High Frequency Information Content in End-User Foreign Exchange Order Flows

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Abstract

This paper considers the impact of foreign exchange order flows on contemporaneous and future stock market returns using a new database of customer order flows in the €-$ exchange rate market as seen by a leading European bank. We do not find clear contemporaneous relationships between FX order flows and stock market changes at high frequencies, but FX flows do appear to have significant power to forecast stock index returns over 1-minute to 30-minute horizons, after controlling for lagged exchange rate and stock market returns. The effects of order flows from financial customers on future stock market changes are negative, while the effects of corporate orders are positive. The latter results are consistent with the premise that corporate order flows contain dispersed, passively acquired information about fundamentals. Thus purchases of the dollar by corporate customers represent good news about the state of the US economy. Importantly, though, there also appears to be extra information in corporate flows which is directly relevant to equity prices over and above the impact derived from stock prices reacting to (predicted) exchange rate changes. Interpretation of the financial customer results is more difficult, although our findings suggest that these flows only affect stock prices through their impact on the value of the dollar.

This paper is an empirical study of cross market short-run correlations between order flows in the foreign exchange market and price changes in the US stock market. We argue that evidence of significant cross market connections inform our understanding of the often observed yet still contentious relationships between FX order flow and FX returns. Specifically, some key hypotheses put forward to explain the correlation of daily order flow and spot exchange rate changes are not consistent with cross market correlations. The one explanation that is consistent is that order flows contain information and that this is impounded into FX rates through the trading process. We also argue that our results shed some light on the nature of the information in order flow. At its most basic, the results suggest that at least part of the information content in flows relates to fundamentals relevant to both stock and FX markets. While this may not appear to narrow the field much, it does suggest that non-fundamental information in order flow – often thought of in terms of the ability of flows to predict future flows – is not the whole story. Further, we find considerable differences between the impact of order flow from corporate customers and that from financial customers, both in terms of the signs of the correlations and the horizons over which these correlations are significant. This suggests that the information in the flows from these different groups of end-users is radically different.

It is relatively uncontroversial that order flow influences price in equity markets. Theoretical models such as those by Kyle (1985) and Glosten and Milgrom (1985) begin with the observation that customers, from time to time, have private information about the fundamentals that drive an asset's true value that is not available to dealers. Transactions by these informed customers cause prices to change as dealers update their bid and ask quotes. At the same time, other market participants observe these quote changes and update their conditional expectations of the asset's value, adjusting their trades and quotes accordingly. Ultimately, the information conveyed by the trades of the informed becomes fully impounded in the market price of the asset. There is a rich history of empirical work supporting the connection between order flow and equity price changes (see, among many others, Shleifer, 1986; Holthausen et al, 1990; Chordia, Roll and Subrahmanyam, 2002). As data became available, and given the similarities with equity markets, evidence soon emerged that a similar relationship between order flow and prices could be observed in bond markets (see Fleming, 2003; Brandt and Kavajecz, 2005; Pasquariello and Vega, 2007).

Given that the exchange rate is just another asset price, it would seem reasonable that the same story should apply in FX markets. While there is plenty of evidence demonstrating a relationship between order flow and spot exchange rate changes, for whatever reason it remains controversial that this reflects the incorporation of private information into the price of FX.[1] In part, this is because, despite years of investigation, there is still no consensus on what the fundamentals are that drive exchange rates. If we do not know what the fundamentals are, it is not easy to convince skeptics that some market participants have private information about them. In part, even if we agree that fundamentals such as interest rates, price levels and income growth rates matter for FX pricing, it is hard to convince skeptics that anyone could have private information about them. And finally, the skepticism about the information content of FX order flows is due in part to theories and evidence suggesting alternative explanations for the relationship between flows and spot rate changes. Inventory management by FX dealers is very aggressive compared to dealers in other assets so inventory risk premia ought to be important. Trades perturb dealer inventories, who need to be compensated with a shift in expected returns (Breedon and Vitale, 2009; Froot and Ramadorai, 2005). Alternatively, the direction of causation between order flow and exchange rate changes comes under question. It is known that both positive and negative feedback trading is prevalent in FX markets. The empirical evidence may be reflecting the response of flows to exchange rate changes, rather than vice versa.

The foreign exchange microstructure literature suggests at least two simple reasons why flows might contain private information. First, the so-called dispersed information approach hypothesizes that individual entities might know (and trade foreign exchange as a result of) a small part of the macroeconomic picture (Evans and Lyons, 2004). The foreign exchange market pools these trades and aggregates the dispersed information, learning the bigger picture. Second, the portfolio shifts approach assumes that investors optimally allocate investments across markets (Evans and Lyons, 2002). Shifts in preferences or risk appetites of individual investors lead to portfolio rebalancing and the resultant order flows reveal information regarding the private shifts of this subset of investors.

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[1] Osler (2008) surveys this literature in detail.

We attempt to shed some light on the nature of the information content of foreign exchange order flows using a unique database of end user transactions as seen by the London foreign exchange trading desk of a major European bank. While only covering 25 days, we analyse a total trading volume in excess of €100bn, of which some €52bn are from end-user customers. Unlike almost all other studies using end user FX flows which are forced to rely on daily aggregated flow measures, our database contains transaction level detail allowing us to perform the one of the first intraday studies of FX end user flows. In particular, since the data are timed to such a fine degree we can test the forecasting power of flows over short horizons (up to thirty minutes). This allows us to minimise the likelihood that correlations between flows and returns are due to momentum or feedback trading. The high frequency nature of our study also allows us to analyse the simple liquidity explanation. If illiquidity lies behind the widely-observed returns-flow correlation we would expect to observe large positive relations between buying pressure and the value of the currency in the short run which reduce as the forecast horizon extends and the market has time to absorb the new inventory. Since we can only examine very short horizons it is not essential for the inventory impact to die to zero. The slightly richer risk premium explanation would in any case suggest that the inventory effect can have very long-lasting effects on returns.

Most innovatively, we concentrate on cross-market effects of FX flows. Specifically, we examine whether end-user flows in the foreign exchange market have forecasting power for equity market returns. Any such evidence would be very hard to explain using feedback trading or inventory effects. They would, however, be consistent with the information content hypothesis since it is quite conceivable that the information contained in FX flows is of value both for foreign exchange rates and stock prices.

Moreover, the set of order flows data used in this paper is broken into categories based on the orders' initiators: corporate customers, financial institutions, internal units, and inter-bank counterparties. This identification of the source of the orders allows us to examine the heterogeneity in high frequency order flows, complementing existing studies using lower frequency end-user flows. Heterogeneity is another facet of the flow-return correlation puzzle that is not easily reconciled by liquidity explanations. Trades of a given size ought to have the same impact regardless of their source if that impact is primarily due to the inability of the

market to absorb the inventory shock. However, since the information content from different sources is very likely to differ, it is quite reasonable to expect heterogeneity under the information hypothesis.

It is therefore important that we demonstrate that foreign exchange order flows have forecasting power for foreign exchange and stock market returns and that the impacts from different groups of customers are distinctly different. We see clear patterns in our results: corporate order flows into the US dollar have positive effects on future US stock returns, while order flows into the US dollar from financial institutions have negative effects on future US stock returns. These results as a whole are difficult to reconcile with competing explanations for correlations between flows and asset price changes such as risk premia or feedback trading. While there are still puzzling aspects of our results, we conclude that there is private information conveyed in foreign exchange order flows which is valuable for both stock and FX markets. For example, our strongest set of results is the link between corporate customer flows into the dollar and subsequent rises in US stock prices. While this could conceivably be due to portfolio reallocations by corporate, it seems more intuitive to suspect this is driven by the extraction of dispersed macroeconomic information from FX order flow which is also relevant for equity prices. For proponents of this approach it is not surprising that FX flows contain information that is price relevant for various asset classes.[2]

The remainder of the paper is organized as follows. In section 1 we provide a brief literature review. The high frequency foreign exchange order flows with exchange rates and stock prices data are presented in section 2. Section 3 outlines the methods used and the hypotheses tested. The empirical findings will be discussed in section 4, and section 5 concludes.

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[2] We accept that it is somewhat surprising that it is priced as rapidly as our results suggest. However, our results are limited to very short horizons by data limitations and while they suggest that there is some very high frequency forecasting power from FX flows to equity returns, they do not rule out the possibility of greater forecasting power over longer horizons. We are investigating this possibility in a separate paper (Marsh and Miao, 2010).

1. Literature Review

Market participants generally differ in their estimates of fundamental value of prices, because they often rely on different sets of data or they have heterogeneous interpretations even of the same set of information. Markets aggregate data from many sources to produce prices that typically estimate fundamental values more accurately than any individual investor can. This determines a non-instantaneous process of trading in the foreign exchange market, and the possibility that order flows which carry information may predict prices during the trading process. Evans and Lyons (2005b) examine the effects of news on transactions in different groups of customers in the foreign exchange market, and they find arrival of news generate subsequent changes in their trading behaviors which will last for days. They provide strong evidence that investors in the foreign exchange market are not responding to news instantaneously, and there is a clear existence of gradual learning process in the market.

Most of the papers in foreign exchange microstructure use low frequency data (most often daily or weekly data). Recent studies with high frequency tick-by-tick data often focus on order flow as a vehicle for macroeconomic news, and investigate the effects of news on the patterns after releases of the public information, in terms of exchange rates as well as foreign exchange order flows. High frequency analysis of news on exchange rates has been done by many. For example, Almeida, Goodhart and Payne (1998) examine the changes of DEM/USD exchange rate after releases of macroeconomic news in Germany and US, and find the impact is significant up to tens of minutes. Evans and Lyons (2008) use four months of tick-by-tick DEM/USD order flows data, and using five-minute frequency analysis they suggest that when news arrives, subsequent order flow is more important in exchange rate determination and the exchange rate can be forecast by inter-dealer order flow in the foreign exchange market. Love and Payne (2008) analyze the number of trades as proxy of order flows over a period of ten months and also suggest that news is transmitted into prices via order flows but will be impounded into the market price faster than those suggested by Evans and Lyons (2008).

An important paper closely related to ours is Osler and Vandrovych (2009). This study examines all the executed price-contingent orders (stop-loss and take-profit orders) placed at the Royal Bank of Scotland from 10 different categories of counterparties (6 from customers, 4 from inter-dealers) over 16 months in 2001 and 2002. The authors document that there are connections

between foreign exchange order flows triggered by these orders and subsequent exchange rate changes at high frequencies. The heterogeneity across counterparty types observed at low frequencies in the foreign exchange market is still present at high frequencies. They also suggest that the leveraged financial institutions such as hedge funds are better informed than other customers, while the inter-dealers are even better placed through observations of orders placed by their customers.

The literature therefore suggests that there should be relationships between disaggregated customer order flows and subsequent exchange rate movements. Our paper is the first to examine a comprehensive order flow data set at such a high frequency since it contains orders triggered both by price contingent orders and market orders placed by a bank's counterparties. More innovatively, we also consider cross market effects of such order flows.

A sizable body of literature investigates the contemporaneous relations between foreign exchange and stock markets. Early empirical studies focus on the return spillovers between the two different financial markets with mixed results. Jorion (1991), Bartov and Bodnar (1994) are among those who fail to find significant contemporaneous relationships between foreign exchange market and stock market returns. On the other hand, Ajayi and Mougoue (1996) find significant short-run and long-run feedback relations between the two markets for eight industrial economies. They show that increases in stock prices have a negative short-run effect on the local currency and long-run positive effect, while the appreciation of the local currency has positive short-run and long-run effects on the stock prices. Andersen, Bollerslev, Diebold and Vega (2007) also find important links between the foreign exchange market and the US stock market, even after controlling for the effects of macroeconomic announcements. He and Ng (1998) and Granger, Huang and Yang (2000) are among others with supportive evidence of cross market effects. Thought the evidence is not unambiguous, there is enough to suggest that the factors driving exchange rates are also relevant for stock prices.

Two studies are closely related to our own as they investigate the relationship between foreign exchange and stock markets with order flow data as additional variables.[3] Dunne et al (2006)

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[3] These two papers explain equity returns using FX order flow. A third paper, Albuquerque, Francisco and Marques (2008), test the relation in the opposite direction, considering the effect of order flows in stock markets on exchange rates.

obtain a structural relationship between exchange rates, domestic and foreign stock market returns and the corresponding stock market order flows from a model of heterogeneous belief changes. Their estimated equations regress a stock market return on contemporaneous FX returns and domestic and foreign equity order flow. Recognising the potential endogeneity of the exchange rate in their econometric specification, they instrument exchange rate changes with interbank FX order flow for a subsample of their data. Interestingly, they find that an appreciation of the dollar and an interbank order flow into the dollar are positively correlated with contemporaneous stock market changes (using daily data).

Francis et al (2006) estimate models very close to our own, using lagged equity and FX returns plus FX order flow to explain equity returns in many countries. The key difference is that their order flow data are from the weekly reports of the FX positions of US banks active in the FX markets. As such, they are a low frequency proxy of the order flows of a select number of participants in the FX market. Francis et al demonstrate significant correlations between flows and future equity market returns. Interestingly, the sign of the coefficients on order flow differ across countries, with inflows to the dollar from the Deutsche mark and yen being associated with US equity price rises, and inflows from the pound and Canadian dollar associated with US equity falls. They attribute there findings to the information content of FX order flows, and argue that the heterogeneity of coefficients is driven by the heterogeneity of information content.

All of the work on cross market effects of order flow performed up to now uses daily or longer horizons. With the unique set of ultra high frequency data used in this paper, high frequency analysis on the relations between the foreign exchange market and the stock market will provide more evidence on how the pricing of information evolves with time.

2. High Frequency Data

There are three main parts to our data. The first is a database of ultra high frequency, tick-by-tick EURUSD order flow, provided by the London trading desk of a leading European commercial bank. The second is a database of high frequency exchange rate prices. This includes both the relevant trade price for the transactions of this specific bank and the matched market clearing price from the interdealer trading network. This tick-by-tick data set opens the way for studying

the foreign exchange market at ultra high frequencies. In this paper we concentrate on intervals from 1-minute to 30-minutes. The last component is a database of stock market prices, including tick-by-tick quotes and trades of Exchange Traded Funds (ETFs) tracking the major US indices – Dow 30 and S&P 500 – and several S&P 500 sectors. The ultra high frequency equity data are collected from TAQ (Trades and Quotes) database in WRDS (Wharton Research Data Services). More details of the data used in this paper are described separately in the following subsections.

2.1 Foreign Exchange Market

The tick-by-tick high frequency Euro-Dollar (denoted as EURUSD afterwards) order flows data used in this paper are provided by the London trading desk of a leading European commercial bank that wishes to remain anonymous. The order flow data records every trade initiated by the bank's counterparties over 25 trading days from 10/Oct/2005 to 11/Nov/2005 and includes trades from both customers and banks in the inter-dealer network.[4] Note that deals smaller than €500,000 are not included in the database. The period chosen for the study was essentially random and does not appear to have been particularly unusual for either the FX or stock markets. Every deal has a time stamp attached, a bought or sold indicator allowing us to sign the direction of trades, the transaction price and the contemporaneous interbank market price together with the size of each deal. In this paper we use the interbank market price to abstract from the inventory implications of the bank's own customer quotes.

The identity of the customers and inter-dealers are identified by a code, allowing us to classify order flows into four categories: financial customers, corporate customers, internal units, and inter-bank counterparties. Flows are signed such that a dollar purchase by a customer (and so a euro sale) is given a positive sign. Flows are measured in Euros.

