A Guided Tour of the Market Micro Structure Approach to Exchange Rate Determination[*]

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June 2004

Abstract

We propose a critical review of recent developments in exchange rate economics. This new strand of research is motivated by some very stark empirical evidence, relating exchange rate returns to order flow. Plenty of empirical evidence shows that order flow, i.e. the imbalance in the sequence of purchases and sales of foreign currencies in the markets for foreign exchange, is an extremely powerful determinant of short-run exchange rate movements. With a simplified analytical framework we see how, according to the rational expectation paradigm of asset pricing, such a relation reflects liquidity and information effects of portfolios shifts.

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Introduction

According to the asset market approach of the early 1970s the exchange rate is the relative price of different national assets, i.e. it maintains the equilibrium between demand and supply of national assets. Such a definition reversed the traditional flows view, according to which the exchange rate maintains the equilibrium of the balance of payments, and shifted the attention of researchers to the study of aggregated stocks.

The abysmal results of the empirical analysis of models of exchange rate determination developed in the 1970s question the validity of the stock view of the asset market approach. In fact, plenty of empirical evidence shows how asset market models of exchange rate determination completely *fails* to explain exchange rate movements in the short-run and can only indicate long-run trends.[1]

A popular explanation for the empirical failure of the asset market approach lies with the particular forward looking nature of the exchange rate and with the impact that macroeconomic news have on exchange rates. Data on macroeconomic variables continuously reach financial markets. Some of these data concern variables which alter the values of currencies, i.e. fundamental variables. Hence, when news arrivals condition market expectations of future values of these fundamental variables, exchange rates immediately react anticipating the effect of these fundamental shifts. Since news are hard to observe, it is difficult to control for news effects in the empirical analysis of exchange rate dynamics and hence it is hard to conduct any meaningful analysis of the asset market approach.

However, a new strand of empirical research has proposed a novel approach to exchange rate determination. Very recently researchers have gained access to transaction data, i.e. to data on the individual trades between agents in foreign exchange (FX) markets. Consequently, it is possible to bypass the analysis of the relation between fundamental values and exchange rates and concentrate on the study of buying/selling pressure in FX markets. Interestingly, this novel approach re-assigns a central role to flows rather than stocks, in that exchange rate movements are associated to order flows, i.e. to the flow of transaction between market participants, rather than to holdings of assets.

In this survey we do not attempt to offer a comprehensive overview of what is generally referred as the market microstructure approach to exchange rates, we rather prefer to conduct a guided tour along some of what we consider the most interesting and promising contributions of this very recent strand of research.

The survey is structured as follows. In Section 1 we briefly present the trading structure of FX

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[1]See *inter alia* Meese and Rogoff (1983) and Frankel and Rose (1994).

markets. In the following Section, it is discussed some preliminary but stark evidence in favour of the explanatory power of order flow with respect to exchange rate dynamics. In Section 3, we discuss estimates of VAR models of order flow and exchange rate returns. In this way proper impulse response functions can be derived and short- and long-term effects of shocks can be studied, so as to outline possibly liquidity and information effects of currency trades. In Section 4, the VAR approach is extended to consider the short- and long-term inter-relations between order flow, exchange rate returns and fundamentals. This allows to shed more light on the distinction between the informative and liquidity effects of order flow.

In Section 5, a simple structural model of exchange rate determination offers a theoretical underpinning for the empirical evidence pertaining to the relation between spot rates, fundamentals and order flow. Since this model and other basic explanations of the explanatory power of order flow assign it an informative role, in Section 6 studies of the inter-relation between order flow, news arrival and spot rates are discussed in some details. In Section 7 we discuss the role of central bank intervention in FX markets, since it corresponds to a very informative component of order flow. A final Section concludes with some general remarks on future developments of this strand of international finance research.

1 The Microstructure of Foreign Exchange Markets

The empirical analysis of the asset market approach shows how traditional models of exchange rate determination completely *fails* to explain exchange rate movements in the short-run and can only indicate long-run trends. Therefore, international finance economists have recently turned their attention to the *organisation* of FX markets. The understanding that market microstructure theory actually studies traders' behaviour in financial markets has led economists such as Jeffrey Frankel to suggest that such a theory may guide exchange rate economics out of the "foggy swamp" it has been mired in for the past ten-twenty years.

