above NOK 1000 the tick size is NOK 1. Orders can be placed with a limit price (limit order) or without a limit price (only valid for odd lot orders). Limit orders are placed in a limit order book for each security and are given a price-time priority. Market limit orders are executed immediately against the limit price in the order book. At the OSE, unlike e.g. the Paris stock exchange, market limit orders are allowed to walk up the book until they are fully executed.

In our study, trading hours at the OSE consist of a pre-trade period from 9.15 CET until 10.00 CET, a continuous trading period from 10:00 CET until 16:00 CET, and a closing auction from 16:00 CET until 16:10 CET (all hours in this essay are in Central European Time). The equilibrium price for the opening auction is set to the price where the maximum volume can be traded (Dutch auction). When a theoretical equilibrium price is calculated for a security, the best buy and best sell prices will be identical and equal to the equilibrium price. At approximately 10:05 orderbooks are uncrossed sequentially where orders that end up in a trade are deleted from the orderbook. During the continuous trading period, orders are automatically matched in the orderbook, meaning that sell and buy orders are matched automatically when the price, volume, and other specifications for a given order corresponds with order(s) previously entered in the order book.

Returns from the three foreign markets are decomposed into daytime and overnight return as shown in figure 1 in the appendix. Daytime returns are the returns during the trading hours at the OSE, while overnight return are returns accumulated in the foreign markets while OSE is closed. In the high-frequency analysis we distinguish between three different regimes, as depicted in Figure 2 in the appendix. The first regime is the time interval when OSE is closed, that is from 16:10 until 10.15 the following morning. The first regime ends at 10:15 due to the fact that the equilibrium prices for each stock derived from the opening auction is calculated sequentially and is not finished before around 10:05. The only difference in the index price from 16:15 and 10:00 the following day (but before the equilibrium prices are calculated) is the price change in the index due to the re-balancing of the index weights. This takes place every trading day before the opening auction starts. The second regime is during the continuous trading period from 10:15 until 16:00. This interval is decomposed into 15-minutes intervals to study the relationship between the foreign markets and OSE on shorter time intervals. The last regime is during the closing auction from 16:00 until 16:10.

We removed one observation from the analysis. During the opening auction on 19 February 2004 the OBX-index went up 3 percent without any significant spillover returns in the foreign markets. This observation had large effect on the parameter values and significance of the variables in the first interval from 10:00 to 10:15.

2.2 Order flow

Order flow is a measure of net buying pressure, and in its simplest version it is the net of buyer-initiated and seller-initiated turnover, see Lyons (2001). In other words, if buyer-initiated turnover is higher than seller-initiated then order-flow is positive, and conversely if buyer-iniated turnover is lower than seller iniated then order-flow is negative.[1] Our OSE dataset consists of all orders placed in the limit order book as well as all transactions for each stock listed on the exchange. This allows us to build the limit order book at any given time and we use the state of the order book at the time of a transaction to assign direction of the trade. If a trade occurs at the best buy price in the order book it is initiated by a seller, and if it occurs at the best sell price in the orderbook it is initiated by a buyer. If the transaction price is between the best quotes at each side of the order book it is considered to be undetermined. Positive and negative order flow for each stock are aggregated and weighted according to its weight in the OBX index for each trading day, and more precisely we define buyer-initiated turnover, seller-initiated turnover and order flow as:

$$OF_t^{Buy} = (\sum_{s=1}^{25} q_{s,t}^{Buy} * w_{s,t}) \tag{1}$$

$$OF_t^{Sell} = (\sum_{s=1}^{25} q_{s,t}^{Sell} * w_{s,t}) \tag{2}$$

$$RelOF_t = (OF_t^{Buy} - OF_t^{Sell})/(OF_t^{Buy} + OF_t^{Sell}) \tag{3}$$

where $q_{s,t}^{Buy}$ is buy-initiated turnover of stock s at t, $q_{s,t}^{Sell}$ is sell-initiated turnover of stock s at t, and $w_{s,t}$ is the index-weight associated with stock s at t. The index weights are updated every day based on closing market values at the previous trading day. Equation (3) is a thus a normalised relative measure of order flow that range from 1 to -1. We could alternatively have measured order flow as the difference between buyer- and seller-initiated number of trades, number of shares or dollars paid. These absolute measures do not perform as well as our measures in the regressions in terms of explanatory power. This is most likely due to the fact that extreme order flow observations has a smaller impact on our variable since it is a relative measure.