Our order flow and price data are drawn from time-stamped, tick-by-tick transactions in the largest spot market, and some data errors or invalid records are inevitable. After excluding any

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[4] Trades with inter-dealer network banks initiated by the data supplier are unfortunately not available.

suspicious entries, such as trades with a rate far away from the price range during a period of time, we have 27,830 transactions over 25 trading days.

Table 1 provides some descriptive statistics for each category of the bank's counterparties and Figure 1 plots the cumulative net order flow for each counterparty type.

Table 1: Summary Statistics of EURUSD Order Flows by Counterparty Type

	Financials	Corporates	Internal	Interbank	Total
Transactions	8898	2584	1905	14443	27830
Avg. Trans. per Day	355.92	103.36	76.20	577.72	1113.20
Percent by Trades	31.97%	9.28%	6.85%	51.90%	100.00%
Net Order Flow	534.84	88.00	-1445.38	384.02	-438.52
Volume	34555.07	18479.44	8927.6	37123.33	100085.44
Mean	3.88	7.54	4.69	2.57	3.60
Standard Dev.	9.48	14.97	12.63	4.00	8.42
Median	2.00	2.52	2.00	1.00	2.00
Percent by Volume	34.53%	18.46%	8.92%	37.09%	100.00%

Notes: The table reports summary statistics for EURUSD order flows from all groups of customers. All volume numbers are in millions of Euros. The sample period is 10/Oct/2005 to 11/Nov/2005.

Figure 1: Cumulated EURUSD Net Order Flows by Counterparty Type
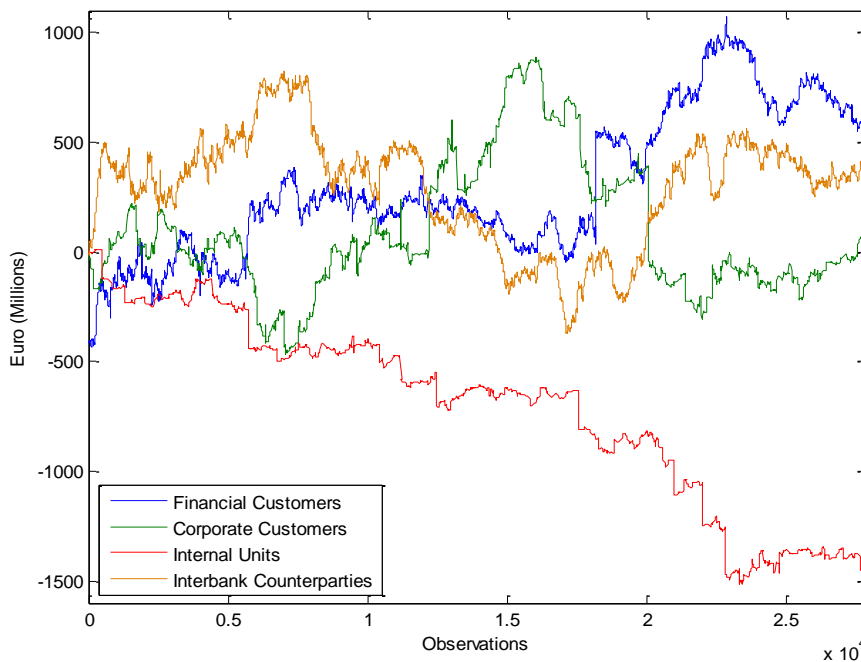
Since this is the first paper to use such high frequency customer order data we emphasise a few key points. In terms of number of transactions, interbank counterparties initiate more than half of the trades and the share of orders initiated by corporate customers is less than 10% of the number of total trades. However, in terms of trading volume, the corporations' share nearly doubled to 18.46%, while the share of interbank counterparties drops from 51.9% to 37.09%. We can put this another way by noticing that the average deal size of corporate customers is much larger than that of interbank counterparties. The proportion of orders triggered by financial customers are similar across the two ways of calculating market shares (31.97% by number of trades and 34.53% by value), while internal units always have the lowest trading activities (6.85% and 8.92%). The variability of the size of customer orders relative to interbank orders is also clear. The standard deviation of the size of financial customer orders is over twice that of interbank orders, while corporate orders are even more variable in size.

The cumulative net order flow of corporate customers, for example, is only €88m on a volume of €18.5bn. Order flows of interbank and financial customers also approximately balance over the sample. Internal customers are an exception since their orders are much more "one-sided" resulting in a large accumulation of flows into the euro equivalent to some 16.2% of their trading volume. Unfortunately, the source bank was unwilling (or unable) to explain why this might be the case.

Due to the irregular spacing of trades during the day we filter the raw data at 1-minute intervals. The order flows data for each category is cumulated during each 1-minute period, and the transaction exchange rate is the price of the last execution in that 1-minute interval. We also use the matched interbank rate as the last price in the interval.

Table 2 shows correlations between orders from different types of counterparties based on the 1-minute frequency data. We find that there are only very small correlations between any two categories out of commercial corporations, financial institutions, internal units and interbank counterparties, with the exception of financial customers and interbank counterparties.

	Financials	**Corporates**	**Internal**	**Interbank**	**Total**
Financials	1.000				
Corporates	-0.016	1.000			
Internal	0.005	0.006	1.000		
Interbank	0.261	-0.005	0.042	1.000	
Total	0.573	0.544	0.370	0.631	1.000

Notes: The table reports correlations of EURUSD 1-minute order flows between different groups of counterparties. The sample period is 10/Oct/2005 to 11/Nov/2005.

2.2 Stock Market

An Exchange Traded Fund (ETF) is an investment vehicle traded on stock exchanges, which is very liquid due to low transactions costs, high tax efficiency, good diversification powers, and pure stock-like features. The first of these, the S&P 500 ETF (denoted as SPY, but more widely known as SPDR), began trading in 1993 and is now the largest ETF in the world. Following SPY's success the "Dow Diamond" (denoted as DIA) ETF was introduced tracking the Dow Jones Industrials Average (DOW 30). Since these are traded instruments that accurately track the value of the major US equity indices we use high frequency trade and quote prices of these two ETFs as our measure of stock index prices in the US.

The tick-by-tick stock market data is collected over the 25 trading days sample from 10/Oct/2005 to 11/Nov/2005, traded between 9:30am to 16:00pm, New York Time. Table 3 lists the average trading frequency for each of the ETFs together with similar information for FX trades seen by our data supplier for comparison. Trading frequency is highest for S&P 500 ETF, while the DOW 30 ETF is also relatively liquid.

Table 3: Average trading frequency for ETFs and customer trades in FX

Index/Counterparty	Trades per Day	Trades per Minute
S&P 500	89920	231
Dow Jones 30	12249	31
Financials	356	0.6
Corporate	103	0.2
Internal	76	0.1
Interbank	578	1.0

Notes: The table reports the number of trades for two ETFs and order flows from different counterparties as seen by our data providing bank (per day and per minute).

Since we are examining foreign exchange order flows from a London desk and US stock market data, the time difference between US and UK needs careful attention. While in the "pure foreign exchange" environment where we only consider FX flows and returns we have approximately 8.5 hours data each day, when considering cross market effects the overlap of data between the two markets is much shorter. The overlapping interval is only from 14:30pm to approximately 5:00pm London time (9:30am to 12:00pm New York time).

When performing regressions in "pure foreign exchange" environment (i.e. only considering order flows and exchange rates), all data from approximately 7:30am to 17:00pm London time is used. After filtering data to 1-minute frequencies, we have approximately 510 observations every day and some 12,775 observations in total. When considering the relationship between FX flows and stock returns, we have approximately 120 observations in the overlapping interval for each day (3025 observations for all 25 days).

3. Hypotheses & Methodology

The focus of this paper is on the cross market relationships but we begin with a brief analysis of the correlations between FX flows and FX returns. We begin with contemporaneous analyses by regressing exchange rate returns between time *t-i* and *t* on flows from the four different customer groups over the same time interval. We vary the size of the window, given by *i*, from 1-minute up to 30-minutes. The different types of counterparties are denoted by *m* where *m=1* corresponds to financial customers, 2 to commercial corporations, 3 to internal transactions within the bank, and 4 to interbank counterparties. Recall that flows are signed such that a positive flow indicates that the counterparty was buying dollars (and so selling euros to the bank). In the regression analysis below we measure flows in units of €100m. Exchange rates are defined such that a positive FX return indicates an appreciation of the dollar. A positive coefficient suggests that a flow into the dollar is associated with a strengthening of the dollar.

$$R_{t-i,t}^{FX} = c + \sum_{m=1}^{4} \beta_m OF_{t-i,t}^{FX} + \varepsilon_t$$

(1)

We run these regressions over the full data sample from approximately 7:30am to 5pm over the 25 days of our sample.

In the forecasting model, we test the effects of cumulated order flows over *i* minutes on exchange rate returns over subsequent *k*-minute intervals, in which *i* and *k* both range from 1 to 30 minutes. In the forecasting regressions we also include the lagged dependent variable on the right hand side of the equation. For example, when *i=3* and *k=5* we use foreign exchange order flows over the last 3 minutes to forecast exchange rate returns over the next 5 minutes, after controlling for the last 3-minute exchange rate return.[5]

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[5] Below we forecast stock returns using lagged FX returns, lagged stock returns and lagged FX order flow. For symmetry we should include lagged stock returns in eq (2). However, lagged US stock returns are only available for a small portion of the trading day which dramatically reduces our sample.

$$R_{t,t+k}^{FX} = c + \gamma R_{t-i,t}^{FX} + \sum_{m=1}^{4} \beta_m OF_{t-i,t}^{FX} + \varepsilon_t$$

(2)

Again, the full sample is used for the forecasting regressions. With intervals greater than 1-minute overlapping observations are used and so all regression models are estimated by using Ordinary Least Squares, correcting the coefficient variance/covariance matrix for autocorrelation and heteroskedasticity using the Newey-West method. These are, of course, in-sample regressions and so not true forecasts. The relatively short data span precludes the use of true out-of-sample forecasting tests.

The main focus of this paper is in the cross market effects from foreign exchange order flows to stock market returns at high frequencies. We run corresponding regressions to those described above where the dependent variable is now a stock market return, either from an ETF of from an individual stock. Our analysis is now constrained to the overlapping period from 2:30pm (London) to approximately 5pm (London).

We begin with the contemporaneous regression:

$$R_{t-i,t}^{S} = c + \gamma R_{t-i,t}^{FX} + \sum_{m=1}^{4} \beta_m OF_{t-i,t}^{FX} + \varepsilon_t$$

(3)

The stock return between time $t - i$ and t is regressed on the contemporaneous FX return and on the contemporaneous disaggregated end-user FX order flows.

$$R_{t,t+k}^{S} = c + \alpha R_{t-i,t}^{S} + \gamma R_{t-i,t}^{FX} + \sum_{m=1}^{4} \beta_m OF_{t-i,t}^{FX} + \varepsilon_t$$

(4)

In the forecasting model given in equation 4 we regress stock market returns over a k-minute interval on lagged stock market returns, lagged exchange rate returns and the four groups of lagged order flows aggregated over an i-minute interval. The four beta coefficients from this model are our focus of interest. Significant coefficients would suggest that lagged end-user FX order flows are useful predictors of future stock returns even when correcting for stock and FX returns contemporaneous with the FX flows.

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4. Empirical Findings

4.1 *Contemporaneous relationships between FX flows and FX returns*

We start by investigating the contemporaneous relation between foreign exchange end-user order flows and exchange rate returns at frequencies from 1-minute to 30-minutes.

Table 4: Impact of order flow on contemporaneous exchange rate changes

	Aggregation window														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Financial	-0.04	-0.03	-0.02	-0.02	-0.02	-0.03	-0.04	-0.04	-0.06	-0.07	-0.09	-0.11	-0.13	-0.14	-0.15
Corporate	0.02	0.02	0.03	0.03	0.03	0.04	0.05	0.05	0.05	0.06	0.07	0.08	0.08	0.09	0.09
Internal	-0.06	-0.12	-0.2	-0.27	-0.31	-0.36	-0.39	-0.43	-0.46	-0.49	-0.51	-0.54	-0.57	-0.59	-0.61
Interbank	-0.11	-0.17	-0.21	-0.23	-0.24	-0.25	-0.25	-0.26	-0.27	-0.27	-0.27	-0.27	-0.27	-0.27	-0.27
	Aggregation window														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Financial	-0.15	-0.15	-0.16	-0.17	-0.17	-0.18	-0.18	-0.18	-0.18	-0.18	-0.17	-0.17	-0.17	-0.17	-0.17
Corporate	0.09	0.1	0.1	0.11	0.11	0.12	0.12	0.13	0.14	0.14	0.14	0.14	0.15	0.15	0.15
Internal	-0.62	-0.63	-0.63	-0.64	-0.65	-0.66	-0.66	-0.66	-0.67	-0.67	-0.68	-0.69	-0.69	-0.69	-0.68
Interbank	-0.28	-0.29	-0.29	-0.29	-0.3	-0.3	-0.3	-0.3	-0.31	-0.31	-0.31	-0.32	-0.32	-0.33	-0.33

Notes: The table reports coefficient estimates from the regression $R_{t-i,t}^{FX} = c + \sum_{m=1}^{4} \beta_m OF_{t-i,t}^{FX} + \varepsilon_t$

The column headings give the value of the aggregation window *i* in the model. Intraday data from 7:30am to 5:00pm for 25 days are used. A lightly shaded cell denotes significance at the ten per cent level using robust standard error estimates. Darker shading denotes significance at the five per cent level. Coefficients represent the percentage change in the euro-dollar exchange rate from a €1bn flow into the dollar, expressed such that a positive sign is an appreciation of the dollar.

From Table 4 we see a clear contemporaneous relationship between foreign exchange order flows and exchange rate. Order flows from other interbank dealers are significantly negative at all aggregation frequencies from 1-minute to 30-minute. Since the literature finds that interdealer orders *in aggregate* are strongly positively correlated with contemporaneous exchange rate changes, our results suggest that the small subset of interdealer flows captured by our data (i.e. flows initiated by other banks against our bank's interdealer quotes) are negatively correlated with the aggregate interdealer flow. Put differently, when our bank passively trades on the interbank market, exchange rates contemporaneously move in its favour. Moore and Payne

(2009) discuss relative bank informedness, and we return to this issue below when we consider our forecasting results.

Order flows from internal customers within the bank also follow the same pattern, are even more significant and bear coefficients of larger magnitude. Unfortunately, we have little understanding of the nature of these internal customer flows since the data provider was unwilling (or unable) to clarify the reasons behind internal transactions.

Order flows from end-user customers are not significant until the aggregation window rises to 16 minutes for corporate and 20 minutes for financials. Furthermore, it is noticeable that order flows from corporations are positively correlated with exchange rate changes, while order flows from other type of counterparties (financials, internal, and interbank) are negatively correlated with exchange rate changes. These are opposite to the correlations typically found at lower frequencies by many other researchers. At daily frequencies, order flows from financial customers are typically positively correlated with contemporaneous exchange rate changes (such that purchases of the dollar by financial sector end-users is typically associated with an appreciation of the dollar) while corporate end-users are more often negatively correlated with changes in the spot rate.