In the words of Maureen O'Hara (1995), "market micro-structure [theory] is the study of the process and outcomes of exchanging assets under explicit trading rules". Thus, it is suggested that the organisation and regulation of trading in securities markets have important implications for the process of price formation and more generally for all characteristics of these markets. This consideration is true for FX markets as well and the analysis of their organisation may lead to some useful hindsights for exchange rate economics.

Hence, let us see in some details the structure of FX markets. We should concentrate on four central aspect of this structure. Firstly, one should note that since these markets by their nature

are dislocated in several financial centres, practically *no* rules can be imposed on their functioning and the activity of their participants. This means that their organisation is not the result of the decisions of some authorities but the consequence of their *natural* evolution.

Secondly, one can easily classify the population of foreign exchange traders according to three different types of agents: FX dealers, brokers and customers. FX dealers, generally from the financial division of major commercial banks, trade among each others and with external customers. These may be large corporations or financial institutions. Brokers are agents which do not trade on their own account. Instead, they help customers and/or FX dealers to complete their desired transactions.

Thirdly, transactions among these market participants can be either *direct* or can be *mediated* by a broker. Several estimations suggest that the inter-dealer market accounts for about 50 to 60 percent of the total volume of trading and that almost 50% of these transactions are carried out through a broker (BIS (2002)).

Fourthly, in FX markets two different mechanisms of trading coexist: the *direct* market is *quote-driven* and *decentralised*, while the *indirect* (brokered) market is *order-driven* and *quasi-centralised*. As transactions can be completed at any time, markets for foreign exchange are also *continuous*. We will now try to explain briefly what we mean with this terminology, whilst for a more extensive analysis we refer to Lyons (2001) and Rime (2003).

In the direct market transactions are the result of private bilateral "meetings" between traders. In the past these "meetings" have generally been conducted on the phone. Nowadays, though, FX dealers employ electronic communication systems, such as Reuters Dealing 2000-1 system.

In the direct market transactions are *quote-driven* because prices are fixed *before* quantities. In fact, clients contact single dealers, which "make the market" quoting bid ask prices for any specific foreign exchange they trade. These quotes specify at which prices dealers (*market makers*) will be ready to buy (bid) and to sell (ask) the specific currency. Then, clients can place orders to buy or sell the currency. Since quotes are valid for market orders not exceeding some prefixed amount, the size of these transactions is limited, even though most market makers will accept very large orders.

The direct market is *decentralised* or fragmented in that transactions are completed through private bilateral deals among traders and *cannot* be observed by other market participants. On the contrary, in other securities markets, such as the NYSE, all transactions are centralised, because trading is organised around a single market maker or according to an *open outcry system*. Moreover, there are other decentralised markets, notably the London Stock Exchange, in which dealers are forced by institutional rules to communicate almost immediately information on their *order flow*

(i.e. their sequence of transactions) to all other traders. These mechanisms of *consolidation* are absent in the direct FX market, that hence remains fragmented and *opaque*.

The indirect market is *order-driven*. Here prices and quantities are set *altogether*. Moreover, transactions are not the result of simple bilateral deals, but are mediated by brokers, that is agents who do not deal on their own but operate on account of clients charging a small transaction fee. Any broker keeps a *book* of *limit orders* placed by his clients. Limit orders placed with a broker are matched against other *market* and limit orders from other traders. A limit order specifies the amount of a particular currency a trader is willing to sell (buy) and the minimum (maximum) price he will accept. A market order indicates the intention to buy (sell) immediately a given quantity of the foreign currency at the existing *best* price.

In the past, the brokered market was operated on the phone. Traders would call a broker and ask for his *internal* spread. This means that the broker would quote the best buy and sell limit orders contained in his book and that then the trader would have the faculty to hit them. In this way priority was (and it is still) given to buy (sell) limit orders with the best prices, rather than to the oldest ones. Nowadays the indirect market is dominated by *electronic* brokerage systems, such as EBS and the Reuters Dealing 2000-2.

