Order flow analysis of exchange rates

Dagfinn Rime, senior adviser in the Research Department of Norges Bank and Elvira Sojli, PhD student at Warwick Business School[1]

Norges Bank recently started to collect new foreign exchange statistics.[2] These statistics provide an overview of which foreign currencies various market participants buy and sell against NOK. Participants' purchases and sales (order flow) are an important variable in exchange rate analysis using microstructure models. Order flow analysis has proved to be helpful in understanding changes in the exchange rate in the short term and the new statistics are well suited for this type of analysis. This article provides an overview of the theory behind order flow analysis and uses the data collected to date to illustrate some concepts.

1 Why order flow analysis?

According to economic theory, exchange rates ought to be determined by a number of macroeconomic conditions. The theory of purchasing power parity posits that the level of the exchange rate between two countries should be the same as the relative price level between the two countries. The theory of uncovered interest parity postulates that the exchange rate today should not systematically deviate from the differential between the exchange rate and interest rate 'some time ago' (depending on the maturity of the interest rates). When combined to create a macro model, for example the Mundell-Fleming model, exchange rates are also determined by GDP growth. Interest rates, inflation, and economic growth are often called *macro fundamentals*.

Empirical studies show that macro fundamentals can explain movements in the exchange rate relatively well, particularly over longer time horizons such as six months or a year, but their explanatory power is lower for daily or weekly horizons. Sometimes, exchange rates seem to live a life of their own, as if completely detached from macro fundamentals.[3]

Exchange rate deviations from fundamentals can be substantial and persist over a sufficiently long period to be significant. What causes such deviations and why do macro fundamentals not 'function' in the short term? This article discusses exchange rate determination in the short term: hence, why exchange rates may deviate from what is believed to be the macro equilibrium exchange rate. Order flow analysis has proved to be useful in establishing this connection and the discussion is therefore based on the theory underlying order flow analysis: the theory of financial market microstructure. Microstructure theory looks at participants in the market and the constraints they face. The application of microstructure theory to the foreign exchange market is a relatively new field of research (late 1990s), and the main contribution to date has been provided by focusing on possible differences in participants' expectations.

That expectations regarding securities prices differ is not new. Insiders in the stock market have been studied for years. Different expectations in the foreign exchange market may, however, seem slightly odd. After all, vast empirical research and the bulk of theory show that exchange rates are determined by macro fundamentals in the long term. Is it not the case that macro fundamentals can be equally well observed by all market participants all the time, and thereby pin down homogeneous expectations? We will therefore look more closely at what might give rise to different expectations in the exchange rate market and how this is captured by order flows. The theory will also be illustrated by an empirical analysis based on the data reported to Norges Bank in the new foreign exchange transaction statistics (see Meyer and Skjelvik, 2006).

2 Different expectations = different information?

When discussing possible sources of differences in expectations, the following expression of the exchange rate may be useful. An exchange rate is determined by:

$$P_t = \frac{E\left[P_{t+1}\left(F_{t+1}\right) \mid \Im_t\right]}{1 + r_t + \rho_t} \qquad (1)$$

where P is the exchange rate (e.g. NOK per EUR), which is a function of expectations regarding discounted future macro fundamentals F and the information set $\Im$, at time on which these expectations are based.[4] E is the ex-pectations operator, r is the interest rate and ρ is a risk premium. The equation implies that today's price is the discounted value of tomorrow's expected price, where tomorrow's expected price is determined by the information available today and anticipated changes in macro fundamentals.

Determining what the correct value of the exchange rate is today is an extremely difficult task because there is so much information that market participants ought to know: What is today's GDP? Or what is the rate of

[1] We would like to thank Bent Vale and Knut Funderud Syrtveit for their useful comments.

[2] The new foreign exchange transaction statistics are described in more detail by Meyer and Skjelvik (2006) in Economic Bulletin 2/2006.

[3] The literature on the exchange rate determination puzzle is extensive and dates back to the early 1980s (Meese and Rogoff, 1983; Cheung, Chinn and Garcia-Pascual, 2003). For those interested, we recommend the overview articles by Frankel and Rose (1995) or Taylor (1995). For a more detailed book about exchange rates, see Sarno and Taylor (2002) and for an introduction to order flow analysis, see Lyons (2001).