As noted above, the usual explanation for the positive contemporaneous correlation for financials is that their order flows conveys useful information to the markets which is subsequently priced into the spot rate. A contemporaneous negative correlation between flows and rate changes is more difficult to explain within the paradigm that there is information in flows (since it would suggest that buying dollars conveys bad news regarding the value of the dollar). Explanations have been advanced based on the idea that markets cannot discern the source of the end-user flow that causes interbank actions by the customer's bank. Thus, the interbank price reacts by an average amount before eventually realizing the true nature of the information content. For some very informed customers there will then be an initial positive reaction followed by further positive reactions as the larger-than-average information content of the flow is recognised. For others, there will be an initially positive reaction followed by a reversal once the market learns this was an uninformed (or at least less informed than average) trade. However these explanations actually imply negative forecasting relationships not a negative contemporaneous correlation. The negative coefficient between financial customer flows and exchange rate

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changes is then doubly puzzling, first because it is the opposite of that usually found, and second because it is found contemporaneously in high frequency data.

One straightforward explanation outside the information paradigm is that financial customers are engaging in negative feedback trading. The contemporaneously negative relationship is because, at very high frequencies, financial customers buy currencies that have just fallen in value. If they are merely feedback trading we would not expect to see subsequent appreciation in the currency purchased. However, if they are informed about future exchange rate movements and choose to time their trades by buying on temporary falls in the value of a currency, we would expect to see both negative contemporaneous correlation and a positive FX forecasting ability. With this in mind, we now turn to our forecasting results.

4.2   *Forecasting relationships between FX flows and FX returns*

The beta coefficients from the estimated FX forecasting equation (2) are reported in Table 5. Lightly shaded cells denote significance at the ten per cent level, darker shading denotes significance at the five per cent level. The coefficients represent the percentage change in the euro-dollar exchange rate from a €1bn flow into the dollar, expressed such that a positive sign is an appreciation of the dollar.

Table 5A. Impact of order flow on future exchange rate changes: Financial customer order flows

Aggregation Window	Forecast Horizon																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	0.04	0.00	-0.03	-0.01	-0.08	-0.09	-0.13	-0.15	-0.17	-0.19	-0.22	-0.22	-0.26	-0.23	-0.17	-0.17	-0.20	-0.18	-0.21	-0.22	-0.17	-0.20	-0.16	-0.16	-0.15	-0.15	-0.09	-0.08	-0.08	-0.09
2	0.00	-0.04	-0.04	-0.07	-0.10	-0.13	-0.16	-0.17	-0.20	-0.22	-0.23	-0.26	-0.26	-0.21	-0.19	-0.20	-0.20	-0.20	-0.22	-0.21	-0.19	-0.19	-0.17	-0.16	-0.16	-0.13	-0.10	-0.09	-0.09	-0.09
3	-0.01	-0.03	-0.05	-0.07	-0.11	-0.13	-0.16	-0.18	-0.20	-0.22	-0.24	-0.25	-0.23	-0.20	-0.19	-0.19	-0.20	-0.20	-0.20	-0.20	-0.18	-0.17	-0.16	-0.15	-0.13	-0.11	-0.08	-0.08	-0.08	-0.08
4	0.00	-0.03	-0.05	-0.08	-0.11	-0.13	-0.16	-0.18	-0.20	-0.22	-0.23	-0.22	-0.21	-0.19	-0.18	-0.19	-0.20	-0.19	-0.19	-0.18	-0.17	-0.16	-0.16	-0.14	-0.12	-0.10	-0.08	-0.08	-0.07	-0.07
5	-0.02	-0.04	-0.07	-0.09	-0.12	-0.14	-0.17	-0.18	-0.21	-0.22	-0.21	-0.21	-0.20	-0.18	-0.18	-0.20	-0.19	-0.19	-0.18	-0.17	-0.16	-0.16	-0.14	-0.13	-0.11	-0.10	-0.08	-0.07	-0.07	-0.08
6	-0.02	-0.04	-0.07	-0.09	-0.12	-0.14	-0.16	-0.18	-0.19	-0.19	-0.19	-0.19	-0.18	-0.18	-0.18	-0.18	-0.18	-0.17	-0.16	-0.15	-0.15	-0.13	-0.12	-0.10	-0.09	-0.08	-0.06	-0.06	-0.06	-0.07
7	-0.02	-0.04	-0.07	-0.09	-0.12	-0.14	-0.16	-0.17	-0.18	-0.18	-0.18	-0.17	-0.17	-0.17	-0.16	-0.17	-0.16	-0.15	-0.15	-0.14	-0.12	-0.11	-0.10	-0.09	-0.07	-0.06	-0.05	-0.05	-0.05	-0.06
8	-0.02	-0.04	-0.07	-0.09	-0.11	-0.13	-0.15	-0.15	-0.16	-0.16	-0.16	-0.16	-0.16	-0.15	-0.15	-0.15	-0.14	-0.13	-0.13	-0.12	-0.10	-0.09	-0.08	-0.07	-0.05	-0.04	-0.03	-0.04	-0.04	-0.05
9	-0.02	-0.04	-0.07	-0.08	-0.11	-0.13	-0.13	-0.14	-0.14	-0.14	-0.15	-0.15	-0.14	-0.14	-0.13	-0.13	-0.12	-0.12	-0.11	-0.10	-0.08	-0.07	-0.06	-0.05	-0.04	-0.03	-0.02	-0.03	-0.03	-0.04
10	-0.02	-0.04	-0.06	-0.08	-0.10	-0.11	-0.12	-0.12	-0.13	-0.13	-0.14	-0.13	-0.13	-0.12	-0.11	-0.11	-0.11	-0.10	-0.09	-0.08	-0.06	-0.05	-0.04	-0.03	-0.02	-0.02	-0.01	-0.01	-0.01	-0.02
11	-0.02	-0.04	-0.06	-0.08	-0.09	-0.10	-0.11	-0.11	-0.12	-0.12	-0.12	-0.12	-0.11	-0.11	-0.10	-0.10	-0.09	-0.08	-0.07	-0.06	-0.04	-0.03	-0.02	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00
12	-0.02	-0.04	-0.06	-0.07	-0.08	-0.09	-0.09	-0.10	-0.11	-0.11	-0.11	-0.10	-0.10	-0.09	-0.08	-0.08	-0.07	-0.06	-0.05	-0.04	-0.02	-0.02	-0.01	0.00	0.00	0.01	0.01	0.01	0.02	0.01
13	-0.02	-0.04	-0.05	-0.06	-0.07	-0.08	-0.09	-0.09	-0.09	-0.10	-0.09	-0.09	-0.08	-0.08	-0.07	-0.06	-0.05	-0.04	-0.03	-0.02	-0.01	0.00	0.00	0.01	0.01	0.02	0.02	0.03	0.03	0.03
14	-0.01	-0.03	-0.04	-0.05	-0.06	-0.07	-0.08	-0.08	-0.08	-0.08	-0.08	-0.07	-0.07	-0.06	-0.05	-0.04	-0.04	-0.02	-0.01	0.00	0.01	0.01	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.04
15	-0.01	-0.02	-0.03	-0.04	-0.06	-0.06	-0.07	-0.07	-0.07	-0.07	-0.07	-0.06	-0.06	-0.05	-0.04	-0.03	-0.02	-0.01	0.00	0.01	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.05
16	-0.01	-0.02	-0.03	-0.04	-0.05	-0.06	-0.06	-0.06	-0.07	-0.06	-0.06	-0.06	-0.05	-0.04	-0.03	-0.02	-0.01	0.00	0.01	0.01	0.02	0.02	0.03	0.04	0.04	0.05	0.06	0.06	0.06	0.06
17	-0.01	-0.02	-0.03	-0.04	-0.05	-0.06	-0.06	-0.06	-0.06	-0.06	-0.05	-0.05	-0.04	-0.03	-0.02	-0.01	0.00	0.01	0.01	0.02	0.02	0.03	0.03	0.04	0.05	0.05	0.06	0.06	0.07	0.06
18	-0.01	-0.02	-0.03	-0.04	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.04	-0.03	-0.02	-0.01	0.00	0.00	0.01	0.02	0.02	0.03	0.03	0.04	0.05	0.05	0.05	0.06	0.07	0.07	0.07
19	-0.01	-0.02	-0.03	-0.04	-0.04	-0.05	-0.05	-0.05	-0.05	-0.04	-0.04	-0.03	-0.02	-0.01	0.00	0.00	0.01	0.01	0.02	0.03	0.03	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.08	0.07
20	-0.01	-0.02	-0.03	-0.03	-0.04	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.02	-0.01	0.00	0.01	0.01	0.01	0.02	0.03	0.03	0.04	0.05	0.05	0.06	0.06	0.07	0.08	0.08	0.08	0.07
21	-0.01	-0.02	-0.02	-0.03	-0.03	-0.04	-0.04	-0.03	-0.03	-0.03	-0.02	-0.01	0.00	0.00	0.01	0.02	0.02	0.03	0.03	0.04	0.05	0.05	0.06	0.07	0.07	0.08	0.08	0.08	0.08	0.08
22	-0.01	-0.01	-0.02	-0.02	-0.03	-0.03	-0.03	-0.03	-0.02	-0.02	-0.01	-0.01	0.00	0.01	0.01	0.02	0.02	0.03	0.04	0.04	0.05	0.06	0.06	0.07	0.08	0.08	0.09	0.08	0.08	0.08
23	-0.01	-0.01	-0.02	-0.02	-0.03	-0.03	-0.02	-0.02	-0.02	-0.01	-0.01	0.00	0.00	0.01	0.02	0.02	0.03	0.04	0.04	0.05	0.06	0.06	0.07	0.08	0.08	0.08	0.08	0.09	0.09	0.08
24	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01	-0.01	0.00	0.00	0.01	0.01	0.02	0.03	0.03	0.04	0.04	0.05	0.06	0.07	0.07	0.08	0.08	0.08	0.08	0.09	0.09	0.08
25	0.00	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02	-0.01	-0.01	-0.01	0.00	0.00	0.01	0.02	0.02	0.03	0.03	0.04	0.05	0.06	0.06	0.07	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09
26	0.00	-0.01	-0.01	-0.01	-0.02	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.01	0.01	0.02	0.03	0.03	0.04	0.05	0.05	0.06	0.07	0.07	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09
27	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.03	0.04	0.04	0.05	0.06	0.06	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.09	0.09
28	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.01	0.01	0.02	0.02	0.03	0.04	0.04	0.05	0.06	0.06	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09
29	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.03	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.07	0.08	0.08	0.09	0.09	0.09	0.09	0.08
30	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.03	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.07	0.08	0.08	0.09	0.09	0.09	0.09	0.08

Table 5B. Impact of order flow on future exchange rate changes: Corporate customer order flows

		Forecast Horizon																													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Aggregation Window	1	0.02	0.04	0.02	0.03	0.03	0.01	0.00	0.03	0.08	0.09	0.10	0.09	0.08	0.08	0.09	0.10	0.12	0.15	0.17	0.18	0.20	0.19	0.16	0.13	0.11	0.15	0.14	0.11	0.12	0.13
	2	0.02	0.02	0.01	0.02	0.01	0.00	0.00	0.04	0.07	0.08	0.08	0.07	0.06	0.07	0.08	0.09	0.12	0.15	0.16	0.17	0.18	0.16	0.13	0.11	0.12	0.13	0.11	0.11	0.11	0.11
	3	0.01	0.01	0.00	0.00	-0.01	-0.01	0.01	0.04	0.06	0.06	0.06	0.05	0.05	0.06	0.07	0.10	0.12	0.14	0.15	0.16	0.15	0.13	0.11	0.11	0.11	0.11	0.10	0.10	0.10	0.09
	4	0.01	0.01	0.00	-0.01	-0.01	0.00	0.02	0.04	0.06	0.06	0.06	0.05	0.06	0.07	0.09	0.11	0.13	0.15	0.15	0.15	0.14	0.12	0.11	0.11	0.10	0.11	0.10	0.10	0.10	0.10
	5	0.00	0.00	-0.01	-0.01	0.00	0.01	0.03	0.05	0.06	0.06	0.06	0.06	0.07	0.08	0.10	0.12	0.14	0.15	0.15	0.15	0.14	0.13	0.12	0.11	0.11	0.12	0.11	0.11	0.11	0.11
	6	0.00	0.00	-0.01	0.00	0.01	0.02	0.04	0.05	0.06	0.06	0.07	0.07	0.08	0.10	0.11	0.13	0.14	0.15	0.15	0.15	0.14	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11
	7	0.00	0.00	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.08	0.09	0.11	0.12	0.14	0.15	0.15	0.15	0.15	0.15	0.14	0.13	0.13	0.12	0.13	0.13	0.13	0.12	0.11
	8	0.00	0.01	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.15	0.16	0.15	0.15	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.12	0.11
	9	0.01	0.01	0.02	0.03	0.03	0.04	0.05	0.06	0.08	0.09	0.10	0.10	0.12	0.13	0.14	0.14	0.15	0.15	0.16	0.15	0.15	0.14	0.14	0.13	0.13	0.14	0.13	0.12	0.12	0.11
	10	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.06	0.08	0.09	0.10	0.11	0.12	0.13	0.13	0.14	0.14	0.15	0.15	0.15	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.11	0.10	0.10
	11	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.07	0.08	0.09	0.10	0.11	0.12	0.12	0.13	0.13	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.11	0.11	0.10
	12	0.01	0.01	0.01	0.02	0.03	0.04	0.05	0.07	0.08	0.09	0.10	0.11	0.11	0.12	0.13	0.13	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.12	0.12	0.12	0.11	0.10	0.10	0.10
	13	0.00	0.01	0.01	0.02	0.03	0.04	0.06	0.07	0.09	0.10	0.10	0.11	0.11	0.12	0.12	0.13	0.13	0.14	0.14	0.13	0.13	0.13	0.12	0.12	0.11	0.11	0.11	0.10	0.10	0.10
	14	0.01	0.01	0.02	0.02	0.03	0.05	0.06	0.08	0.09	0.09	0.10	0.10	0.10	0.11	0.12	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.11	0.11	0.11	0.10	0.10	0.09
	15	0.01	0.01	0.02	0.03	0.04	0.05	0.06	0.08	0.09	0.10	0.10	0.10	0.11	0.11	0.12	0.12	0.13	0.13	0.13	0.13	0.13	0.12	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.09
	16	0.01	0.01	0.02	0.03	0.04	0.05	0.07	0.08	0.09	0.09	0.10	0.10	0.11	0.11	0.12	0.12	0.12	0.13	0.13	0.13	0.12	0.11	0.11	0.10	0.10	0.10	0.10	0.09	0.09	0.09
	17	0.01	0.02	0.02	0.03	0.04	0.06	0.07	0.08	0.08	0.09	0.10	0.10	0.10	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.10	0.10	0.10	0.10	0.09	0.09	0.09	0.08
	18	0.01	0.02	0.03	0.04	0.05	0.05	0.06	0.07	0.08	0.09	0.09	0.10	0.10	0.10	0.11	0.11	0.12	0.12	0.12	0.11	0.11	0.10	0.10	0.10	0.09	0.09	0.09	0.08	0.08	0.08
	19	0.01	0.02	0.03	0.04	0.04	0.05	0.06	0.07	0.08	0.08	0.09	0.09	0.09	0.10	0.10	0.11	0.11	0.11	0.11	0.10	0.10	0.10	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08
	20	0.01	0.02	0.03	0.03	0.04	0.05	0.06	0.07	0.07	0.08	0.08	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.07
	21	0.01	0.02	0.02	0.03	0.04	0.05	0.05	0.06	0.07	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07
	22	0.01	0.01	0.02	0.03	0.03	0.04	0.05	0.06	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06
	23	0.01	0.01	0.02	0.03	0.03	0.04	0.05	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06
	24	0.01	0.01	0.02	0.02	0.03	0.04	0.04	0.05	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
	25	0.01	0.01	0.02	0.02	0.03	0.04	0.04	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05
	26	0.01	0.01	0.02	0.02	0.03	0.03	0.04	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05
	27	0.01	0.01	0.02	0.02	0.03	0.03	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	28	0.01	0.01	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04
	29	0.01	0.01	0.01	0.02	0.03	0.03	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04
	30	0.01	0.01	0.01	0.02	0.02	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.03