The trading platforms of these electronic brokerage systems share some common features. The platform's subscribers are attached to a screen reporting the best outstanding buy and sell limit orders for a set of foreign currencies. All other limit orders remain in the background and are used to up-date the information available to the subscribers when a transaction is completed or one of the best orders is withdrawn. At any time subscribers can hit the limit orders posted on the screen or add their own ones.

Since these are centralised mechanisms of trading, the indirect market is *quasi-centralised*. However, given that the identities of traders which complete a transaction are kept *anonymous*, in that they are not published on the platform screen, the indirect market remains partially opaque.

To conclude this brief Section we should mention that there is a qualitative difference between the direct and the brokered market, as they respond to different needs of market participants. The direct market guaranties the immediacy of execution for all market orders. Even if quotes may not be favorable clients are always able to complete a transaction with a market maker. In the brokered market the execution of limit orders is uncertain and may take a while, but traders benefit from the fact that they can trade at the desired price.

2 The Explanatory Power of Order Flow

Traditional models of exchange rate determination are based on two fundamental principles: i) exchange rate determination is basically a macro phenomenon, in that exchange rate movements are uniquely determined by shifts in macro aggregates; and ii) exchange rates immediately react to shifts in macro aggregates. In other words, after a variation in the price level or in output a new equilibrium value for the exchange rate is reached without any change in investors' portfolios.

The poor explanatory power of these traditional models alongside with the empirical evidence showing the importance of micro-structural aspects of the functioning of equity markets in explaining short-term movements in equity prices have turned the attention of many researchers to *order flow* in FX markets.

Order flow is defined as the *net* of the buyer-initiated and seller-initiated orders in a securities market. It is the simplest measure of buying *pressure* and it is calculated from: i) the sequence of market orders reaching market makers in dealership markets; and ii) the sequence of market and limit orders which reach brokered markets and cross with existing posted limit orders. Order flow might be interpreted as the transmission link between information and exchange rates, in that it conveys information on deeper determinants of exchange rates, which FX markets need to aggregate and impound in currency values.

Evans and Lyons (2002) consider a very simple model of exchange rate determination which makes use of the information contained in order flow. According to this model daily exchange rate variations are determined by changes in the interest rate differential, as suggested by traditional models, and *signed order flow*. Thus,

$$\Delta s_{t+1} = \beta_i \, \Delta(i_t - i_t^*) + \beta_z \, z_t, \tag{1}$$

where: Δs_{t+1} is the first difference in the log of the foreign exchange price within day t, $s_{t+1} - s_t$, $\Delta(i_t - i_t^*)$ is the first difference in the interest rate differential, $(i_t - i_t^*) - (i_{t-1} - i_{t-1}^*)$, and z_t is the difference between the number of buyer-initiated trades and seller initiated trades in day t.

To interpret this simple linear specification consider that a positive value for z_t implies that within day t the number of buy orders exceed that of sell ones. This means that a majority of traders has purchased the foreign currency during the day indicating that they consider the foreign currency undervalued. This imbalance might reflect all that news, in the form of macro announcements, data releases, etc., which reaches FX markets and induces traders to modify their evaluations of exchange rate returns and their portfolios of assets.

Evans and Lyons employ data pertaining to *all* bilateral transactions completed among FX dealers via Reuters Dealing 2000-1 electronic trading system in the spot DEM/USD and JPY/USD markets between May 1st and August 31st 1996. Their data-set *indicates* for any transaction the exchange rate, which of the two counter-parties bought and sold and, more importantly, which initiated the transaction, allowing thus to define the corresponding direction (i.e. if a buy or a sell order) of the trade. The data-set does *not* report either the transaction *size* or the counter-parties identity.