[4] Uncovered interest parity is a form of equation (1) where the interest rate is a proxy for fundamentals and can be expressed as follows: $P_t = E\left[P_{t+1} \mid \Im_t\right]\left(1+r^*\right)\Big/\left(1+r+\rho\right)$ where r is the Norwegian interest rate, r* is the foreign interest rate and the risk premium ρ is the excess return required at home in order not to invest abroad.

inflation? Who knows what is 'expected' or what that might imply for GDP or inflation tomorrow, or in a month's time? Difficult? Let us continue: Who knows what the correct discount rate is for exchange rates? And to make things even more difficult: how can you know how exchange rates will *react* to macro fundamentals (the functional form in the expectation, the 'correct' model), when there is insufficient supporting empirical evidence? Finally: Who knows which information set can be used to answer these questions?

A number of disappointing empirical results show that few people are fortunate enough to have the answers to all these questions (see overview articles mentioned in footnote 3). And yet every day, market participants have to base their decision on some form of information when setting their prices (market-makers) or taking a position (investors). We will look more closely at how they might make this decision in the next section and focus on possible reasons for differing expectations in the remainder of the section.

First we would like to clarify one question. Given that it is so difficult to determine the exchange rate, are different expectations necessarily the best way to explain why movements in the exchange rate deviate from what is indicated by macro fundamentals? Understandably, it is difficult to determine the fundamental exchange rate when everyone has equal access to insufficient and uncertain information. But, if participants have rational expectations, they should not make systematic errors, which they seem to do in the short term in the foreign exchange market (when not using the information set used by the market itself). It might be that not all market participants have rational expectations. If that is the case, it seems reasonable to assume that they would also have different expectations. Microstructure theory is based on rational expectations, but the most important results may also apply to bounded rational expectations that can be modelled.

Another reason for different expectations could be that if it is true that public information – information that is the same for everyone – is basically of little use in the short term (as indicated by empirical studies), it would be natural to look for other sources of information that are not necessarily publicly available. This is precisely what most of the world's foreign exchange banks do today and it is also the reason why Norges Bank has started to collect the new foreign exchange transaction statistics.

The information that banks collect and process is called *customer order flows,* which comprise customers' disaggregated purchases and sales of foreign currency. Norges Bank's statistics on foreign exchange transactions provide an overview of how much different customer groups buy and sell. If a customer buys EUR from NOK, we say that the order flow is positive, and if he sells EUR, the order flow is negative. This makes it possible to measure whether there is buying or selling pressure in the market, even though there is of course a purchase for every sale and vice versa.[5] The idea is that the parties to the transaction fulfil different roles. One offers liquidity and the other buys liquidity. Banks set the price and thereby offer liquidity (they make money from the service by selling at a higher rate than they bought). Customers are willing to pay for liquidity and it is therefore assumed that they have a well-founded reason for doing so. It is this well-founded reason that we hope to capture by studying order flows. As there are no disclosure requirements in the foreign exchange market, information concerning customer order flows is a bank's private information.

Information about customer order flows may well be a bank's private information, but information also has to be useful in order to justify collecting and processing it. So, to understand what can be learned from order flows, let us go back to equation (1). We can divide what we learn according to whether it gives us information about the numerator (information set, functional form, etc.) or the denominator (risk premium). The first is the most important, as it comprises information about returns in a world populated by risk-neutral participants. It is therefore referred to as risk-free evaluation information, or just return information. Information about the relevant risk premium is called discount information. Private information about returns or discount rates may either be concentrated on a few participants, e.g. insider information in the stock market, or dispersed among participants. We can therefore draw a two-by-two matrix of what we have learned, if anything, about order flows (see Table 1).

The cells in the table illustrate our reasoning. A leak from the authorities concerning future economic policy would be return-relevant information, and leaks are

Table 1 Possible types of information in order flows.

	Return information	**Discount information**
Concentrated private information	• Leaks from the authorities • Bank with monopolies in important customer segments	*Not so relevant*
Dispersed private information	• Micro elements in trade balance • Behaviour patterns in connection to macro news	• Risk assessment • Risk compensation

[5] Order flows are not the same as excess demand. Excess demand does not necessarily result in actual transactions. Order flows measure the direction of the actual transactions, i.e. it is a vote count of what the equilibrium price ought to be.

often targeted at a very small number of participants (upper left-hand corner). This would correspond to insider information in the stock market and even though such information is considered to be of little relevance in the foreign exchange market, it can be used to illustrate how order flows influence exchange rates.