Table 5C. *Impact of order flow on future exchange rate changes: Internal customer order flows*

Aggregation Window	Forecast Horizon																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	-0.04	-0.07	-0.08	-0.06	-0.05	-0.07	-0.09	-0.08	-0.09	-0.08	-0.12	-0.08	-0.06	-0.06	-0.09	-0.09	-0.05	-0.05	-0.04	0.01	0.03	0.02	0.01	-0.04	-0.02	-0.02	0.03	0.03	0.04	0.13
2	-0.03	-0.06	-0.05	-0.04	-0.05	-0.06	-0.07	-0.07	-0.07	-0.08	-0.08	-0.05	-0.05	-0.06	-0.07	-0.05	-0.03	-0.03	0.00	0.04	0.04	0.03	0.01	0.00	0.00	0.03	0.05	0.06	0.11	0.16
3	-0.03	-0.04	-0.03	-0.03	-0.04	-0.05	-0.05	-0.05	-0.06	-0.06	-0.05	-0.03	-0.04	-0.04	-0.04	-0.03	-0.01	0.01	0.04	0.06	0.06	0.04	0.03	0.02	0.04	0.06	0.08	0.12	0.16	0.19
4	-0.02	-0.02	-0.02	-0.03	-0.03	-0.04	-0.04	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03	-0.02	-0.01	0.01	0.04	0.06	0.07	0.06	0.05	0.05	0.05	0.07	0.09	0.13	0.16	0.19	0.20
5	-0.01	-0.02	-0.03	-0.02	-0.03	-0.03	-0.04	-0.04	-0.04	-0.03	-0.03	-0.03	-0.02	-0.02	-0.01	0.01	0.03	0.05	0.06	0.07	0.07	0.06	0.06	0.07	0.09	0.12	0.16	0.18	0.20	0.20
6	-0.01	-0.02	-0.02	-0.02	-0.03	-0.04	-0.04	-0.03	-0.03	-0.03	-0.03	-0.02	-0.02	-0.01	0.00	0.02	0.04	0.06	0.06	0.07	0.07	0.07	0.08	0.08	0.12	0.15	0.18	0.19	0.20	0.20
7	-0.01	-0.02	-0.02	-0.02	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	-0.01	0.00	0.02	0.04	0.05	0.06	0.07	0.07	0.08	0.09	0.09	0.11	0.14	0.17	0.19	0.19	0.20	0.20
8	-0.01	-0.02	-0.02	-0.02	-0.02	-0.03	-0.03	-0.02	-0.03	-0.02	-0.02	-0.01	0.00	0.02	0.03	0.05	0.06	0.07	0.07	0.09	0.09	0.10	0.12	0.14	0.16	0.18	0.19	0.20	0.20	0.21
9	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01	0.00	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.10	0.10	0.12	0.14	0.16	0.20	0.20	0.21	0.21	0.21	0.21
10	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01	0.00	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.11	0.12	0.14	0.16	0.17	0.18	0.19	0.20	0.21	0.21	0.21
11	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01	-0.01	0.00	0.01	0.03	0.04	0.04	0.05	0.06	0.08	0.09	0.10	0.12	0.14	0.16	0.17	0.17	0.19	0.19	0.21	0.21	0.21	0.21
12	-0.01	-0.01	-0.01	-0.01	-0.02	-0.01	-0.01	-0.01	0.00	0.01	0.02	0.04	0.04	0.05	0.06	0.07	0.09	0.10	0.12	0.15	0.16	0.17	0.18	0.18	0.19	0.20	0.21	0.21	0.22	0.22
13	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.10	0.12	0.14	0.16	0.17	0.18	0.18	0.19	0.20	0.21	0.21	0.22	0.22	0.22
14	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.01	0.02	0.03	0.04	0.05	0.05	0.07	0.08	0.09	0.11	0.13	0.15	0.17	0.18	0.18	0.19	0.19	0.20	0.21	0.22	0.22	0.22	0.22
15	-0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.01	0.02	0.03	0.03	0.04	0.05	0.06	0.07	0.08	0.11	0.13	0.15	0.16	0.17	0.18	0.18	0.19	0.20	0.20	0.21	0.22	0.22	0.22	0.23
16	-0.01	-0.01	-0.01	-0.01	0.00	0.01	0.02	0.03	0.03	0.04	0.05	0.06	0.07	0.08	0.10	0.11	0.13	0.15	0.16	0.17	0.18	0.18	0.18	0.18	0.19	0.20	0.21	0.21	0.22	0.22
17	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.03	0.04	0.04	0.05	0.07	0.08	0.09	0.11	0.12	0.13	0.15	0.16	0.17	0.18	0.17	0.17	0.18	0.18	0.19	0.20	0.21	0.22	0.23
18	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.04	0.04	0.05	0.06	0.07	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.16	0.16	0.17	0.17	0.18	0.19	0.20	0.22	0.23
19	0.00	0.00	0.00	0.01	0.02	0.02	0.03	0.04	0.05	0.05	0.06	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.16	0.15	0.15	0.16	0.17	0.18	0.19	0.21	0.22	0.24
20	0.00	0.00	0.01	0.02	0.02	0.03	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11	0.11	0.13	0.14	0.14	0.15	0.15	0.15	0.15	0.15	0.16	0.18	0.19	0.21	0.23	0.24
21	0.00	0.00	0.01	0.01	0.02	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.10	0.11	0.12	0.13	0.13	0.14	0.14	0.14	0.14	0.15	0.16	0.18	0.20	0.21	0.23	0.24
22	0.00	0.00	0.01	0.01	0.02	0.03	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.09	0.10	0.11	0.11	0.12	0.12	0.13	0.13	0.13	0.13	0.14	0.16	0.18	0.20	0.22	0.23	0.24
23	0.00	0.00	0.01	0.01	0.02	0.03	0.03	0.05	0.06	0.06	0.07	0.08	0.08	0.09	0.10	0.10	0.10	0.11	0.11	0.12	0.12	0.12	0.13	0.15	0.16	0.18	0.20	0.22	0.23	0.25
24	0.00	0.00	0.01	0.01	0.02	0.03	0.04	0.05	0.05	0.06	0.07	0.07	0.08	0.09	0.09	0.09	0.10	0.10	0.11	0.11	0.12	0.12	0.13	0.15	0.17	0.19	0.20	0.22	0.24	0.25
25	0.00	0.00	0.01	0.02	0.02	0.03	0.04	0.05	0.06	0.06	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.10	0.10	0.11	0.12	0.13	0.14	0.16	0.17	0.19	0.21	0.23	0.24	0.25
26	0.00	0.01	0.01	0.02	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.10	0.11	0.12	0.13	0.14	0.16	0.18	0.19	0.21	0.23	0.24	0.26
27	0.00	0.01	0.01	0.02	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.07	0.07	0.08	0.08	0.09	0.10	0.11	0.13	0.14	0.15	0.16	0.18	0.20	0.22	0.23	0.25	0.26
28	0.00	0.01	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.06	0.06	0.07	0.07	0.08	0.09	0.10	0.12	0.13	0.14	0.15	0.17	0.18	0.20	0.22	0.23	0.25	0.26
29	0.00	0.01	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.07	0.08	0.09	0.10	0.12	0.13	0.14	0.15	0.17	0.18	0.20	0.22	0.24	0.25	0.26
30	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.06	0.06	0.08	0.09	0.11	0.12	0.13	0.14	0.16	0.17	0.19	0.20	0.22	0.24	0.25	0.26

Table 5D. Impact of order flow on future exchange rate changes: Interbank counterparty order flows

Aggregation Window		Forecast Horizon																													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	1	0.01	-0.03	-0.06	-0.07	-0.09	-0.07	-0.06	-0.03	-0.02	0.01	0.03	0.04	0.02	0.03	0.00	-0.01	0.03	0.00	0.03	0.04	0.03	0.09	0.09	0.10	0.14	0.13	0.09	0.11	0.12	0.13
	2	-0.01	-0.05	-0.07	-0.08	-0.08	-0.07	-0.04	-0.03	-0.01	0.02	0.03	0.02	0.02	0.01	-0.01	0.01	0.01	0.01	0.03	0.03	0.06	0.08	0.09	0.11	0.12	0.10	0.09	0.11	0.12	0.12
	3	-0.02	-0.05	-0.06	-0.06	-0.06	-0.04	-0.02	0.00	0.02	0.03	0.04	0.03	0.02	0.02	0.02	0.02	0.03	0.04	0.05	0.07	0.08	0.10	0.12	0.13	0.13	0.12	0.12	0.13	0.14	0.13
	4	-0.02	-0.04	-0.05	-0.04	-0.03	-0.02	0.00	0.02	0.04	0.05	0.05	0.05	0.04	0.03	0.03	0.03	0.04	0.05	0.06	0.08	0.09	0.10	0.13	0.14	0.14	0.14	0.14	0.15	0.15	0.14
	5	-0.02	-0.03	-0.03	-0.03	-0.02	0.00	0.02	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.06	0.07	0.08	0.10	0.11	0.13	0.14	0.15	0.15	0.16	0.16	0.16	0.16	0.15
	6	-0.01	-0.02	-0.02	-0.01	0.00	0.02	0.04	0.05	0.06	0.06	0.06	0.06	0.05	0.06	0.06	0.07	0.09	0.10	0.11	0.13	0.14	0.15	0.16	0.16	0.17	0.17	0.17	0.17	0.16	0.15
	7	-0.01	-0.01	-0.01	0.00	0.01	0.03	0.04	0.05	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.09	0.10	0.11	0.13	0.14	0.15	0.16	0.17	0.17	0.18	0.18	0.17	0.17	0.16	0.15
	8	0.00	0.00	0.00	0.01	0.02	0.04	0.05	0.05	0.06	0.06	0.06	0.06	0.07	0.07	0.08	0.10	0.11	0.12	0.14	0.15	0.16	0.17	0.17	0.18	0.18	0.18	0.17	0.17	0.16	0.15
	9	0.00	0.00	0.01	0.02	0.03	0.04	0.04	0.05	0.06	0.06	0.06	0.07	0.07	0.08	0.09	0.10	0.12	0.13	0.14	0.15	0.16	0.17	0.17	0.18	0.18	0.17	0.16	0.16	0.15	0.15
	10	0.00	0.00	0.01	0.02	0.03	0.03	0.04	0.05	0.05	0.06	0.06	0.07	0.08	0.09	0.09	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.17	0.17	0.17	0.16	0.16	0.15	0.15	0.15
	11	0.00	0.01	0.01	0.02	0.02	0.03	0.04	0.04	0.05	0.06	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.16	0.17	0.16	0.16	0.15	0.15	0.15	0.15	0.14
	12	0.00	0.00	0.01	0.01	0.02	0.03	0.03	0.04	0.05	0.06	0.07	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.16	0.16	0.16	0.15	0.15	0.14	0.14	0.14	0.14
	13	0.00	0.00	0.00	0.01	0.02	0.02	0.03	0.04	0.05	0.06	0.07	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.13	0.13
	14	0.00	0.00	0.00	0.01	0.02	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.09	0.10	0.11	0.12	0.13	0.14	0.14	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.13	0.13	0.12
	15	0.00	0.00	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.07	0.08	0.09	0.10	0.10	0.11	0.12	0.13	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.12	0.12
	16	0.00	0.00	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.09	0.10	0.11	0.12	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.12	0.12	0.11
	17	0.00	0.00	0.01	0.01	0.02	0.04	0.05	0.06	0.07	0.08	0.08	0.09	0.10	0.10	0.11	0.12	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.13	0.13	0.12	0.12	0.11	0.11
	18	0.00	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.08	0.09	0.10	0.11	0.11	0.12	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.11	0.11	0.11
	19	0.00	0.01	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.09	0.10	0.11	0.11	0.12	0.12	0.12	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.10
	20	0.00	0.01	0.02	0.02	0.03	0.04	0.06	0.07	0.07	0.08	0.09	0.10	0.10	0.10	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.10	0.10	0.10
	21	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.07	0.08	0.09	0.09	0.10	0.10	0.10	0.11	0.11	0.11	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.10	0.10	0.10	0.10	0.10
	22	0.01	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.07	0.08	0.09	0.09	0.09	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.09
	23	0.01	0.01	0.02	0.03	0.04	0.05	0.05	0.06	0.07	0.08	0.08	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.09	0.09
	24	0.01	0.01	0.02	0.03	0.04	0.04	0.05	0.06	0.07	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.09	0.09	0.09	0.08
	25	0.01	0.01	0.02	0.03	0.04	0.04	0.05	0.06	0.07	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08
	26	0.01	0.01	0.02	0.03	0.03	0.04	0.05	0.06	0.06	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08
	27	0.01	0.01	0.02	0.03	0.03	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07
	28	0.01	0.01	0.02	0.03	0.03	0.04	0.05	0.05	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07
	29	0.01	0.01	0.02	0.02	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
	30	0.01	0.01	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06

Notes: The tables report coefficient estimates in the regression $R_{t,t+k}^{FX} = c + \gamma R_{t-i,t}^{FX} + \sum_{m=1}^{4} \beta_m OF_{t-i,t}^{FX} + \varepsilon_t$.

Panels A, B, C and D report, respectively, the coefficient estimates for financial end-user customer order flows, corporate end-user order flows, internal customer order flows and interbank counterparty order flows. The horizontal axis varies over the *k*-minute forecast horizon; the vertical axis varies according to the aggregation window of foreign exchange order flows through the *i*-minute period. A lightly shaded cell denotes significance at the ten per cent level using robust standard error estimates. Darker shading denotes significance at the five per cent level. Intraday data from 7:30am to 5:00pm for 25 days are used. Coefficients represent the percentage change in the euro-dollar exchange rate from a €1bn flow into the dollar, expressed such that a positive sign is an appreciation of the dollar.

We highlight the following findings

1) The effect of financial customer foreign exchange order flows on future exchange rate changes follows a clear pattern. Over short horizons and with short aggregations windows (that is k and i both between five and fifteen minutes), flows into the dollar forecast a statistically significant subsequent decline in the dollar. However, as both the aggregation window and forecast horizon increase, the sign of the forecasting correlation reverses. While not becoming significant even when both aggregation and forecasting windows reach half an hour, it is conceivable that for larger values of i and k than we can examine in our data the forecasting correlation becomes sufficiently positive to generate the positive contemporaneous correlation seen at daily frequencies. As noted above, this pattern would be consistent with financial customers timing their trades by buying (selling) on temporary dips (rises) before the information in their trades is slowly priced into FX rates. There is small positive autocorrelation in FX returns which may also be responsible for the negative short-term forecasting ability of financials' FX orders.