All securities in the OBX-index are included when calculating the order flow variable for each day, but we have removed two observations from the dataset regarding the order flow

[1] As a consequence this is a transaction based way of assigning direction to trades. An alternative way of assigning direction of trades is the quote based algorithm of Lee and Ready(1991). According to this algorithm a trade is classified as buyer (seller) initiated if it is closer to the ask (bid) of the prevailing quote.

at the OSE. The Norwegian Ministry of Petroleum and Energy sold 100 million and 18 million shares in Statoil at the 9^{th} of June and 16^{th} of June respectively. This caused a large order flow imbalance that was known to the public before the event took place, and is therefore not relevant for our analysis.

Transactions data are included or excluded according to two criteria. First, the transaction has to occur during the continuous trading period. Transactions resulting from the opening auction occur when the continuous trading period starts but are excluded. Second, we do not include transactions with a price between the best buy and sell price in the limit order book. 2.5 percent of all transactions (during the continuous trading period) in the securities included in the OBX-index were excluded due to this criterion. When an investor posts an order that results in a transaction, this order can match several orders in the order book, but is only regarded as *one* transaction. If an investor for example post a limit order to buy 100 000 shares at the best sell price in the order book this will result in a single transaction of 100 000 shares if the depth at the best sell is larger or equal to this order size. This definition is independent of whether the buy order matches several orders, possibly from different brokers, or only one single order in the order book (with time priority at the best sell and at least the size of 100 000 shares).

2.3 Foreign financial markets

We use the transaction price implied by Brent crude futures for the earliest delivery month at the International Petroleum Exchange (IPE) in London as a proxy for the spot oil price for European oil.[2] The IPE Brent Crude futures contract is a deliverable contract based on Exchange of futures for physical (EFP) delivery with an option for cash settlement. A continuous price series for the price per barrel of Brent Crude oil is constructed by means of a back-adjusted splicing algorithm using 5-minutes log-returns of the associated futures traded at the International Petroleum Exchange (IPE) in London. The splicing occurs at the end of the trading day before the last day the future is traded at the IPE, typically around the 15th in each month, and the source of our untransformed data is Olsen Financial Technologies (OFT).[3]

To analyse the effect on OSE from the stock market in Europe and the US we use the NYSE Composite Index and the EuroFirst100 (EURF100) Index as proxies.[4] The NYSE Composite Index is designed to measure the performance of all common stocks listed on the NYSE. As of year-end 2004, the NYSE Composite consists of over 2,000 U.S. and non-U.S. stocks. It is a measure of the changes in aggregate market value of all NYSE-listed common stocks, adjusted to eliminate the effects of capitalization changes, new listings and delistings. The index is weighted using free-float market capitalization and calculated on both price and total return basis.

[2] The source of the data is Olsen Financial Technologies (OFT).

[3] One extreme observation was deleted prior to transformations. The deleted observation corresponds to the last trade in the interval 17:50 CET - 17:55 CET on 23 August 2004, and entails a 51% drop in log-return from 43.28 USD in the previous interval to 25.95 USD.

[4] Again, the source of the data is OFT.

The EURF100 Index is comprised of the 60 largest securities from eligible markets (Eurozone + UK) plus 40 securities chosen from the most underweighted economic groups relative to the index universe. None of them were listed on the OSE in 2004.

NYSE has continuous trading from 15:30 until 22.00, EURF100 is traded from 9:00 until 17:30 while the IPE is open from 11:00 until 20:30 (in November and December 2004 it did not open before 15:30). When decomposing the NYSE composite return, the daytime return (NYSE_t) is calculated as the log-return from 15:30 until 16:10, while overnight return (NYSE^*_{t-1}) is calculated from 16:10 until 22:00 when OSE is closed. Daytime and overnight return are also calculated for the two other markets, see figure 1 in the appendix.