Assume that the market-maker in a bank suspects that he is dealing with a customer who has this kind of insider information.[6] The customer in question wants to trade in foreign currency and the market-maker quotes the buying and selling prices. If the customer then buys EUR, the market-maker takes this as an (uncertain) signal that the customer in question has information which implies that EUR will increase in value in relation to NOK (EUR appreciates, NOK depreciates). Based on this new information, the market-maker revises his price upwards. He has tried to extract the information underlying the customer's transaction decision by looking at what he actually does.

However, most people believe that concentrated private information is not particularly relevant in the foreign exchange market, but the various bits of information that could help to establish the correct exchange rate are dispersed among many participants. The problem is aggregating the various pieces of information in order to establish the correct exchange rate. This is the task of the market-maker.

Evans and Lyons have studied this in a series of papers. In an article in *Journal of Political Economy* in 2002, they assume that order flows provide information about the necessary risk premiums required to clear the market (lower, right-hand corner). This is the other extreme (insider information being the first). Let us assume that someone sells NOK and buys EUR for reasons that have nothing to do with fundamental economic conditions. Evans and Lyons (2002) show that order flows can still provide valuable information, in that they reveal the risk premium required to return to equilibrium. The market-maker, who receives NOK in the first instance, is often subject to constraints and does not want to hold the position. There are no customers seeking to buy NOK at the current exchange rate, so in order to make buying NOK and selling EUR attractive to customers, the exchange rate has to change. If the NOK exchange rate depreciates slightly, other customers may be interested in selling EUR and buying NOK, as they believe they are being compensated for the risk of holding NOK, which they did not want in the first place, by selling at a higher exchange rate.

Evans and Lyons (2003) show that order flows can also reflect return-relevant information that is dispersed among participants. Again, let us illustrate with a plausible example, this time related to the lower, left-hand corner in Table 1. The most recent productivity figures are high. In a world where all expectations and information are the same, the exchange rate would simply jump to a new equilibrium level. But in a world with different expectations, market-makers have to interpret the news. Were expectations too high or too low and what are the implications for the exchange rate? A possible equilibrium is one where the dominant perception around the news' implications for the exchange rate is the one that will ultimately determine the exchange rate. How do market-makers identify the dominant view? By counting the votes of the market! Those who believe that the exchange rate will appreciate are most likely to buy EUR, and those who think it will depreciate will sell EUR. If the order flow is positive (purchases exceed sales), this tells market-makers that the dominant view in the market is that the exchange rate will appreciate on the basis of the new information. Evans and Lyons (2003) find that order flows, in particular, can help to explain a substantial share of the reaction to such announcements, contrary to what one might believe, if the market agreed on how the announcement should be interpreted.

One final example studied in Evans and Lyons (2005) is based on the assumption that macro figures are an aggregate of an array of micro information and are announced with a lag. Is it, for example, possible that a bank with a large number of customers in the import and export business might get an early indication of what the next trade balance figures are likely to be? If the bank has more or less a monopoly in a customer segment that is important to the trade balance, for example, a monopoly on oil business transactions, it is possible that it has concentrated private information about the next trade balance figures (upper left-hand corner in Table 1). On the other hand, if the bank is one of many in the market, it is more likely that order flows will reflect dispersed micro elements of information that will be aggregated and published as macro fundamentals (lower left-hand corner). Using data from Citibank, Evans and Lyons show that financial customers' order flows can predict macro 'shocks' one quarter in advance!

Some analysts may raise the following objections to the above: Buying and selling foreign currency is nothing more than good old-fashioned supply and demand and price adjustments are simply made to achieve equilibrium. There is of course some truth to this, but that is forgetting that securities prices also have a role in aggregating information. It is this role that we have highlighted and that we believe is most important. In the majority of foreign exchange market models, where all parties have equal information, exchange rates will *jump* when new information becomes available. This jump will create a new equilibrium without the need for any exchange rate transactions (supply and demand curves jump by the same amount). There is quite simply too much trading in the foreign exchange market for a perspective based on symmetric information to be reasonable. Another objection to the interpretation that order flows correlate with exchange rates might be that only transactions based on technical analysis drive

[6] The market-maker is defined here as dealers in the interbank market and dealers who receive customer orders.

the exchange rate. In technical analysis, the decision to trade is based on historical information and such feedback trading may of course be part of the explanation for the importance of order flows. However, several papers have shown that the causality direction is from order flows to exchange rates. The opposite would be the case if technical analysis was the dominant underlying factor.[7]