2) The effect of corporate foreign exchange order flows on future exchange rate changes is essentially uniformly positive and statistically significant given appropriate aggregation windows and forecast horizons (that is i and k both lie between ten and twenty minutes). Significance disappears once both the aggregation window and forecast horizon increase to half an hour, and there is no evidence of very short term forecasting power using small aggregation windows.

3) The coefficient magnitudes typically suggest a 30bp change in the exchange rate following a €1bn net flow into the market. This is in line with the findings of other studies. Berger et al (2006), for example, suggest that a $1bn flow in the interbank market is associated with a 55bp price impact at the one-minute horizon,

4) Correlations between order flows from internal and interbank counterparties and future exchange rate changes are negative at very short horizons but positive as forecast horizons and aggregation windows expand.

5) Interbank order flows rarely reach significance suggesting that the data providing bank cannot learn much about the value of the currency from the flows it receives from interbank counterparties. Since the bank is large and active in the currency markets we can infer that its counterparties are typically less informed than it is. This contrasts with

the evidence in Frommel et al. (2007) from a smaller European bank which gets much of its information from flows from interbank counterparties. See Moore and Payne (2009) for further discussion of relative bank informedness.

6) R^2 figures are low and range from 0.05% for short-horizon/short aggregation window combinations to 0.50% for long-horizon/long aggregation window combinations.

7) We conduct F-tests on the coefficients on order flow terms in equation (2). They show clearly that the four different sources of order flow are jointly significant at almost all aggregation window-forecast horizon combinations. Similarly, the end-user customer flows from corporates and financials are jointly significant in the majority of cases. Finally, the coefficients on corporate and financial customer flows are different from each other in most cases. It is clear that customer order flows matter for the pricing of foreign exchange rates, and that there is heterogeneity in the flows which matters for FX pricing.

Recall that the order flows used in this paper are those seen by a specific bank. As measured, they are not available to the wider FX market. How then do these flows impact on market foreign exchange rates? Three explanations suggest themselves[6]:

(i)   The customers of this bank are able to forecast high frequency returns and hence can position themselves accordingly.

(ii)   The bank trades upon these customer flows, either by passing these trades directly onto the interbank market and/or by actively trading based upon the information content, revealing the information to the wider market.

(iii)   The flows seen by the bank are correlated with the flows seen across the wider market.

We have no information to guide us with regard to this issue, but discussions with the bank supplying the data lead us to believe that (iii) is likely for corporate customers, (ii) is likely for corporate, financial and internal customers and (i) is possible for a (small) subset of customers.

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[6] We thank the referee for clarifying our thinking on this, and other, issues in the paper.

Previous papers have demonstrated forecasting power from order flows to future exchange rates using both end-user flows (Evans and Lyons, 2005a) and interbank flows (Rime, Sarno, and Sojli, 2009). This is the first paper, to our knowledge, that demonstrates intra-day forecasting power using end-user flows. Beyond the mere existence of some forecasting power, the main contribution of the analysis has been to highlight the heterogeneity across the different end-user categories. Both signs and horizons over which there is forecasting power differ noticeably between corporate and financial end-users. We return to discuss the foreign exchange forecasting results later in the paper where we can interpret them with the aid of the cross-market relationship results, to which we now turn.

4.3   *Contemporaneous relationships between FX flows and stock market index returns*

We start with the two ETFs tracking stock market indices, SPY (S&P 500) and DIA (DOW 30) within the contemporaneous model discussed in previous sections. Based on the estimated equation $R_{t-i,t}^{S} = c + \gamma R_{t-i,t}^{FX} + \sum_{m=1}^{4} \beta_m OF_{t-i,t}^{FX} + \varepsilon_t$ we obtain the coefficients given in Tables 6 and 7 for the SPY and DIA respectively.

Table 6: SPY Regression results in cross market contemporaneous model

	Aggregation Window														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Financial	0.05	0.08	0.09	0.07	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.04	0.05
Corporate	0.02	0.15	0.23	0.29	0.37	0.35	0.33	0.30	0.27	0.26	0.25	0.25	0.23	0.23	0.23
Internal	0.01	0.16	0.26	0.26	0.30	0.23	0.22	0.24	0.21	0.20	0.19	0.16	0.10	0.08	0.07
Interbank	-0.03	-0.09	-0.08	-0.02	0.02	0.05	0.07	0.08	0.07	0.05	0.00	-0.02	-0.05	-0.06	-0.10
Rfx	0.40	0.28	0.21	0.38	0.52	0.63	0.77	0.86	0.98	1.11	1.15	1.18	1.20	1.21	1.25
	Aggregation Window														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Financial	0.05	0.05	0.05	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.08	0.09	0.10	0.11	0.12
Corporate	0.22	0.21	0.19	0.18	0.16	0.13	0.09	0.04	0.01	-0.01	-0.03	-0.03	-0.04	-0.06	-0.09
Internal	0.05	-0.01	-0.08	-0.11	-0.20	-0.31	-0.45	-0.58	-0.66	-0.74	-0.79	-0.82	-0.83	-0.86	-0.91
Interbank	-0.16	-0.20	-0.23	-0.24	-0.25	-0.27	-0.29	-0.32	-0.32	-0.33	-0.31	-0.28	-0.24	-0.23	-0.22
Rfx	1.32	1.47	1.63	1.79	1.90	2.03	2.11	2.19	2.28	2.35	2.41	2.47	2.54	2.59	2.63

Table 7: DIA Regression results in cross market contemporaneous model

	Aggregation Window														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Financial	0.07	0.08	0.08	0.07	0.07	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.05
Corporate	0.03	0.09	0.17	0.21	0.32	0.33	0.32	0.30	0.27	0.22	0.19	0.18	0.16	0.14	0.14
Internal	0.16	0.23	0.32	0.39	0.48	0.41	0.42	0.48	0.51	0.49	0.48	0.45	0.41	0.34	0.33
Interbank	0.04	-0.12	-0.09	-0.03	0.01	0.03	0.03	0.02	0.01	-0.03	-0.08	-0.11	-0.15	-0.17	-0.21
Rfx	0.37	0.19	0.06	0.18	0.32	0.35	0.47	0.55	0.72	0.87	0.97	1.03	1.09	1.11	1.16
	Aggregation Window														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Financial	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.05
Corporate	0.12	0.12	0.11	0.10	0.08	0.04	0.01	-0.04	-0.06	-0.09	-0.09	-0.10	-0.10	-0.11	-0.13
Internal	0.30	0.26	0.21	0.18	0.10	-0.01	-0.12	-0.24	-0.33	-0.40	-0.45	-0.47	-0.47	-0.48	-0.53
Interbank	-0.26	-0.29	-0.31	-0.32	-0.33	-0.36	-0.38	-0.41	-0.41	-0.42	-0.41	-0.39	-0.36	-0.34	-0.33
Rfx	1.22	1.33	1.48	1.63	1.72	1.85	1.94	2.02	2.12	2.19	2.25	2.31	2.38	2.44	2.48

Notes: The table reports coefficient estimates from the regression $R^{FX}_{t,t+i} = C + \gamma R^{FX}_{t,t+i} + \beta m \sum_{m=1}^{4} OF^{FX}_{t,t+i} + \varepsilon$

The column heading give the value of the aggregation window *i* in the model. Intraday data from 2:30pm to 5:00pm for 25 days are used. A lightly shaded cell denotes significance at the ten per cent level using robust standard error estimates. Darker shading denotes significance at the five per cent level. Coefficients represent the percentage change in the SPY or DIA ETF price from a €1bn flow into the dollar.

We find essentially no contemporaneous relationship between foreign exchange order flows and stock market changes. All but one of the coefficients on order flows are insignificant, and there is no consistency in signs for any category of the bank's counterparties. There is a clear positive contemporaneous relationship between exchange rate returns and stock market returns (over aggregation horizons longer than 10 minutes) which is consistent with many previous studies on return spillovers between different markets (see Ajayi and Mougoue, 1996; Andersen et al., 2007).

4.4   Forecasting relationships between FX flows and stock market index returns

We next investigate the forecasting power of order flows for stock market changes. In the Table 8 we report the coefficient estimates on the four categories of order flow from the forecasting model $R^S_{t,t+k} = c + \alpha R^S_{t-i,t} + \gamma R^{FX}_{t-i,t} + \sum_{m=1}^{4} \beta_m OF^{FX}_{t-i,t} + \varepsilon_t$. The horizontal axis varies over the *k*-minute forecast horizon; the vertical axis varies according to the accumulation of foreign exchange order flows through the *i*-minute period. The coefficients represent the percentage change in the stock index from a €1bn flow into the dollar, expressed such that a positive sign is a rise in the ETF price. We only report the results for the SPY since those for the DIA are very similar. Light shading denotes significance at the ten per cent level, dark shading denotes significance at the five per cent level.

Table 8A. Impact of order flow on future SPY ETF price changes: Financial customer order flows

Aggregation Window \ Forecast Horizon	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	0.04	0.08	0.03	-0.03	-0.03	-0.03	0.02	0.04	0.10	0.05	0.09	0.00	-0.02	0.12	0.04	0.01	0.00	0.04	-0.01	0.04	0.04	0.05	-0.01	-0.02	-0.08	-0.05	-0.06	-0.09	-0.10	-0.06
2	0.04	0.04	-0.02	-0.04	-0.04	-0.02	0.02	0.06	0.06	0.05	0.02	-0.03	0.03	0.06	0.01	-0.01	0.00	0.00	0.00	0.03	0.03	0.01	-0.03	-0.06	-0.08	-0.06	-0.08	-0.10	-0.09	0.00
3	0.01	-0.01	-0.05	-0.06	-0.05	-0.02	0.02	0.03	0.04	0.00	-0.02	-0.01	0.00	0.01	-0.03	-0.03	-0.04	-0.02	-0.02	0.01	-0.01	-0.03	-0.07	-0.09	-0.10	-0.10	-0.12	-0.12	-0.06	-0.04
4	0.00	-0.02	-0.05	-0.05	-0.03	0.00	0.02	0.03	0.02	-0.01	0.00	-0.01	-0.01	-0.01	-0.03	-0.04	-0.03	-0.02	-0.02	-0.01	-0.03	-0.06	-0.08	-0.09	-0.11	-0.11	-0.11	-0.08	-0.07	-0.02
5	-0.01	-0.02	-0.03	-0.03	0.00	0.01	0.03	0.02	0.01	0.01	0.00	-0.02	-0.02	-0.01	-0.04	-0.04	-0.03	-0.02	-0.02	-0.02	-0.05	-0.06	-0.09	-0.10	-0.12	-0.11	-0.09	-0.08	-0.05	-0.03
6	0.00	0.00	-0.01	0.00	0.01	0.02	0.02	0.01	0.02	0.00	-0.01	-0.03	-0.02	-0.03	-0.04	-0.04	-0.03	-0.03	-0.03	-0.04	-0.06	-0.07	-0.10	-0.11	-0.12	-0.10	-0.09	-0.07	-0.05	-0.04
7	0.00	0.00	0.01	0.00	0.02	0.02	0.01	0.02	0.01	-0.01	-0.02	-0.03	-0.04	-0.03	-0.04	-0.04	-0.03	-0.04	-0.05	-0.05	-0.06	-0.08	-0.11	-0.12	-0.11	-0.10	-0.08	-0.07	-0.06	-0.06
8	0.01	0.01	0.00	0.01	0.01	0.00	0.02	0.01	0.00	-0.02	-0.03	-0.05	-0.04	-0.04	-0.04	-0.05	-0.05	-0.05	-0.06	-0.06	-0.08	-0.10	-0.12	-0.11	-0.11	-0.09	-0.08	-0.08	-0.08	-0.08
9	0.01	0.01	0.01	0.00	-0.01	0.01	0.01	0.00	-0.02	-0.03	-0.05	-0.06	-0.05	-0.05	-0.06	-0.06	-0.07	-0.07	-0.08	-0.08	-0.10	-0.12	-0.12	-0.12	-0.11	-0.11	-0.10	-0.10	-0.10	-0.10
10	0.00	0.00	-0.01	-0.02	-0.01	-0.01	-0.01	-0.03	-0.03	-0.05	-0.06	-0.07	-0.06	-0.06	-0.07	-0.08	-0.08	-0.09	-0.10	-0.11	-0.12	-0.12	-0.13	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12
11	0.01	0.00	-0.01	-0.01	-0.01	-0.02	-0.02	-0.03	-0.05	-0.06	-0.06	-0.07	-0.07	-0.07	-0.08	-0.09	-0.09	-0.10	-0.11	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.12	-0.13	-0.13	-0.13	-0.13
12	0.00	-0.01	-0.01	-0.02	-0.02	-0.03	-0.03	-0.05	-0.05	-0.07	-0.07	-0.08	-0.08	-0.08	-0.09	-0.10	-0.10	-0.11	-0.12	-0.12	-0.12	-0.12	-0.12	-0.13	-0.13	-0.13	-0.14	-0.14	-0.14	-0.15
13	0.00	0.00	-0.01	-0.02	-0.03	-0.03	-0.04	-0.04	-0.05	-0.06	-0.07	-0.08	-0.08	-0.08	-0.08	-0.10	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.12	-0.12	-0.13	-0.13	-0.14	-0.14	-0.15	-0.17
14	0.01	0.00	-0.01	-0.02	-0.03	-0.03	-0.04	-0.04	-0.05	-0.06	-0.07	-0.08	-0.08	-0.08	-0.10	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.12	-0.13	-0.13	-0.14	-0.14	-0.14	-0.16	-0.17	-0.18
15	0.00	-0.01	-0.02	-0.03	-0.04	-0.04	-0.04	-0.05	-0.05	-0.07	-0.08	-0.09	-0.09	-0.10	-0.11	-0.12	-0.12	-0.12	-0.11	-0.11	-0.12	-0.13	-0.14	-0.14	-0.15	-0.15	-0.16	-0.18	-0.19	-0.19
16	0.00	-0.01	-0.02	-0.03	-0.04	-0.04	-0.04	-0.05	-0.06	-0.07	-0.08	-0.09	-0.10	-0.10	-0.12	-0.12	-0.12	-0.11	-0.12	-0.12	-0.13	-0.13	-0.14	-0.15	-0.15	-0.16	-0.18	-0.19	-0.20	-0.20
17	-0.01	-0.01	-0.02	-0.03	-0.03	-0.04	-0.04	-0.05	-0.06	-0.07	-0.08	-0.09	-0.10	-0.11	-0.11	-0.12	-0.11	-0.11	-0.12	-0.12	-0.13	-0.14	-0.14	-0.15	-0.16	-0.17	-0.18	-0.19	-0.20	-0.21
18	0.00	-0.01	-0.02	-0.03	-0.03	-0.04	-0.04	-0.05	-0.06	-0.07	-0.08	-0.10	-0.10	-0.10	-0.11	-0.11	-0.11	-0.12	-0.12	-0.13	-0.13	-0.14	-0.15	-0.16	-0.17	-0.18	-0.19	-0.20	-0.21	-0.21
19	-0.01	-0.01	-0.02	-0.03	-0.03	-0.04	-0.05	-0.06	-0.07	-0.08	-0.09	-0.10	-0.10	-0.11	-0.11	-0.12	-0.12	-0.12	-0.13	-0.13	-0.14	-0.15	-0.16	-0.18	-0.19	-0.19	-0.20	-0.21	-0.21	-0.21
20	0.00	-0.01	-0.02	-0.03	-0.04	-0.04	-0.05	-0.06	-0.07	-0.09	-0.09	-0.10	-0.11	-0.10	-0.11	-0.12	-0.12	-0.13	-0.13	-0.13	-0.14	-0.15	-0.17	-0.18	-0.19	-0.20	-0.20	-0.21	-0.21	-0.21
21	0.00	-0.01	-0.02	-0.03	-0.04	-0.05	-0.05	-0.06	-0.08	-0.09	-0.09	-0.10	-0.10	-0.11	-0.12	-0.12	-0.13	-0.13	-0.13	-0.14	-0.15	-0.16	-0.18	-0.19	-0.20	-0.20	-0.21	-0.21	-0.21	-0.21
22	0.00	-0.01	-0.02	-0.03	-0.04	-0.05	-0.06	-0.07	-0.08	-0.09	-0.10	-0.10	-0.10	-0.11	-0.12	-0.12	-0.13	-0.13	-0.13	-0.14	-0.16	-0.17	-0.18	-0.19	-0.20	-0.20	-0.21	-0.21	-0.21	-0.20
23	0.00	-0.01	-0.03	-0.04	-0.04	-0.05	-0.06	-0.07	-0.08	-0.09	-0.09	-0.10	-0.11	-0.11	-0.12	-0.12	-0.13	-0.13	-0.14	-0.15	-0.16	-0.17	-0.18	-0.19	-0.20	-0.20	-0.20	-0.20	-0.20	-0.20
24	-0.01	-0.02	-0.03	-0.04	-0.04	-0.05	-0.06	-0.07	-0.08	-0.09	-0.09	-0.10	-0.11	-0.11	-0.12	-0.12	-0.13	-0.13	-0.15	-0.16	-0.17	-0.18	-0.19	-0.19	-0.20	-0.20	-0.20	-0.19	-0.20	-0.19
25	-0.01	-0.01	-0.02	-0.04	-0.04	-0.05	-0.06	-0.07	-0.07	-0.08	-0.09	-0.10	-0.10	-0.11	-0.11	-0.12	-0.13	-0.14	-0.15	-0.16	-0.16	-0.17	-0.18	-0.19	-0.19	-0.18	-0.19	-0.19	-0.19	-0.19
26	-0.01	-0.01	-0.03	-0.04	-0.05	-0.06	-0.07	-0.07	-0.08	-0.09	-0.10	-0.10	-0.11	-0.11	-0.11	-0.12	-0.13	-0.14	-0.15	-0.16	-0.17	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.19	-0.19	-0.19
27	-0.01	-0.02	-0.03	-0.05	-0.06	-0.07	-0.07	-0.08	-0.09	-0.10	-0.10	-0.11	-0.11	-0.11	-0.12	-0.12	-0.13	-0.14	-0.15	-0.16	-0.17	-0.17	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.19
28	-0.01	-0.02	-0.04	-0.05	-0.06	-0.07	-0.08	-0.09	-0.09	-0.10	-0.10	-0.11	-0.11	-0.11	-0.12	-0.13	-0.13	-0.14	-0.15	-0.16	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.18	-0.18	-0.18
29	-0.01	-0.02	-0.04	-0.06	-0.07	-0.08	-0.08	-0.09	-0.10	-0.10	-0.11	-0.11	-0.11	-0.11	-0.12	-0.13	-0.13	-0.14	-0.15	-0.16	-0.16	-0.16	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.18	-0.18
30	-0.01	-0.03	-0.04	-0.06	-0.07	-0.08	-0.08	-0.09	-0.10	-0.10	-0.10	-0.11	-0.11	-0.11	-0.12	-0.12	-0.13	-0.14	-0.15	-0.15	-0.15	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.17	-0.17	-0.18