This transaction data-set is used by Evans and Lyons to estimate their linear model. Note that the interval $(t, t+1)$ does not correspond to calendar time but corresponds to transaction time, meaning that the observed data are not equally spaced in time, but refers to the random completion of new trades. However, Evans and Lyons consolidate the transaction data at the daily level, so that in the estimation of equation (1) the interval $(t, t+1)$ corresponds to 24 hours.[2]

Evans and Lyons find that both for the DEM/USD and JPY/USD regressions a positive value for the order flow, z_t, induces an appreciation of the foreign currency. Thus in the case of the DEM/USD, Evans and Lyons estimate that in a day where DEM buy orders exceed DEM sell orders by 1000 the German currency appreciates by 2.1%. Given that the average trade size in the sample for the DEM/USD spot market is $3.9 million, $1 billion net purchases of the German currency increases its value by 0.54%. Assuming that the spot rate is 1.5 DEM/USD, the value of the DEM augments by 0.8 pfenning (i.e. 0.08 DEM).

Both for the DEM/USD and JPY/USD regressions rate the coefficient of the interest rate differential is either not significant or does not contribute to the empirical fit of the regression. In particular, the coefficient of multiple correlation, R^2, in the case of the DEM/USD rate takes values larger than 0.6 when the order flow variable is included and falls dramatically when it is excluded. A similar conclusion is drawn in the case of the JPY/USD rate. Here, however, the explanatory power of the order flow variable is smaller, as the R^2 takes values smaller than 0.5. Possibly, this difference is due to the different degree of diffusion of Reuters Dealing 2000-1 system among FX dealers trading in the DEM/USD and JPY/USD markets.[3]

Evans and Lyons follow Meese and Rogoff (1983) methodology to study the out of sample forecasting ability of their simple linear model. The entire sample is split in two. The first 39 observations are employed as an estimation sub-sample and the following 50 are used as a forecasting sub-sample. The root mean squared forecasting errors (RMSEs) are calculated for the time interval between day 40 and day 89 and are compared with those obtained with a simple random walk model.

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[2]Results based on the transaction data are even stronger.

[3]Other studies, notably Biønnes and Rime (2001), Carpenter and Wang (2003), Danielsson *et al.* (2002), have reported very similar results to those of Evans and Lyons for other markets and periods.

Both for the DEM/USD and JPY/USD rates the linear model presents smaller RMSEs than those obtained with a simple random walk at the daily, weekly and bi-weekly horizons. Given the standard errors of the estimated RMSEs, such difference is significant uniquely at the one-day horizon. This result might not, at first sight, look particularly impressive, in that: i) the predicting power of the model dies away pretty quickly; and ii) proper forecasts are not obtained, since *actual* values of the explanatory variables are used. Anyhow, Evans and Lyons' results are dramatically different from those obtained by Meese and Rogoff for the traditional models. In addition, professional traders would love to be able to predict exchange rates even at the one day horizon.

A legitimate criticism against the linear regression proposed by Evans and Lyons refers to the issue of simultaneity bias, which emerges if exchange rate movements cause order flow. In fact, in the case in which the exchange rate presents a *feed-back* effect on order flow the OLS estimates of the coefficients β_z is biased. Suppose, in particular, that $z_t = z_{1,t} + z_{2,t}$, where

$$z_{2,t} \; = \; \gamma\,\Delta s_{t+1}, \quad \text{while} \quad \Delta s_{t+1} \; = \; \alpha\,z_{1,t} \; + \; \epsilon_t.$$

If we run the regression
$$\Delta s_{t+1} \; = \; \beta_z\,z_t \; + \; \eta_t$$
the value of β_z is equal to

$$\beta_z \; = \; \frac{\alpha\,(1\,+\,\gamma\,\alpha)\,+\,\gamma\,\phi}{(1\,+\,\gamma\,\alpha)^2\,+\,\gamma^2\,\phi} \quad \text{where} \quad \phi \; = \; \frac{\sigma_\epsilon^2}{\sigma_{z,1}^2}.$$

Since $z_{2t,}$ is not directly observable, it is not possible to establish whether a positive value for the estimate of β_z corresponds to either $\alpha > 0$ (for either $\gamma \neq 0$ or $\gamma = 0$), so that order flow causes exchange rates to move (with or without a feed-back effect on order flow), or $\alpha = 0$ and $\gamma > 0$, so that the estimated β_z assumes a positive value only because of a *positive* feed-back effect of the exchange rate on order flow. Thus, in the presence of *positive* feed-back trading rules ($\gamma > 0$) the results reported by Evans and Lyons are spurious and hence misleading.