3 Results

3.1 The uncontrolled impact of order flow on OBX returns

In Evans and Lyons (2002) daily order flow alone is capable of accounting for a substantial part of the daily variations in exchange rate returns. The purpose of this subsection is to obtain an idea of how the explanatory power of our order-flow variable compares with theirs, and to this end we estimate the "uncontrolled" impact of order flow on OBX returns at both the daily and intradaily levels. With "uncontrolled" we simply mean that we do not control for the impact of other variables by including them in the regressions. For the daily analysis we run the regression:

$$r_t^{obx} = a_0 + a_1 * RelOF_t + u_t \tag{4}$$

$RelOF_t$ is the normalised relative order flow (see equation 3) and u_t is the error-term. r_t^{obx} is the log return in the market index between 10:10 and 16:00. In this analysis we do not want to include overnight return. The reason for this is that overnight return occurs as a result of new information when the OSE is closed. When we study the impact from order flow on the market return we look at the return during the continuous trading day. The trades from the opening auctions are typically registered around 10:05 so it is natural to look at the market return between 10:10 and 16:10.

In the intradaily case we want to separate the effect from order flow during the opening minutes from the rest of the day. We therefore construct two variables. The first variable includes order flow in the time interval from 10:00 until 10:15. We have one observation of this variable each trading day. The opening auction ends at 10:00 and the equilibrium price from this auction is typically calculated around 10:05 (the exact time varies from day to day). Trades from the opening auction are not included in this analysis due to the fact that an equilibrium price is calculated for this auction, and it is therefore not meaningful to assign order flow for these trades. The second variable includes order flow in the time interval from 10:15 until 16:00 and are split into 15 minute intervals. The first observation each trading day of this variable is order flow in the time interval 10:15 to

10:30, followed by 10:30-10:45 and so on until the last time interval which ends at 16:00 when the continuous trading period ends. We have 24 intervals for the second variable each trading day (see figure 2 in the appendix). This results in the following regression for the intradaily analysis:

$$r_{t,n}^{obx} = \begin{cases} f_1 \text{ when } n = 1 \\ f_2 \text{ when } n \in \{2, 3, \ldots, 25\} \end{cases}$$

where

$$f_j = a_{0,n} + a_1 * RelOF_{t,n} + u_{t,n} \quad \text{for j=1,2} \tag{5}$$

$RelOF_{t,n}$ is the normalised relative order flow in the time interval n and u_t is the error-term. The high-frequency analysis is divided into two regimes. The first, f_1 studies the order flow in in the first 15 min of trading at OSE (from 10:00 until 10:15). The return in this period is the log difference in return from the market price at 10:15 and the closing price the previous trading day adjusted for the re-balancing of the market index. The second regime, f_2, is divided into 15 min intervals ranging from 10:15 until 16:00 when the continuous trading period is over. n=1 for observations in the time interval from 10:00 until 10:15. In this case j=1. For the observations occurring in the time interval 10:15 until 16:00 (a total of 24 each trading day), j=2. The closing auction is not included in this analysis. The reason for this is the same as for not including trades from the opening auction.

Estimation results for the two models are presented in table 2. Panel A presents the results for the daily analysis. The second column shows that contemporaneous order flow is significant at the 1 percent significance level. The variable has the expected positive sign; when buyer initiated turnover of a security is higher(lower) than seller initiated turnover for the same security you would expect that this buying(selling) pressure would increase(decrease) contemporaneous market return. The explanatory power is good; R^2 of 27.4 percent. This compares with 63 and 40 percent for DEM/USD and YEN/USD return variation in Evans and Lyons (2002, table 1 on p. 177), and about 10 percent in Hasbrouck (1991, table 1 on p. 194).[5] A significant portion of the daily stock market movement can be explained by the buying and selling activity of the general public. The results reveal, as in Chordia et al. (2002), that microstructure effects are not restricted to the level of the individual stocks; order flow also influence the price process at the aggregate market level.

The relationship between the OBX returns and order flow is also significant when analysing intradaily data as shown in table 2, Panel B. Relative order flow is significant on a 1 percent significance level during the whole trading day. The impact from order flow

[5] Dunne et al. (2005) do not report regressions of equity returns regressed on order flow alone. Hasbrouck (1991) specification is on quote revisions rather than transaction prices, uses a possibly inferior orderflow measure and includes other variables in addition.

seems to be larger during the first 15 minute of trading than for the rest of the continuous trading day. The explanatory power of the intradaily regression is 14 percent.