Table 8B. Impact of order flow on future SPY ETF price changes: Corporate customer order flows

Aggregation Window	Forecast Horizon																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	0.21	0.41	0.46	0.59	0.53	0.67	0.61	0.61	0.75	0.65	0.57	0.48	0.63	0.72	0.81	0.75	0.63	0.62	0.66	0.90	0.93	0.81	0.90	0.72	0.95	1.13	1.20	1.02	0.71	0.81
2	0.21	0.33	0.43	0.46	0.50	0.54	0.51	0.57	0.57	0.47	0.38	0.40	0.51	0.58	0.59	0.50	0.44	0.45	0.60	0.74	0.69	0.67	0.63	0.65	0.87	1.00	0.95	0.69	0.58	0.66
3	0.15	0.26	0.26	0.32	0.35	0.38	0.41	0.39	0.37	0.27	0.24	0.26	0.33	0.37	0.33	0.29	0.27	0.36	0.47	0.52	0.55	0.47	0.51	0.59	0.77	0.79	0.64	0.50	0.44	0.54
4	0.13	0.16	0.19	0.24	0.26	0.33	0.31	0.27	0.22	0.17	0.15	0.16	0.21	0.21	0.19	0.17	0.22	0.29	0.35	0.43	0.39	0.40	0.47	0.55	0.64	0.56	0.48	0.39	0.37	0.46
5	0.07	0.12	0.14	0.18	0.23	0.25	0.21	0.16	0.14	0.09	0.07	0.07	0.09	0.09	0.09	0.12	0.17	0.20	0.28	0.30	0.32	0.36	0.44	0.46	0.46	0.42	0.36	0.31	0.31	0.40
6	0.07	0.11	0.13	0.19	0.20	0.20	0.15	0.11	0.09	0.05	0.03	0.02	0.04	0.04	0.08	0.11	0.13	0.19	0.21	0.28	0.32	0.37	0.41	0.36	0.37	0.34	0.32	0.29	0.30	0.36
7	0.06	0.10	0.13	0.15	0.15	0.13	0.10	0.07	0.05	0.01	-0.03	-0.03	-0.01	0.02	0.06	0.07	0.12	0.13	0.19	0.27	0.32	0.33	0.31	0.28	0.30	0.30	0.29	0.26	0.26	0.34
8	0.05	0.10	0.10	0.11	0.09	0.09	0.06	0.03	0.01	-0.04	-0.07	-0.07	-0.03	0.01	0.03	0.06	0.07	0.11	0.19	0.27	0.29	0.25	0.24	0.22	0.25	0.26	0.25	0.23	0.25	0.32
9	0.06	0.07	0.07	0.06	0.06	0.05	0.02	-0.01	-0.05	-0.09	-0.11	-0.09	-0.05	-0.03	0.01	0.01	0.05	0.11	0.18	0.23	0.20	0.18	0.18	0.17	0.21	0.22	0.21	0.20	0.22	0.28
10	0.03	0.04	0.03	0.03	0.02	0.01	-0.02	-0.07	-0.09	-0.13	-0.13	-0.11	-0.08	-0.04	-0.04	-0.01	0.04	0.10	0.15	0.15	0.14	0.12	0.13	0.14	0.17	0.18	0.18	0.18	0.19	0.26
11	0.02	0.02	0.02	0.01	0.00	-0.01	-0.06	-0.09	-0.11	-0.13	-0.12	-0.11	-0.07	-0.07	-0.04	0.00	0.06	0.10	0.10	0.12	0.11	0.11	0.12	0.13	0.16	0.17	0.18	0.17	0.20	0.26
12	0.01	0.01	0.00	0.00	-0.02	-0.05	-0.08	-0.11	-0.12	-0.12	-0.13	-0.11	-0.09	-0.06	-0.02	0.03	0.06	0.06	0.07	0.09	0.10	0.10	0.12	0.12	0.16	0.17	0.18	0.18	0.20	0.27
13	0.01	0.01	0.00	-0.01	-0.04	-0.05	-0.08	-0.09	-0.10	-0.11	-0.10	-0.10	-0.06	-0.02	0.02	0.04	0.04	0.05	0.07	0.09	0.10	0.11	0.12	0.14	0.18	0.19	0.21	0.23	0.26	0.30
14	0.01	0.00	-0.01	-0.03	-0.05	-0.06	-0.07	-0.08	-0.09	-0.09	-0.10	-0.08	-0.04	-0.01	0.03	0.02	0.03	0.04	0.07	0.10	0.11	0.11	0.14	0.15	0.19	0.21	0.22	0.23	0.26	0.31
15	0.00	-0.01	-0.02	-0.04	-0.06	-0.06	-0.07	-0.08	-0.07	-0.09	-0.09	-0.06	-0.01	0.02	0.01	0.01	0.02	0.04	0.06	0.10	0.11	0.12	0.15	0.16	0.21	0.22	0.24	0.25	0.27	0.32
16	0.00	-0.01	-0.02	-0.03	-0.04	-0.04	-0.05	-0.06	-0.07	-0.07	-0.05	-0.02	0.01	0.00	0.00	0.00	0.02	0.04	0.06	0.09	0.12	0.13	0.16	0.18	0.22	0.24	0.26	0.26	0.29	0.33
17	-0.01	-0.02	-0.02	-0.03	-0.03	-0.03	-0.04	-0.06	-0.06	-0.05	-0.02	-0.01	-0.01	-0.01	-0.01	0.00	0.01	0.03	0.06	0.10	0.12	0.14	0.17	0.19	0.24	0.26	0.27	0.28	0.30	0.34
18	0.00	-0.01	-0.01	-0.02	-0.03	-0.02	-0.04	-0.04	-0.03	-0.01	0.00	0.00	-0.01	0.00	-0.01	0.00	0.02	0.04	0.07	0.11	0.14	0.16	0.19	0.22	0.26	0.28	0.29	0.30	0.31	0.34
19	-0.01	-0.01	-0.02	-0.03	-0.03	-0.03	-0.04	-0.03	-0.01	0.00	-0.01	-0.02	-0.01	-0.01	-0.01	0.00	0.01	0.04	0.08	0.12	0.15	0.17	0.21	0.24	0.26	0.29	0.31	0.31	0.31	0.36
20	0.00	-0.01	-0.02	-0.02	-0.03	-0.02	-0.01	0.00	0.01	-0.01	-0.01	-0.02	-0.01	-0.01	-0.01	0.00	0.02	0.05	0.09	0.14	0.17	0.20	0.24	0.25	0.29	0.31	0.32	0.32	0.34	0.39
21	-0.01	-0.01	-0.01	-0.03	-0.02	0.00	0.01	0.01	0.00	-0.01	-0.02	-0.02	-0.02	-0.02	-0.01	0.01	0.03	0.06	0.11	0.16	0.19	0.22	0.24	0.27	0.30	0.32	0.32	0.34	0.36	0.40
22	-0.01	-0.01	-0.02	-0.02	0.00	0.02	0.02	0.00	0.00	-0.02	-0.03	-0.03	-0.02	-0.02	0.00	0.02	0.05	0.09	0.13	0.18	0.21	0.23	0.26	0.29	0.31	0.32	0.34	0.35	0.37	0.41
23	0.00	-0.01	0.00	0.01	0.02	0.03	0.02	0.01	0.00	-0.01	-0.02	-0.02	-0.01	0.00	0.02	0.04	0.08	0.12	0.16	0.21	0.23	0.25	0.29	0.30	0.33	0.35	0.37	0.38	0.40	0.43
24	-0.01	0.00	0.01	0.02	0.03	0.03	0.02	0.01	0.00	-0.01	-0.01	-0.01	0.01	0.02	0.04	0.07	0.11	0.15	0.19	0.22	0.25	0.28	0.30	0.31	0.35	0.38	0.40	0.40	0.42	0.44
25	0.01	0.02	0.03	0.04	0.04	0.03	0.02	0.01	0.01	0.00	0.00	0.01	0.03	0.05	0.07	0.10	0.14	0.17	0.20	0.24	0.28	0.30	0.32	0.35	0.38	0.41	0.42	0.42	0.43	0.45
26	0.01	0.03	0.03	0.03	0.02	0.02	0.01	0.00	0.00	-0.01	0.00	0.02	0.04	0.06	0.09	0.12	0.15	0.18	0.22	0.26	0.28	0.30	0.34	0.36	0.40	0.42	0.43	0.43	0.43	0.46
27	0.01	0.02	0.02	0.01	0.00	0.00	-0.01	-0.01	-0.01	-0.01	0.00	0.02	0.05	0.08	0.11	0.14	0.16	0.19	0.23	0.27	0.29	0.32	0.36	0.38	0.41	0.42	0.43	0.43	0.44	0.45
28	0.01	0.01	0.00	-0.01	-0.02	-0.01	-0.02	-0.02	-0.01	-0.01	0.01	0.03	0.07	0.10	0.12	0.14	0.17	0.21	0.24	0.27	0.31	0.34	0.37	0.40	0.42	0.43	0.43	0.43	0.43	0.44
29	0.00	-0.01	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01	0.00	0.02	0.05	0.08	0.11	0.13	0.15	0.19	0.21	0.24	0.29	0.33	0.35	0.38	0.40	0.42	0.43	0.43	0.42	0.41	0.42
30	-0.01	-0.01	-0.02	-0.02	-0.02	-0.01	-0.01	-0.01	0.01	0.02	0.05	0.08	0.11	0.12	0.15	0.17	0.20	0.22	0.27	0.31	0.34	0.37	0.39	0.40	0.42	0.43	0.42	0.41	0.40	0.41

Table 8C. Impact of order flow on future SPY ETF price changes: Internal customer order flows