3   Order Flow and Exchange Rate Returns Analysis

To take account of the possible feed-back effects of the exchange rate on order flow, an alternative methodology can be employed. This is based on the study of a simple linear VAR model for trades and quote revisions originally proposed by Hasbrouck (1991) for the analysis of the NYSE.

Payne (2003) applies Hasbrouck's methodology to a transaction data-set which refers to the brokered section of the FX spot market. His study can then be considered a complement to that of Evans and Lyons, which instead analyse the direct market. He considers all inter-dealer trades completed via Reuters Dealing 2000-2 system in the USD/DEM spot market over the week between October 6th and October 10th 1997. While this period is rather short, his data-set contains information over roughly 30,000 transactions, with a total volume of more than \$60 billion. These figures confirm that foreign exchange markets present a huge volume of transactions and an impressive trading pace, in that several transactions are usually completed within a minute.

Differently from Evans and Lyons, Payne has access to information on the size of all transactions. This extra bit of information allows to measure more precisely the informational content of order flow, as in the presence of asymmetric information rational expectations models of asset price determination show a clear dependence of signed order size on information. Payne's empirical methodology is based on the following VAR model for exchange rate returns and trades:

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\begin{cases}
r_t = \sum_{i=1}^{p} \alpha_i\, r_{t-i} + \sum_{i=0}^{p} \beta_{zi}\, z_{t-i} + \epsilon_{1,t}, \\
\\
z_t = \sum_{i=1}^{p} \gamma_i\, r_{t-i} + \sum_{i=0}^{p} \delta_{zi}\, z_{t-i} + \epsilon_{2,t}.
\end{cases}
$$

In his study Payne does not consolidate transactions and hence the interval $(t, t+1]$ does not refer to a given period of time, such as the day considered by Evans and Lyons. Indeed, Payne does not use calendar time, but an event time, where an event is any instance in which either the exchange rate best quotes (i.e. the best bid and ask prices) are revised or a transaction is completed on Reuters Dealing 2000-2 system. In this way the interval $(t, t+1]$ refers to the spell of time between two subsequent events.

In this simple VAR model z_t is now a *vector* containing trades information. This comprises: a signed trade indicator, which takes value 1 (-1) if an order to buy (sell) the US dollar is completed at time t and 0 if a quote revision takes place at time t triggered by the introduction or the cancellation of a limit order; a signed trade *size* variable, to analyse the effect of volume on exchange rates; a squared trade indicator, which is introduced to account for possible non linearities in the relation between price revisions and order flow.

Note that this VAR specification is not entirely standard, in that the *contemporaneous* value of the order flow variables, z_t, enters into the excess return, r_t equation, when in fact these two values are determined simultaneously. Also notice that the excess return on the foreign currency, r_t, differs from the exchange rate variation, $s_t - s_{t-1}$, by the interest rate differential $i_{t-1}^* - i_{t-1}$. The difference is inconsequential at these very high frequencies, because over such short spells of time the period-by-period interest rate differential, $i_{t-1}^* - i_{t-1}$, is negligible. This component of the excess return is hence ignored in the calculation of r_t.

In the two equations which form the VAR model the contemporaneous realisation of z_t enters into the regression for the exchange rate return. The opposite is not true, in that in the regression for z_t only lag values of the excess return are considered. According to this formulation transactions logically *anticipate* quote revisions and hence the opposite causality is not allowed. This assumption, alongside with that the innovation terms, $\epsilon_{1,t}$ and $\epsilon_{2,t}$, are uncorrelated, permits identifying the VAR model.

The innovation term $\epsilon_{1,t}$ can be interpreted as quote revisions induced by the arrival of public information, associated with news releases and the like. The innovation term $\epsilon_{2,t}$ refers instead to unpredictable trading activity, possibly associated to private information.