Table 2: OBX returns and Order flow

The table contains ordinary least squares (OLS) estimated regressions of OBX returns on normalised relative order flow and on an intercept. Panel A contains the estimates for the daily data, and panel B contains the estimates for the intra-daily data. The t-statistics in panel B are computed using White (1980) standard errors, and coefficients in bold mean they are significantly different from zero (two-sided test) at the 1 percent level. In the daily analysis r_t^{obx} is the log return in the market index between 10:00 and 16:10. In the intra-daily analysis $r_{t,n}^{obx}$ divided into 25 intervals. The first interval is the return from 16:10 the previous day until 10:15 the following day (corrected for the daily re-balancing of the market index. The remaining 24 intervals are 15 minute intervals from 10:15 until 16:00.

Panel A: Dependent variable: r_t^{obx}

Regressor	coeff	t-Statistics
$RelOF_t$	**0.032**	9.54
Intercept	-0.001	-2.28
Adjusted R^2	0.274	
Number of observations	239	

Panel B: Dependent variable: $r_{t,n}^{obx}$

	Opening auc. (f_1)		Continuous auc. (f_2)	
Regressor	coeff	t-Statistics	coeff	t-Statistics
$RelOF_{t,n}$	**0.008**	4.66	**0.001**	35.24
Intercept	0.000	1.19	0.000	-1.67
Adjusted R^2	0.142			
Number of observations	5974			

3.2 Daily international financial market linkages and order flow

The following analysis studies the short-term impact on the OBX index of OBX order flow, of US stock markets markets, the oil price and European stock markets. Order flow is measured by normalised relative order flow (see equation 3) and daytime (overnight) returns of the US stock markets, the oil price and European markets are denoted as $\text{nyse}_t(\text{nyse}^*_{t-1})$, $\text{eurf}_t(\text{eurf}^*_{t-1})$ and $\text{oil}_t(\text{oil}^*_{t-1})$ respectively. The return on the OBX-index is calculated as the log difference between the closing price at day t and the closing price the previous trading day (t-1) adjusted for the rebalancing of the index-weights. A key question in our analysis is to what extent other exchanges influence the OBX index, and to this end we pay careful attention to the chronological order of the trading segments in the different markets when constructing our variables, so that no overlap occurs.

Table 3 contains estimates of two specifications, one equal to

$$\begin{aligned} r_t^{obx} &= a_0 + a_1 * r_{t-1}^{obx^*} + a_2 * r_t^{eurf} + a_3 * r_{t-1}^{eurf^*} + a_4 * r_t^{nyse} + a_5 * r_{t-1}^{nyse^*} + \\ & a_6 * r_t^{oil} + a_7 * r_{t-1}^{oil^*} + a_8 * RelOF_t + a_9 * RelOF_{t-1} + u_t, \end{aligned} \tag{6}$$

Table 3: Impact from foreign markets and order flow on the OBX index: Daily analysis

The table contains OLS estimated regressions of daily OBX log-returns. The full model contains all the regressors, whereas the parsimonious model only contains the significant regressors at 1 percent from the full model. The t-statistics are computed using White (1980) standard errors, and coefficients in bold mean they are significantly different from zero (two-sided test) at the 1 percent level.

Panel A: Dependent variable: r_t^{obx}

	Full model		Parsimonious model	
Regressor	coeff	t-Statistics	coeff	t-Statistics
r_{t-1}^{obx}	0.044	0.78		
$eurf_t$	**0.596**	5.19	**0.664**	7.16
$eurf^*_{t-1}$	**0.632**	5.23	**0.759**	10.86
$nyse_t$	0.193	1.28		
$nyse^*_{t-1}$	0.153	0.98		
oil_t	0.062	1.94		
oil^*_{t-1}	**0.092**	4.47	**0.095**	4.52
$RelOF_t$	**0.025**	6.43	**0.027**	7.57
$RelOF_{t-1}$	0.004	0.20		
Intercept	0.000	0.88		
Adjusted R^2	0.551		0.538	
Number of observations	238		238	