Aggregation Window	Forecast Horizon																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	0.07	-0.09	-0.18	-0.33	-0.70	-0.92	-0.83	-0.88	-0.93	-0.94	-0.91	-1.25	-0.88	-1.00	-0.99	-1.25	-1.28	-1.40	-1.35	-1.75	-1.81	-1.53	-1.42	-1.65	-1.79	-2.31	-2.11	-2.40	-2.80	-2.55
2	-0.06	-0.16	-0.26	-0.49	-0.81	-0.83	-0.79	-0.87	-0.99	-0.95	-1.20	-1.30	-1.11	-1.23	-1.37	-1.48	-1.52	-1.63	-1.88	-2.09	-2.02	-1.77	-1.88	-2.05	-2.38	-2.48	-2.49	-2.86	-2.95	-2.95
3	-0.04	-0.15	-0.33	-0.56	-0.72	-0.73	-0.72	-0.84	-0.89	-1.05	-1.15	-1.23	-1.14	-1.33	-1.39	-1.49	-1.55	-1.80	-1.98	-2.04	-1.92	-1.87	-1.97	-2.27	-2.36	-2.53	-2.67	-2.83	-2.98	-3.00
4	-0.05	-0.21	-0.38	-0.50	-0.62	-0.63	-0.68	-0.75	-0.95	-1.01	-1.11	-1.21	-1.22	-1.34	-1.41	-1.50	-1.68	-1.87	-1.94	-1.92	-1.91	-1.89	-2.09	-2.22	-2.35	-2.58	-2.63	-2.81	-2.95	-2.94
5	-0.10	-0.26	-0.35	-0.45	-0.54	-0.59	-0.62	-0.81	-0.91	-0.98	-1.10	-1.24	-1.23	-1.34	-1.41	-1.59	-1.73	-1.84	-1.85	-1.90	-1.89	-1.98	-2.05	-2.22	-2.42	-2.55	-2.63	-2.80	-2.89	-2.86
6	-0.11	-0.20	-0.28	-0.36	-0.48	-0.51	-0.64	-0.75	-0.85	-0.94	-1.09	-1.19	-1.19	-1.30	-1.45	-1.59	-1.68	-1.72	-1.79	-1.83	-1.91	-1.91	-2.03	-2.25	-2.37	-2.51	-2.59	-2.71	-2.78	-2.76
7	-0.06	-0.14	-0.21	-0.32	-0.41	-0.53	-0.60	-0.70	-0.81	-0.93	-1.05	-1.14	-1.16	-1.32	-1.45	-1.54	-1.57	-1.66	-1.71	-1.82	-1.83	-1.88	-2.06	-2.21	-2.32	-2.45	-2.50	-2.60	-2.67	-2.61
8	-0.05	-0.11	-0.20	-0.28	-0.44	-0.49	-0.56	-0.68	-0.83	-0.92	-1.03	-1.14	-1.21	-1.36	-1.44	-1.49	-1.58	-1.65	-1.76	-1.79	-1.84	-1.96	-2.07	-2.23	-2.34	-2.42	-2.47	-2.57	-2.59	-2.57
9	-0.03	-0.12	-0.17	-0.33	-0.42	-0.47	-0.57	-0.72	-0.84	-0.94	-1.06	-1.21	-1.28	-1.39	-1.43	-1.53	-1.59	-1.71	-1.76	-1.83	-1.93	-2.00	-2.12	-2.27	-2.34	-2.43	-2.48	-2.53	-2.57	-2.51
10	-0.05	-0.11	-0.22	-0.31	-0.41	-0.49	-0.62	-0.75	-0.87	-0.98	-1.14	-1.28	-1.32	-1.38	-1.47	-1.56	-1.66	-1.72	-1.81	-1.92	-1.97	-2.05	-2.17	-2.27	-2.34	-2.43	-2.44	-2.51	-2.51	-2.42
11	-0.03	-0.14	-0.20	-0.30	-0.41	-0.52	-0.64	-0.77	-0.89	-1.04	-1.19	-1.30	-1.31	-1.41	-1.50	-1.61	-1.66	-1.75	-1.88	-1.94	-2.00	-2.08	-2.16	-2.27	-2.34	-2.38	-2.42	-2.45	-2.42	-2.33
12	-0.08	-0.15	-0.21	-0.32	-0.46	-0.57	-0.68	-0.82	-0.97	-1.12	-1.24	-1.31	-1.36	-1.45	-1.56	-1.63	-1.71	-1.83	-1.92	-1.99	-2.04	-2.09	-2.17	-2.27	-2.30	-2.37	-2.38	-2.38	-2.34	-2.26
13	-0.04	-0.11	-0.19	-0.32	-0.46	-0.55	-0.67	-0.83	-0.98	-1.10	-1.19	-1.30	-1.33	-1.45	-1.52	-1.61	-1.73	-1.82	-1.91	-1.97	-1.99	-2.05	-2.12	-2.19	-2.25	-2.28	-2.26	-2.22	-2.15	-2.09
14	-0.05	-0.12	-0.23	-0.34	-0.46	-0.57	-0.71	-0.88	-1.00	-1.09	-1.20	-1.30	-1.37	-1.45	-1.54	-1.67	-1.76	-1.85	-1.92	-1.95	-1.98	-2.03	-2.07	-2.16	-2.19	-2.20	-2.17	-2.16	-2.15	-2.09
15	-0.06	-0.16	-0.25	-0.36	-0.50	-0.63	-0.78	-0.91	-1.01	-1.12	-1.22	-1.34	-1.37	-1.48	-1.60	-1.70	-1.79	-1.87	-1.92	-1.94	-1.97	-2.00	-2.06	-2.11	-2.12	-2.12	-2.09	-2.10	-2.09	-1.99
16	-0.08	-0.17	-0.25	-0.38	-0.53	-0.67	-0.79	-0.90	-1.02	-1.13	-1.25	-1.33	-1.38	-1.52	-1.61	-1.72	-1.79	-1.85	-1.89	-1.92	-1.92	-1.97	-2.00	-2.03	-2.03	-2.03	-2.01	-2.03	-1.98	-1.90
17	-0.08	-0.16	-0.26	-0.42	-0.58	-0.68	-0.78	-0.92	-1.03	-1.14	-1.23	-1.33	-1.42	-1.53	-1.64	-1.73	-1.79	-1.83	-1.87	-1.88	-1.92	-1.94	-1.95	-1.97	-1.96	-1.97	-1.96	-1.94	-1.90	-1.81
18	-0.07	-0.18	-0.31	-0.47	-0.60	-0.69	-0.81	-0.93	-1.04	-1.12	-1.22	-1.35	-1.43	-1.56	-1.66	-1.73	-1.78	-1.82	-1.84	-1.88	-1.89	-1.88	-1.88	-1.90	-1.91	-1.92	-1.88	-1.86	-1.81	-1.74
19	-0.10	-0.23	-0.37	-0.50	-0.61	-0.72	-0.83	-0.95	-1.03	-1.13	-1.25	-1.37	-1.47	-1.59	-1.67	-1.73	-1.77	-1.80	-1.84	-1.86	-1.84	-1.83	-1.83	-1.86	-1.86	-1.84	-1.81	-1.79	-1.75	-1.64
20	-0.12	-0.26	-0.37	-0.48	-0.61	-0.71	-0.82	-0.91	-1.01	-1.13	-1.25	-1.38	-1.47	-1.57	-1.64	-1.70	-1.72	-1.77	-1.80	-1.78	-1.76	-1.74	-1.76	-1.79	-1.77	-1.75	-1.71	-1.70	-1.63	-1.53
21	-0.13	-0.24	-0.33	-0.46	-0.58	-0.68	-0.76	-0.87	-0.99	-1.11	-1.24	-1.36	-1.43	-1.52	-1.59	-1.63	-1.68	-1.71	-1.71	-1.69	-1.67	-1.66	-1.68	-1.68	-1.66	-1.64	-1.61	-1.57	-1.50	-1.40
22	-0.10	-0.19	-0.31	-0.43	-0.54	-0.62	-0.71	-0.85	-0.96	-1.09	-1.22	-1.32	-1.38	-1.47	-1.52	-1.59	-1.62	-1.62	-1.61	-1.59	-1.58	-1.58	-1.57	-1.57	-1.55	-1.54	-1.48	-1.44	-1.37	-1.29
23	-0.09	-0.19	-0.30	-0.41	-0.51	-0.60	-0.71	-0.84	-0.97	-1.10	-1.20	-1.30	-1.35	-1.42	-1.50	-1.55	-1.55	-1.54	-1.53	-1.53	-1.50	-1.49	-1.48	-1.47	-1.43	-1.40	-1.37	-1.33	-1.28	-1.19
24	-0.10	-0.20	-0.30	-0.40	-0.50	-0.61	-0.73	-0.86	-0.99	-1.09	-1.19	-1.28	-1.32	-1.41	-1.47	-1.50	-1.49	-1.49	-1.49	-1.46	-1.43	-1.41	-1.42	-1.37	-1.33	-1.28	-1.25	-1.19	-1.16	-1.12
25	-0.09	-0.19	-0.27	-0.38	-0.50	-0.61	-0.73	-0.87	-0.97	-1.07	-1.16	-1.23	-1.30	-1.38	-1.41	-1.42	-1.42	-1.43	-1.44	-1.41	-1.38	-1.35	-1.34	-1.31	-1.27	-1.23	-1.19	-1.16	-1.12	-1.05
26	-0.09	-0.17	-0.27	-0.40	-0.52	-0.63	-0.76	-0.88	-0.97	-1.06	-1.13	-1.23	-1.28	-1.33	-1.35	-1.36	-1.37	-1.39	-1.37	-1.34	-1.31	-1.28	-1.24	-1.22	-1.18	-1.15	-1.11	-1.09	-1.05	-0.98
27	-0.08	-0.17	-0.28	-0.41	-0.54	-0.66	-0.76	-0.87	-0.96	-1.03	-1.13	-1.20	-1.23	-1.27	-1.29	-1.31	-1.33	-1.31	-1.30	-1.27	-1.24	-1.19	-1.16	-1.13	-1.10	-1.07	-1.04	-1.02	-0.98	-0.91
28	-0.09	-0.20	-0.31	-0.45	-0.58	-0.67	-0.77	-0.87	-0.94	-1.03	-1.11	-1.16	-1.17	-1.21	-1.24	-1.27	-1.26	-1.25	-1.23	-1.20	-1.15	-1.11	-1.07	-1.05	-1.02	-1.00	-0.97	-0.95	-0.91	-0.85
29	-0.11	-0.21	-0.33	-0.47	-0.57	-0.66	-0.75	-0.83	-0.92	-1.00	-1.05	-1.09	-1.11	-1.15	-1.19	-1.19	-1.19	-1.17	-1.16	-1.11	-1.06	-1.01	-0.99	-0.97	-0.95	-0.93	-0.90	-0.88	-0.85	-0.79
30	-0.10	-0.22	-0.33	-0.45	-0.55	-0.63	-0.70	-0.80	-0.87	-0.93	-0.97	-1.02	-1.04	-1.09	-1.10	-1.11	-1.10	-1.09	-1.05	-1.01	-0.96	-0.92	-0.89	-0.89	-0.87	-0.85	-0.82	-0.81	-0.77	-0.71

Table 8D. Impact of order flow on future SPY ETF price changes: Interbank counterparty order flows

Aggregation Window \ Forecast Horizon	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	0.00	-0.19	-0.07	-0.10	0.02	0.09	0.07	0.03	-0.10	-0.28	-0.28	-0.30	-0.37	-0.67	-0.91	-0.89	-0.78	-0.68	-0.76	-0.61	-0.59	-0.53	-0.40	-0.44	-0.24	-0.12	0.01	-0.04	-0.25	-0.21
2	-0.08	-0.10	-0.06	-0.02	0.06	0.09	0.06	-0.04	-0.17	-0.29	-0.30	-0.34	-0.51	-0.77	-0.88	-0.82	-0.72	-0.72	-0.67	-0.58	-0.54	-0.45	-0.42	-0.34	-0.19	-0.07	-0.04	-0.20	-0.28	-0.28
3	-0.01	-0.03	0.04	0.08	0.12	0.12	0.05	-0.06	-0.17	-0.26	-0.28	-0.40	-0.58	-0.75	-0.79	-0.72	-0.68	-0.62	-0.58	-0.50	-0.44	-0.41	-0.32	-0.23	-0.09	-0.04	-0.11	-0.20	-0.27	-0.21
4	-0.01	-0.01	0.04	0.06	0.09	0.06	-0.03	-0.12	-0.22	-0.29	-0.38	-0.53	-0.66	-0.76	-0.76	-0.73	-0.66	-0.61	-0.57	-0.48	-0.45	-0.37	-0.28	-0.19	-0.11	-0.15	-0.18	-0.26	-0.27	-0.22
5	0.01	0.02	0.05	0.06	0.06	0.00	-0.08	-0.17	-0.24	-0.36	-0.48	-0.60	-0.68	-0.74	-0.75	-0.70	-0.64	-0.59	-0.53	-0.47	-0.40	-0.32	-0.22	-0.18	-0.17	-0.18	-0.22	-0.25	-0.25	-0.20
6	0.01	0.00	0.02	0.01	-0.03	-0.08	-0.15	-0.23	-0.34	-0.47	-0.57	-0.64	-0.69	-0.75	-0.74	-0.69	-0.64	-0.57	-0.53	-0.44	-0.37	-0.28	-0.22	-0.23	-0.21	-0.23	-0.23	-0.25	-0.25	-0.23
7	-0.01	-0.01	-0.01	-0.06	-0.09	-0.14	-0.21	-0.31	-0.43	-0.55	-0.61	-0.66	-0.71	-0.74	-0.73	-0.68	-0.61	-0.57	-0.49	-0.40	-0.33	-0.28	-0.27	-0.27	-0.26	-0.24	-0.24	-0.25	-0.27	-0.25
8	0.00	-0.02	-0.05	-0.09	-0.13	-0.17	-0.26	-0.38	-0.49	-0.57	-0.62	-0.67	-0.70	-0.72	-0.70	-0.64	-0.59	-0.52	-0.44	-0.35	-0.30	-0.29	-0.27	-0.28	-0.24	-0.23	-0.23	-0.26	-0.27	-0.24
9	-0.01	-0.06	-0.08	-0.12	-0.16	-0.23	-0.34	-0.45	-0.53	-0.60	-0.65	-0.68	-0.70	-0.72	-0.68	-0.64	-0.56	-0.49	-0.41	-0.35	-0.33	-0.31	-0.30	-0.29	-0.25	-0.24	-0.25	-0.28	-0.28	-0.25
10	-0.04	-0.08	-0.10	-0.14	-0.20	-0.29	-0.39	-0.49	-0.55	-0.63	-0.65	-0.68	-0.70	-0.70	-0.68	-0.61	-0.53	-0.45	-0.40	-0.37	-0.34	-0.33	-0.30	-0.28	-0.26	-0.26	-0.27	-0.28	-0.28	-0.25
11	-0.03	-0.07	-0.10	-0.16	-0.24	-0.33	-0.42	-0.49	-0.57	-0.62	-0.64	-0.67	-0.67	-0.67	-0.63	-0.56	-0.48	-0.42	-0.40	-0.36	-0.34	-0.32	-0.29	-0.27	-0.26	-0.27	-0.27	-0.28	-0.27	-0.24
12	-0.04	-0.08	-0.13	-0.21	-0.29	-0.36	-0.43	-0.51	-0.57	-0.62	-0.64	-0.64	-0.65	-0.64	-0.59	-0.51	-0.45	-0.42	-0.39	-0.36	-0.33	-0.30	-0.28	-0.28	-0.27	-0.26	-0.26	-0.27	-0.26	-0.24
13	-0.04	-0.10	-0.17	-0.24	-0.31	-0.37	-0.45	-0.51	-0.56	-0.60	-0.60	-0.62	-0.61	-0.58	-0.53	-0.48	-0.44	-0.41	-0.38	-0.34	-0.30	-0.28	-0.27	-0.27	-0.25	-0.24	-0.24	-0.25	-0.25	-0.24
14	-0.06	-0.13	-0.20	-0.27	-0.32	-0.39	-0.45	-0.50	-0.55	-0.57	-0.59	-0.58	-0.56	-0.53	-0.50	-0.46	-0.42	-0.39	-0.36	-0.31	-0.28	-0.27	-0.26	-0.25	-0.23	-0.22	-0.22	-0.23	-0.24	-0.23
15	-0.07	-0.15	-0.21	-0.26	-0.32	-0.37	-0.43	-0.48	-0.51	-0.54	-0.53	-0.52	-0.49	-0.48	-0.47	-0.43	-0.39	-0.35	-0.31	-0.27	-0.26	-0.25	-0.23	-0.22	-0.19	-0.19	-0.19	-0.21	-0.22	-0.19
16	-0.07	-0.14	-0.18	-0.24	-0.29	-0.34	-0.39	-0.43	-0.47	-0.48	-0.46	-0.44	-0.43	-0.44	-0.41	-0.39	-0.34	-0.30	-0.27	-0.24	-0.22	-0.20	-0.18	-0.17	-0.15	-0.15	-0.16	-0.18	-0.17	-0.15
17	-0.06	-0.12	-0.17	-0.22	-0.27	-0.32	-0.35	-0.40	-0.42	-0.42	-0.39	-0.39	-0.39	-0.40	-0.38	-0.35	-0.30	-0.27	-0.24	-0.22	-0.19	-0.17	-0.15	-0.13	-0.12	-0.13	-0.14	-0.15	-0.14	-0.13
18	-0.05	-0.11	-0.16	-0.21	-0.25	-0.29	-0.33	-0.35	-0.36	-0.36	-0.34	-0.35	-0.35	-0.37	-0.35	-0.31	-0.27	-0.24	-0.22	-0.18	-0.16	-0.14	-0.11	-0.11	-0.10	-0.11	-0.11	-0.12	-0.12	-0.12
19	-0.06	-0.11	-0.16	-0.21	-0.24	-0.27	-0.30	-0.31	-0.31	-0.32	-0.32	-0.33	-0.34	-0.34	-0.31	-0.27	-0.25	-0.22	-0.19	-0.16	-0.13	-0.11	-0.09	-0.10	-0.09	-0.09	-0.09	-0.10	-0.12	-0.08
20	-0.05	-0.11	-0.15	-0.18	-0.22	-0.24	-0.25	-0.26	-0.27	-0.29	-0.29	-0.31	-0.31	-0.30	-0.28	-0.25	-0.22	-0.19	-0.16	-0.12	-0.10	-0.08	-0.08	-0.08	-0.06	-0.06	-0.07	-0.09	-0.08	-0.05
21	-0.05	-0.10	-0.13	-0.17	-0.19	-0.19	-0.20	-0.22	-0.25	-0.27	-0.28	-0.28	-0.28	-0.27	-0.26	-0.22	-0.19	-0.16	-0.12	-0.09	-0.07	-0.07	-0.06	-0.06	-0.04	-0.05	-0.06	-0.06	-0.04	0.00
22	-0.05	-0.08	-0.12	-0.14	-0.14	-0.15	-0.16	-0.19	-0.22	-0.25	-0.25	-0.25	-0.25	-0.25	-0.22	-0.18	-0.15	-0.11	-0.08	-0.06	-0.05	-0.05	-0.04	-0.03	-0.02	-0.03	-0.03	-0.02	0.00	0.02
23	-0.04	-0.07	-0.08	-0.09	-0.10	-0.11	-0.14	-0.17	-0.20	-0.22	-0.22	-0.22	-0.22	-0.21	-0.18	-0.15	-0.11	-0.08	-0.06	-0.04	-0.04	-0.03	-0.01	-0.01	-0.01	0.00	0.01	0.02	0.02	0.04
24	-0.03	-0.05	-0.05	-0.06	-0.08	-0.10	-0.12	-0.16	-0.19	-0.20	-0.20	-0.20	-0.20	-0.18	-0.16	-0.11	-0.08	-0.06	-0.05	-0.04	-0.03	-0.01	0.00	0.00	0.02	0.03	0.04	0.03	0.04	0.05
25	-0.01	-0.02	-0.03	-0.04	-0.07	-0.09	-0.12	-0.15	-0.17	-0.19	-0.19	-0.18	-0.17	-0.16	-0.13	-0.09	-0.07	-0.05	-0.04	-0.03	-0.01	0.00	0.00	0.02	0.04	0.05	0.05	0.04	0.04	0.04
26	-0.01	-0.02	-0.03	-0.05	-0.08	-0.11	-0.13	-0.16	-0.17	-0.19	-0.19	-0.18	-0.17	-0.15	-0.12	-0.09	-0.08	-0.07	-0.05	-0.03	-0.02	-0.01	0.01	0.02	0.05	0.04	0.04	0.03	0.01	0.01
27	-0.01	-0.02	-0.04	-0.07	-0.10	-0.12	-0.14	-0.16	-0.18	-0.20	-0.19	-0.18	-0.16	-0.15	-0.12	-0.11	-0.09	-0.07	-0.05	-0.04	-0.03	-0.01	0.01	0.03	0.04	0.03	0.02	0.00	-0.01	-0.02
28	-0.01	-0.04	-0.05	-0.09	-0.11	-0.13	-0.15	-0.17	-0.19	-0.19	-0.19	-0.17	-0.16	-0.15	-0.13	-0.12	-0.09	-0.07	-0.06	-0.05	-0.02	0.00	0.02	0.03	0.03	0.02	0.00	-0.02	-0.04	-0.04
29	-0.02	-0.04	-0.07	-0.09	-0.11	-0.13	-0.15	-0.17	-0.18	-0.19	-0.17	-0.16	-0.15	-0.15	-0.14	-0.11	-0.09	-0.07	-0.07	-0.04	-0.02	0.01	0.02	0.02	0.03	0.00	-0.02	-0.04	-0.06	-0.06
30	-0.02	-0.05	-0.07	-0.09	-0.11	-0.13	-0.15	-0.16	-0.17	-0.17	-0.16	-0.15	-0.15	-0.15	-0.13	-0.11	-0.09	-0.07	-0.05	-0.02	0.00	0.01	0.02	0.02	0.01	-0.01	-0.03	-0.06	-0.07	-0.07