3 An example based on foreign exchange transaction statistics

The examples above give a simple empirical prediction: if there is net buying pressure for EUR (positive order flow), the exchange rate will rise (the krone depreciates). The results of Evans and Lyons (2002) are noteworthy: using daily data over a 4-month period, they can explain over 60 per cent of movements in the Deutche mark/dollar exchange rate. Naturally, exchange rates are not only driven by order flows, so the interest rate differential is also included in the regression equation. The interest rate differential, however, can only explain 1 per cent of the changes. Other studies have confirmed Evans and Lyons' findings, albeit with lower levels of explanatory power.[8]

However, in order for information to be useful in a financial context, the effect of order flow cannot "disappear", it has to be permanent. To understand this, imagine a random walk model for securities prices. In such a model, a shock would have a permanent effect. The price jumps when the shock occurs and after the shock, expected prices are the same as the current prices. The effect from the shock does not dissipate. The price in a random walk model is a function of cumulative shocks. Similarly, the level of the exchange rate must be a function of cumulative customer order flows. Hence, the exchange rate and cumulative customer order flows can be said to be cointegrated.

The random walk comparison above results in several postulates. New information is by definition, unexpected. It is the information that drives the exchange rate and not the exchange rate that drives the information. Customer order flows should be exogenous in relation to the exchange rate. Furthermore, it is the unexpected elements of order flow that drives exchange rate fluctuations. The expected elements will already be impounded in the price.

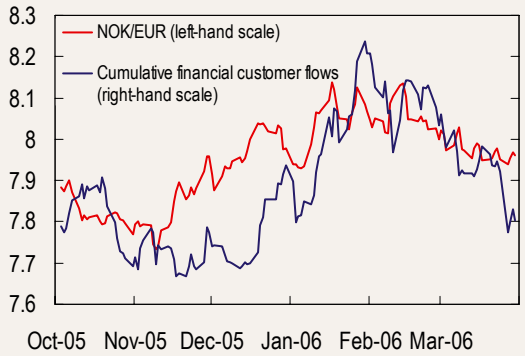
The final postulate is the following: If there is no uncertainty, there is nothing to learn from order flows and consequently order flows have no explanatory power. This implies that the effect from order flow will vary according to uncertainty in the market, which may make it difficult to find stable coefficients over longer periods of time. In longer data series than the one used here, it may be important to take into account the possibility of such instability.

Bearing this in mind, we test the model on the first 129 daily observations in the new statistics on foreign exchange transactions (see Meyer and Sjelvik (2006) for a more detailed description of the data). The sample size is relatively small, so this should only be taken as an illustration and not a complete model ready for use in analysis. Several Norwegian and foreign banks report their purchases and sales in foreign currency against NOK, in transactions with a number of defined customer groups. Since earlier studies show that the explanatory power of transactions initiated in the financial sector (excluding banks) is good, we will focus on this group's trading in NOK/EUR.[9] The order flow variable used is the sum of all spot and forward transactions. Some of the spot transactions may be secured with (reverse) forward transactions and by adjusting for this, we get a proxy for unsecured, speculative spot transactions. The 3-month interest rate differential against the euro area, is used as a proxy for macro fundamentals.

Chart 1 shows the fluctuations in the level of the NOK/EUR exchange rate and the cumulative order flow from financial customers. From the chart we notice that financial customer's order flow and the NOK exchange rate appear to be cointegrated and that there might be a long-term relationship between them. The depreciation until the end of January 2006 was followed by a build-up of EUR holdings, which were then gradually reduced as the exchange rate appreciated (accumulated NOK).

Tests confirm that order flow and exchange rate are cointegrated, the interest rate differential (not stationary in this selection) and exchange rates are cointegrated,

Chart 1 NOK/EUR exchange rate and cumulative order flow from financial customers



We have excluded values on the right-hand scale for financial customers as this is not publicly available data.

Source: EcoWin and Norges Bank.

[7] Danielsson and Love (2006) show that if the possibility of technical analysis is taken into account when measuring order flows, the effect of order flows that are not based on technical analyses, is in fact greater!

[8] Rime (2001a, b), Evans (2002), Payne (2003), Bjønnes and Rime (2005), Bjønnes, Rime and Solheim (2005), Froot and Ramadorai (2005), Marsh and O'Rourke (2005), Danielsson and Love (2006), Killeen, Lyons, Moore (2006), Danielsson and Love (2006), Rime, Sarno and Sojli (2006).

[9] See Fan and Lyons (2003), Bjønnes, Rime and Solheim (2005) and Marsh and O'Rourke (2005).

and the exchange rate, order flow and interest rate differential are cointegrated.[10] The preferred model is presented in Table 2.