and one parsimonious version of this specification. The parsimonious specification is obtained by deleting regressors that are insignificant at the 1 percent significance level. Both contemporaneous and lagged returns of the EURF100 index are statistically significant at 1 percent. Interestingly neither contemporaneous nor lagged returns of the NYSE Composite Index have a significant impact on the most liquid Norwegian companies (this is also the case at the 10 percent level). A possible reason for this is that the impact of NYSE works through the EURF100 index, since some European markets open earlier: Shares in the EURF100 index are traded from 09:00 in the morning while the OBX-index is first updated when the continuous trading starts at around 10:05, and the overnight return of the EURF100 index is calculated from 16:10 the previous day until 10:00 (see figure 1 in the appendix). Both strong sample correlations between US and European returns, and auxiliary regressions support that the impact of the US works through European markets. In particular, a regression (not reported) of OBX return on a constant, $nyse_t^*$ and $nyse_{t-1}^*$ alone produces significant regressors at 1 percent, and a notable R^2 of 32 percent. Overnight oil price return is significant at 1 percent, whereas the contemporaneous oil price return is significant at 10 percent. This suggests that the impact of oil price is stronger overnight than during trading hours and may come as a surprise, since a large part of the OBX index consists of oil related companies. Contemporaneous orderflow is significant at the 1 percent level equation after controlling for the impact of foreign financial markets. This suggests that net-buying pressure at the Oslo stock exchange by itself has an effect independent of how foreign markets move. Admittedly, a full analysis of this requires the joint modelling of orderflow as an endogenous variable, but this is not explored further in this version of our paper. Finally, we note that the explanatory power (R-squared above 50 percent) of both specifications in table 3 is relatively high—in particular since residuals are more fat-tailed than the normal distribution.

3.3 Intradaily international financial market linkages and order flow

In our intraday analysis we divide the day into 26 intervals. The first interval we will refer to as the "opening" session and goes from 16:10 in day $t-1$ to 10:15 in day t. The next 24 intervals are each of 15 minutes length, so interval number 2 goes from 10:15 to 10:30 in day t, interval 3 goes from 10:30 to 10:45 in day t, and so on. The last interval of the day corresponds to the closing session and goes from 16:00 to 16:10 in day t.

For each foreign market we have three variables. The first variable (time interval n=1) represents the spillover return from the previous trading day in the foreign markets after OSE closed (from 16:10 until 10:15 the following trading day). The second variable covers the return in each of the 15 minute intervals during the continuous trading period between 10:15 until 16:00. There are 24 such intervals daily(n=2,...,25). The last variable is the return during the closing auction from 16:00 until 16:10 (time interval n=26). Note however, that for the US index only two observations exist for the second variable each day. Since trading in the US market starts at 15.30 we can only calculate returns for the two last time intervals during the continuous trading interval (15:45 and 16:00). We estimate the following model for the intradaily analysis:

$$r_{t,n}^{obx} = \begin{cases} f_1 \text{ when } n = 1 \\ f_2 \text{ when } n \in \{2, 3, \dots, 25\} \\ f_3 \text{ when } n = 26 \end{cases}$$

where

$$\begin{aligned} f_1 &= \alpha_0 + a_1 r_{t,n-1}^{obx} + a_2 r_{t,n}^{nyse} + a_3 r_{t,n}^{eurf} + a_4 r_{t,n-1}^{eurf} + \\ &\quad a_5 r_{t,n}^{oil} + a_6 r_{t,n-1}^{oil} + a_7 RelOF_{t,n} + a_8 RelOF_{t,n-1} + u_{t,n}. \\ f_2 &= \alpha_0 + b_1 r_{t,n-1}^{obx} + b_2 r_{t,n}^{nyse} + b_3 r_{t,n}^{eurf} + b_4 r_{t,n-1}^{eurf} + \\ &\quad b_5 RelOF_{t,n} + b_6 RelOF_{t,n-1} + u_{t,n}. \\ f_3 &= \alpha_0 + c_1 r_{t,n-1}^{obx} + c_2 r_{t,n}^{nyse} + c_3 r_{t,n-1}^{nyse} + c_4 r_{t,n}^{eurf} + \\ &\quad c_5 r_{t,n-1}^{eurf} + c_6 r_{t,n}^{oil} + u_{t,n}. \end{aligned}$$

The results for the intradaily analysis is presented in table 4.