Notes: The tables report coefficient estimates in the regression $R_{t,t+k}^{S} = c + \alpha R_{t-i,t}^{S} + \gamma R_{t-i,t}^{FX} + \sum_{m=1}^{4} \beta_m OF_{t-i,t}^{FX} + \varepsilon_t$.

Tables A, B, C and D report, respectively, the coefficient estimates for financial end-user customer order flows, corporate end-user order flows, internal customer order flows and interbank counterparty order flows. The horizontal axis varies over the *k*-minute forecast horizon; the vertical axis varies according to the aggregation window of foreign exchange order flows through the *i*-minute period. A lightly shaded cell denotes significance at the ten per cent level using robust standard error estimates. Darker shading denotes significance at the five per cent level. Intraday data from 2:30pm to 5:00pm for 25 days are used. Coefficients represent the percentage change in the SPY ETF price resulting from a €1bn flow into the dollar.

Once again a clear heterogeneity of relationships between end-user order flows in FX and subsequent stock index movements emerges. The findings are consistent for the two index-tracking ETFs.

1) Compared to the findings in the contemporaneous regressions, where FX order flows play no role in explaining concurrent stock market changes at market level, there are strong relationships between foreign exchange order flows and future stock market returns in the forecasting model, even after controlling for lagged exchange rate and stock market returns.

2) There is little evidence of short horizon forecasting power using financial customer flows. However financial customer FX order flows have statistically significant forecasting power for longer forecasting horizons, especially when flows are aggregated over long windows. The uniformly negative signs suggest that when financial customers are buying dollars, US stock indices will subsequently fall in value. This rather odd result is addressed further in Section 4.5.

3) The effect of corporate customer order flows on stock market changes is mainly positive. Statistical significance is less prevalent for this customer class and is confined to relatively short aggregation windows, however there is statistical forecasting power even over relatively long horizons. The results are stronger for the less liquid DIA than the SPY. The nature of these results is consistent with the FX forecasting power of corporate customer order flows.

4) Internal customer forecasting correlations are uniformly negative (like those of financial customers) and highly significant. Given our lack of knowledge of the nature of internal flows we cannot explore this avenue further. Interbank flows have inconsistent forecasting signs but are negative when significant (aggregation windows of around fifteen minutes and forecasting horizons of around ten minutes). As such they are very similar to the findings for financial customers.

5) The lagged exchange rate has strong forecasting power at high frequencies, suggesting that an appreciation of the dollar is associated with a subsequent rise in US stock indices, again consistent with the previous literature looking at returns spillovers.

6) Similar to findings in the pure foreign exchange environment, the magnitudes of coefficients for financial customer order flows are such that when €1bn flows into the FX

market the forecast percentage change in stock market prices peaks at around 0.3%. Corporate customer flows are much more powerful though, and the maximum coefficient is closer to 1.2%. Internal customer order flows are stronger still with maximal coefficients of close to 2.6%, though negatively signed.

7) Regression R^2 suggest that approximately 6% of variations of market level equity returns can be explained by foreign exchange order flows, lagged exchange rate changes and lagged stock market returns.

8) Again, unreported F-tests suggest that the four classes of customer order flows are jointly significant in explaining future stock returns, corporate and financial end-user flows are jointly significant, and that the coefficient estimates for corporate and financial customers are significantly different at the critical parts of the results tables. FX order flows are important predictors of future stock returns and order flow is heterogeneous.

4.5 Interpretation

The previous sections have detailed the heterogeneous contemporaneous and forecasting relationships between FX order flows from different end-users and FX and stock returns. In this sub-section we attempt to interpret these results.

The foreign exchange rate results are a puzzle. The contemporaneous correlations between flows from corporate and financial end-users have the opposite sign to that commonly found in the literature. This could simply be due to the intra-day nature of our analysis since the literature is typically based on data sampled at the data frequency. The forecasting results suggest that the significantly negative short-term relationship for financials becomes positive as forecasting horizons and aggregation window extend. Although we are unable to examine this further due to data limitations, it may be that both contemporaneous and forecasting correlations become significantly positive as the aggregation window extends which would generate results consistent with the data sampled at a daily frequency.

The results are not obviously consistent with the simple liquidity story. None of the patterns suggest an illiquidity-induced peak price impact which gradually declines as the market absorbs

the inventory.[7] Of course, the issue is partly obscured by the fact that we are unsure how quickly customer inventory is passed through to the interbank market by our source bank. If they hold the inventory on their own books for several minutes before passing it onto the market we might expect a delayed (positive) reaction in the market price which subsequently declines.[8] This is partially consistent with the results from corporate customers since the price impact of their orders declines both as the aggregation window widens and as the forecast horizon lengthens. However, this cannot explain the financial customer flows where the "price impact" is actually negative unless we are willing to accept, against what evidence we do have, that the inventory is held for more than thirty minutes, since it is only over these long horizons that financial customer price-return correlations turn positive.

One possible explanation, as discussed above, is that financial customers time their FX trades to benefit from temporary price moves. If the information on which they are trading is relatively long-lived (in a high frequency context) they may wait to buy a currency cheap on a short-term dip which would lead to a negative high frequency contemporaneous correlation between exchange rate returns and their order flows. Since FX returns are slightly positively autocorrelated at high frequencies, buying on dips might also lead to negative short-horizon forecasting correlations. Only as the market slowly prices the (positive) information in their order does the currency appreciate. At longer horizons this would result in both positive contemporaneous and forecasting correlations, the former consistent with the literature based on daily data and the latter weakly consistent with the longer horizon results in this paper.

The results from the cross asset regressions are our main interest here, and it is even harder to explain the significant results here without recourse to the information hypothesis. Since corporates are highly unlikely to be trading equities, the ability of their FX flows into the dollar to predict equity price rises is not caused by liquidity effects. When financial customers buy the dollar, equity prices subsequently fall, particularly over relatively long horizons. Both of these

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[7] The only exception to this is in the very short horizon where both of the end-user customer flows show positive point estimates which subsequently decline. However, none of these estimates is significant.

[8] Lyons (1998) suggests an inventory half life from an active dealer of around ten minutes. However, the move to electronic interbank dealer systems has improved dealers' opportunities to pass inventory into the market faster and cheaper so this ten minute level might be seen as an upper limit. Discussions with bankers suggest that inventories are now managed over 1-2 minute horizons.

are consistent with the idea that their flows predict movements in the dollar (in different directions) and that movements in the dollar are significantly correlated with equity returns. We explore this further by running the following regression:

$$R_{t,t+k}^{S} = c + \alpha R_{t-i,t}^{S} + \gamma R_{t-i,t}^{FX} + \delta R_{t,t+k}^{FX} + \sum_{m=1}^{4} \beta_{m} OF_{t-i,t}^{FX} + \varepsilon_{t}$$

$$(5)$$

That is, we augment the equity market forecasting regression with the future FX change. We find that the coefficient on financial customer order flow collapses to zero in all cases in this regression. This suggests that financials' FX order flow (negatively) predicts the dollar, and this subsequent dollar movement is contemporaneously (positively) correlated with equity price movements. There is no information in the FX flow of financial customers which helps predict equity returns over and above the information relevant for exchange rate movements (and recall that we concede the negative short-term relationship between financial flows and exchange rate changes might be due to these customers timing their trades rather than information content).

Conversely, the significance of the corporate flows remains even after including future FX returns in the regression. This suggests that corporate flows are (positively) correlated with future changes in the value of the dollar, and while equities move in response to these exchange rate changes there is additional information in the flows of corporate customers relevant for equity values.[9]

We are again forced to speculate in explaining this finding, but two scenarios present themselves. First, the dispersed macro information we hypothesise to be revealed by FX flows may have two components, one relevant for FX rates and another relevant for equities. Lagged order flows would then explain stock returns over and above lagged and current exchange rates. Second, equity and FX markets might price the same information differently. Most straightforwardly, suppose that the information in customer flows suggests that GDP is to rise globally. The simple monetary approach to the exchange rate would not predict any exchange rate change if two

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[9] We note that this is not the case for interbank flows, however, which retain negative and significant forecasting power even after accounting for future exchange rate movements.

countries' income levels were to rise equally. However, we would expect both countries' stock markets to rise on this good news.

4   Conclusions

In addition to the daily relationship between order flows in the foreign exchange market and exchange rate changes in many well-established papers (see Evans and Lyons, 2002, among many others), some studies also give evidence that foreign exchange order flows are correlated with exchange rate changes at high frequencies (see Love and Payne, 2008, and Osler and Vandrovych 2009, among others). Besides the relationships found in the pure exchange rate market environment, orders flows in one market also play an important role in the movements of other markets, and some studies document the evidence of the cross market effects from currency order flows at a daily frequency (e.g. Francis, Hasan and Hunter, 2006, and Dunne, Hau and Moore, 2006). However, to the best of our knowledge, no one has reported any effects of foreign exchange order flows on other market changes at high frequencies. In this paper, we use a unique set of tick-by-tick foreign exchange order flows data including end-user orders and inter-dealer orders to test the effects of order flows on stock market changes at frequencies from 1-minute to 30-minute, in addition to the dynamic relationship between currency order flows and exchange rate fluctuations at high frequencies.

We find statistically significant impacts of foreign exchange order flows on contemporaneous and future exchange rate changes at high frequencies. Order flows from corporate customers are positively related to exchange rate changes, while order flows from financial customers are negatively signed. We note that these signs contradict results in published studies using daily order flow data, e.g. Evans and Lyons (2006). The high frequency findings are consistent with Osler and Vandrovych (2009), who also report mixed signs for their ten groups of counterparties at frequencies less than 30-minute, suggesting that this puzzle may be related to the frequency of observation.

This paper's main contribution is to consider the impact of foreign exchange order flows on contemporaneous and future stock market returns. We do not find clear contemporaneous relationships between FX order flows and stock market changes at high frequencies, but FX

flows appear to have significant power to forecast stock index returns over 1-minute to 30-minute horizons, after controlling for lagged exchange rate and stock market returns. The effects of order flows from financial customers on future stock market changes are negative, while the effects of corporate orders are positive. When financial clients of our data provider are buying dollars, the US stock market subsequently falls in value. This is entirely driven by the positive effect that changes in the value of the dollar have on contemporaneous equity returns. Since financial customer flows (puzzlingly) negatively predict dollar price changes, they also negatively predict US stock returns. We that this may in part be due to financial customers attempting to time their trades in the FX market by trading in response to temporary price changes (feedback trading).

Conversely, when corporates are buying dollars the US stock indices rise in value. These latter results are entirely consistent with one of the most basic premises underlying FX market microstructure modeling – that corporate order flows contain dispersed, passively acquired information about fundamentals. Thus purchases of the dollar by corporate customers represent good news about the state of the US economy. This would be consistent with such orders being associated with subsequent appreciations of the dollar and with rising stock index prices. Importantly, though, there appears to be extra information in corporate flows which is directly relevant to equity prices over and above the impact derived from stock prices reacting to (predicted) exchange rate changes.

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