The cointegrating relationship is shown at the top of the table and the equilibrium correction VAR in the lower part. All figures in brackets are t-statistics. The interest rate has a strong effect in the cointegrating relationship. If Norwegian interest rates rise by 0.25 percentage point and European interest rates remain unchanged, the NOK/EUR exchange rate appreciates by 4 per cent. The effect from order flows is smaller. If financial customers buy EUR equivalent to NOK 1 billion, the exchange rate depreciates by 0.27 per cent. Is that a little? A billion is of course a substantial amount of money, but for a group as a whole it is far from an inconceivable amount. In addition, compared with an average daily movement of 0.01 per cent in the exchange rate, order flow induced fluctuation are relatively substantial and are also substantial compared with other studies. The trend ought to capture the effect of other variables that are not included in the model.

The first line in the equilibrium correction VAR is the equilibrium correction term. It is the residual term from the previous day's co-integration equation. The minus sign in front of the error correction value means that if the exchange rate level yesterday was higher than implied by the interest differential, order flow and trend, there will be a downward adjustment today. As the error correction term is not significant in the equation for the interest differential, the interest differential does not respond to deviations from the cointegration equation. The interest rate differential is thus said to be weakly exogenous. Order flow is possibly also weakly exogenous, but this conclusion should be viewed with caution as it is not exogenous in other models not presented here. We see from the penultimate line that the model can explain 19 per cent of the daily fluctuations in the NOK/EUR exchange rate. This may not be high, but it is higher than the results of many other foreign exchange rate studies. In this analysis we have not separated expected order flow from the unexpected one.

Given the fluctiations in market conditions and investors' appetite for risk, order flow coefficients might not be stable. One way of dealing with the problem of unstable coefficients is to adjust the order flow with a variable that captures uncertainty in the market. Although uncertainty in the market is not an observable variable, there are several possible candidates. We have multiplied order flow by the differential between the highest and lowest quoted exchange rate in the course of the day, divided by the average differential for the whole selection. The idea is that days with a wider than average gap between the highest and the lowest exchange rate are characterised by greater uncertainty. There was little qualitative difference in the results when we included such an adjustment.

4 Conclusion

In recent years, order flow analysis has produced some promising results in terms of explaining movements in the exchange rate. The new statistics on foreign exchange transactions mean that Norges Bank now has high quality statistics that can be used for order flow analysis of the Norwegian foreign exchange market.

Order flows are central to microstructure theory as they are thought to be a variable that exposes the

Table 2 Cointegrating relationships and vector-equilibrium correction model

log(NOK/EUR) = 2.09 – 0.16 • Interest Diff + 0.0027 • Fin. Order Flow – 0.0002 • trend
(–9.52) (2.37) (4.09)

	Δ log(NOK/EUR)	Δ Interest Diff	Δ Fin. Order Flow
Equilibrium correction	–0.25938	–0.38212	18.20015
	(–5.02)	(–1.07)	(1.80)
Δ logNOK/EUR (–1)	0.30719	0.31234	48.20678
	(3.68)	(0.53980)	(2.96)
Δ Interest Diff (–1)	0.03286	–0.02112	3.16451
	(2.26)	(–0.21)	(1.12)
Δ Fin. Order flow (–1)	–0.00004	–0.00323	–0.46771
	(–0.09)	(–1.17)	(–6.00)
Constant term	0.00014	–0.00231	0.00506
	(0.56)	(–1.36)	(0.11)
Explanatory degree (adj. R^2)	0.19	–0.01	0.26
NB/selection	127	6.10.2005 – 31.03.2006	

log(NOK/EUR) is the logarithm of the NOK/EUR exchange rate at end-of-day (source: EcoWin).
Interest Diff. is the difference between the Norwegian and Euro area 3-month interest rate.
Fin. Order Flow is the cumulative order flow for financial customers. Greek Δ indicates first differential. Figures in brackets are t-statistics.

[10] The interest rate differential for longer horizon interest rates is, however, not cointegrated with the exchange rate in this sample.

'motive' of the participant initiating the transaction. By observing order flows, market-makers who determine the exchange rate can access the information of traders. They can thus aggregate information, which they previously did not have, into the exchange rate.

Order flow analysis was applied to the first data set from the foreign exchange transaction statistics. The series is relatively short, but the results partly supported the theory and provide hope that future analyses may help us to better understand the functioning of the foreign exchange market.

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