Table 4: Impact from foreign markets and order flow on the OBX index: Intradaily analysis

In this model we have studied the impact from the overnight return, returns from the continuous trading period and the returns from the closing auction. The results are presented in three columns. The second column presents the parameter values from the overnight return and their respective p-values. The third and fourth column presents the results from the continuous trading period and the returns from the closing auction respectively. The lagged variables in the second and third regime represent the return (or order flow) in the previous 15 minute interval. The lagged variables in the first regime will affect the dependent variable in the 15 minute interval between 10:15 and 10:30. Note that for the oil price we have not included any observations in the second regime since the opening of this market changed during 2004. The t-statistics are computed using White (1980) standard errors, and coefficients in bold mean they are significantly different from zero (two-sided test) at the 1 percent level.

Panel A: Dependent variable: $r_{t,n}^{obx}$

	Opening auc. (f_1)		Continuous auc. (f_2)		Closing auc. (f_3)	
Regressor	coeff	t-Statistics	coeff	t-Statistics	coeff	t-Statistics
$r_{t,n-1}^{obx}$	-0.509	-1.99	**-0.038**	-2.90	0.098	1.86
$r_{t,n}^{nyse}$	0.114	1.28	**0.061**	3.78	-0.140	-1.12
$r_{t,n-1}^{nyse}$					-0.135	-1.09
$r_{t,n}^{eurf}$	**0.574**	8.33	**0.357**	17.30	0.249	2.21
$r_{t,n-1}^{eurf}$	0.030	1.80	**0.128**	7.00	0.862	2.19
$r_{t,n}^{oil}$	**0.063**	5.01			0.045	1.79
$r_{t,n-1}^{oil}$	0.012	2.77				
$RelOF_{t,n}$ *	**0.396**	3.94	**0.111**	32.38		
$RelOF_{t,n-1}$ *	0.116	2.77	-0.001	-0.31		
Intercept	0.000	-0.58	0.000	-0.58	0.000	-0.58
Adjusted R^2			0.429			
Number of observations			5973			

* multiplied by 100

$r_{t,n}^{nyse}$ are insignificant at 10 percent during the two first regimes. Lags of these variables ($r_{t,n-1}^{nyse}$) where also statistically insignificant at 10 percent and are therefore not included in the regression. $r_{t,n-1}^{oil}$ in the third regime is not included for the same reason. The overnight return in all the foreign markets have a positive impact on the opening price at the OSE. $r_{t,n}^{eurf}$ and $r_{t,n}^{oil}$ are significant at 1 percent, while $r_{t,n}^{nyse}$ is not significant even at 10 percent during the first 15 minutes of trading. As for the daily analysis, a likely cause for this result is that overnight return in the NYSE works through the EURF100 index. The impact from a one percent increase in the spillover return in the European market is almost 10 times larger than a corresponding increase in the oil price. The European and US stock market have a statistically significant impact on the OBX-return during continuous trading hours. Bear in mind that the US market opens only 45 minutes before OSE close. OSE is open from 10:00 until 16:10 while the US market opens 15:30. The European stock market has also a lead effect on the the OSE during the continuous trading period. We have not included the oil price during the continuous trading period session. The reason for this is that until the end of October the Brent Crude oil at the IPE where traded from 11:00 while trading did not start before 15:30 during November and December 2004. During the closing session EURF100 is significant on a 5 percent level. The contemporaneous impact from the US market is not significant during the closing session while the lagged variable in this regime is significant and negative at a 10 percent level. This indicates that a positive (negative) return in the NYSE index in the period 16:00 to 16:10 will have a negative(positive) impact on the overnight return in the OBX index.

The relative measure of order flow, defined in equation 3, is significant at 1 percent in both the first 15 minutes during the continuous trading period as well as during the time period between 10:15 and 16:00. The coefficients are both positive as expected. If the market value of the buyer initiated transactions are larger(smaller) than the market value of the seller initiated transactions we have a buying(selling) pressure which will result in a increase(decrease) in the OBX-return. This effect is larger during the first 15 minutes of trading. Order flow does not have a lead effect on the returns. The explanatory power is relatively large, 42.9 percent.

4 Conclusion

In this paper we have analysed to what extent the market return at the OSE depends on foreign financial markets and order flow. We find that a high percentage of aggregate market return at OSE is explained jointly by foreign financial markets and aggregated order flow. The explanatory power in both models that measure the impact from foreign markets and order flow in the market index are quite large; 55 percent for the daily analysis and 43 percent from the intra-daily analysis. Overnight return from from the European stock markets as well as from the oil price have a significant impact on the next day's return at OSE. These results hold for both the daily and intra-daily analysis. Our results also suggest that return from NYSE has an impact on the OSE that works through the European stock markets. Both strong sample correlations between US and European returns and auxiliary regressions support these findings.

Our results suggest that net-buying pressure from at the Oslo Stock Exchange by itself has an effect independent of how foreign markets move. This result hold both for the daily and intra-daily analysis. Contemporaneous order flow is positive indicating that a net-buying (net-selling) pressure on the most liquid Norwegian companies will increase (decrease) the return on the OBX-index.

References

Arshanapali, B. and J. Doukas (1993). International stock market linkages: Evidence from the pre- and post-october 1987 period. *Journal of Banking and Finance 17*, 193–208.

Blume, M., A. MacKinlay, and B. Terker (1989). Order imbalances and stock price movements on october 19 and 20. *Journal Of Finance 44*.

Chordia, T., R. Roll, and A. Subrahmanyam (2002). Order imbalance, liquidity and market returns. *Journal Of Financial Economics 65*.

Copeland, M. and T. Copeland (1998). Lead, lags, and trading in global markets. *Financial Analyst Journal 54*, 70–80.

Dunne, P., H. Hau, and M. Moore (2005). International order flows: Explaining equity and exchange rate returns.

Eun, C. and S. Shim (1989). International transmission of stock market movements. *Journal of Financial and Quantitative Analysis 24*, 241–256.

Evans, M. and R. Lyons (2002). Order flow and exchange rate dynamics. *Journal of Political Economy 110*.

Glosten, L. and P. Milgrom (1985). Bid, ask, and transaction prices in a specialist market with heterogeneously informed trades. *Journal of Financial Economics 13*.

Grubel, H. (1968). Internationally diversified portfolios: Welfare gains and capital flows. *American Economic Review 58*, 1299–1314.

Hasbrouck, J. (1991). Measuring the information contents of stock trades. *The Journal of Finance 46*.

Huang, R. and H. Stoll (1997). The components of the bid-ask spread: A general approach. *Review of Financial Studies 10*.

Lauterbach, B. and U. Ben-Zion (1993). Stock market crashes and the performance of circuit breakers: Empirical evidence. *Journal Of Finance 48*.

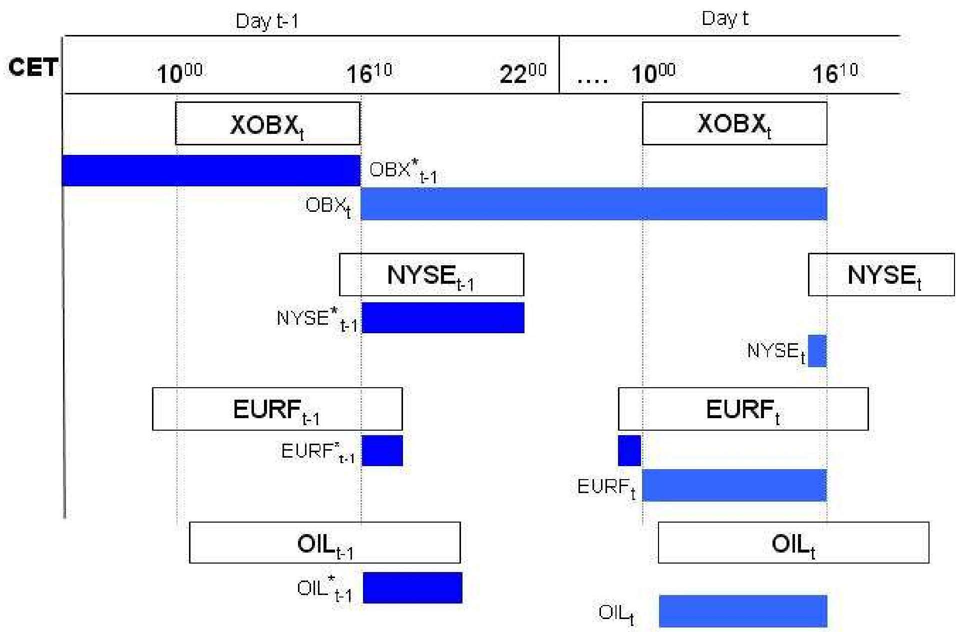
Lee, C. and M. Ready (1991). Inferring trade direction from intraday data. *Journal Of Finance 46*.

Lyons, R. (2001). New perspectives on fx markets: Order-flow analysis. *International Finance 4*, 303–320.

Malliaris, A. and J. Urrutia (1992). The international crash of october 1987: Causality tests. *Journal of Financial and Quantitative Analysis 27*.

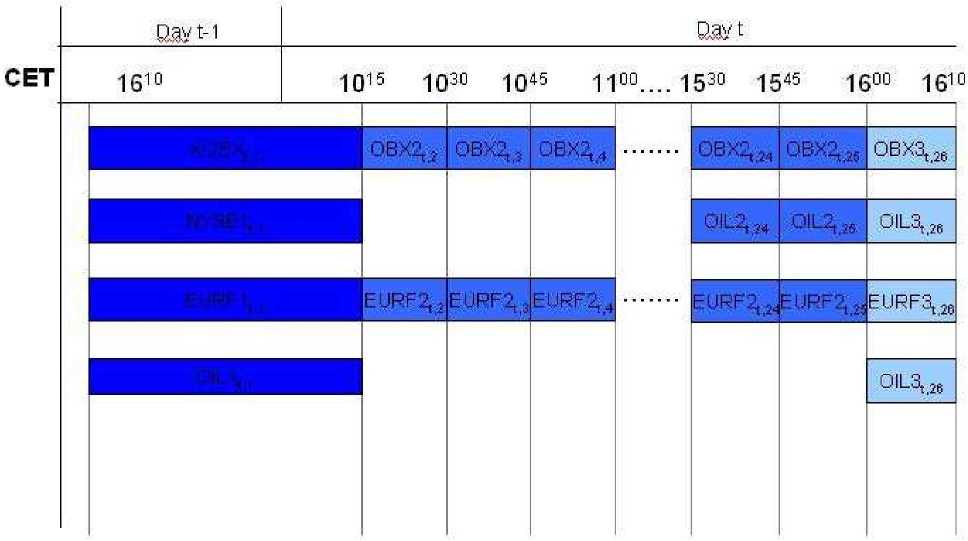
White, H. (1980). A heteroscedastistisity-consistent covariance estimator and a direct test for heteroscedasticity. *Econometrica 48*.

Figure 1: Trading Hours



Note: This figure shows the different trading hours (opening session not included) in the foreign markets as well as at the Oslo Stock Exchange (OSE). The return in the foreign financial markets are decomposed into daytime and overnight return according to overlapping with the Norwegian stock market. OSE has a continuous trading session from 10:00 until 16:00 CET and a closing auction the following 10 minutes. Overnight return is defined as the return between 16:00 and 10:00 the following trading day. Daytime return is the return from 10:00 until the closing auction ends at OSE at 16:10. For the OBX-index we calculate close-to-close return, i.e. return from 16:10 until 16:10 the following trading day. Note that the brent crude futures contract at the International Petroleum Exchange where traded from 11:00 until 20:30 from January 2004 until the end of October 2004, and from 15:00 until 20:30 in November and December 2004.

Figure 2: Intra-daily analysis



Note: This figures shows the different time intervals on the intra-daily analysis. There are three different regimes. The first goes from 16:10 the day before until 10:15 the next morning. The second regime include the 15-minute intervals from 10:15 until 16:00 during the continuous trading period on OSE. The third regime is during the closing auction from 16:00 until 16:10. all together we have 26 intervals. The first interval covers the overnight return, 24 intervals covers the continuous trading period at OSE between 10:00 and 16:00 while the last interval covers the closing auction. For the NYSE Composite Index we only have returns from the two last intervals during the second regime (from 15:30 until 15:45 and from 15:45 until 16:00). For the Brent Crude oil we have not included any observations from the second regime since the opening of this market changed during 2004.