Writing the VAR model in matrix form and inverting the VAR specification one can derive the following VMA representation:

$$\begin{pmatrix} r_t \\ z_t \end{pmatrix} = \begin{pmatrix} a(L) & \mathbf{b}(\mathbf{L}) \\ c(L) & \mathbf{d}(\mathbf{L}) \end{pmatrix} \begin{pmatrix} \epsilon_{1,t} \\ \epsilon_{2,t} \end{pmatrix},$$

where $a(L)$, $\mathbf{b}(\mathbf{L})$, $c(L)$ and $\mathbf{d}(\mathbf{L})$ are infinite lag polynomials which represent the impulse response functions implied by the VAR model. In particular, $\mathbf{b}(\mathbf{L})$ represents the impact of trade innovations, $\epsilon_{2,t}$, on subsequent returns, capturing the effects of private information on exchange rates. Indeed, $\sum_{i=0}^{\infty} \mathbf{b}_i$ indicates the long-run response of exchange rates to trade innovation and can be considered a measure of the information content of order flow.

The lag polynomial $\mathbf{b}(\mathbf{L})$ allows to measure the information content of order flow, but does not permit assessing its contribution to the total volatility of exchange rates. However, under the hypothesis that exchange rates can be decomposed in a random walk and a stationary process, the total volatility of the permanent component of the exchange rate process is given by the following expression:

$$\sigma_w^2 = \left(\sum_{i=0}^{\infty} \mathbf{b}_i \right) \mathbf{\Sigma} \left(\sum_{i=0}^{\infty} \mathbf{b}_i' \right) + \left(1 + \sum_{i=1}^{\infty} a_i \right)^2 \sigma^2,$$

where $\mathbf{\Sigma}$ is the variance-covariance matrix of the order flow innovation, $\epsilon_{2,t}$, and σ^2 is the variance

of the exchange rate innovation, $\epsilon_{1,t}$.

The permanent effect of a public innovation $\epsilon_{1,t} = 1$ on the exchange rate is given by 1, the contemporaneous effect, plus $\sum_{i=1}^{\infty} a_i$ and hence the variability in the permanent component of the exchange rate process that we can assign to public information is given by $(1 + \sum_{i=1}^{\infty} a_i)^2 \sigma^2$. On the contrary, the permanent effect of an expected innovation in the order flow $\epsilon_{2,t} = \mathbf{1}$ on the exchange rate is $\sum_{i=0}^{\infty} \mathbf{b}_i$, so that its contribution to the total variability of the exchange rate is given by σ_x^2, where

$$\sigma_x^2 = \left(\sum_{i=0}^{\infty} \mathbf{b}_i \right) \mathbf{\Sigma} \left(\sum_{i=0}^{\infty} \mathbf{b}_i' \right).$$

Thus, in synthesis, the importance of private information-based trades in determining exchange rate movements can be measured via the ratio σ_x^2/σ_w^2.

Employing only the signed trade indicator ($z_t = 1, -1, 0$) among the transaction characteristics, Payne estimates an exchange rate equation with 8 lags in z_t. He finds that the coefficient of multiple determination, R^2, is equal to 0.25. Moreover, the sum of the β_{zi} is positive (0.00668) and significantly different from zero, suggesting that order flow has a positive impact on exchange rates (indeed, all coefficients β_{zi}'s are positive and significantly so). From the VMA representation it is found that the total impact of a US dollar buy order on the USD/DEM rate is equal to 0.005%, i.e. that a purchase of the American currency brings about roughly a 1 basis point increase in its value, while from the variance decomposition Payne finds that more than 40% of the exchange rate variability must be attributed to unpredictable trading activity, in that $\sigma_x^2/\sigma_w^2 = 0.41$.

One should also notice that signed trade size and squared trade size when introduced among transaction characteristics are not significant. A possible explanation of this finding rests with the very small variability observed in the trade size variable. However, it is rather worrying for an information based argument to find no relation between trade size and price impact. Finally, Payne finds that time-of-the-day and liquidity effects complicate the relation between order flow and excess returns, in that the asymmetric information coefficients (the coefficients β_{iz}'s) are not stable across different level of market liquidity and different time intervals.

In synthesis, we conclude from his analysis that even when we take into account the possibility of feed-back trading rules order flow imbalance is *still* a fundamental determinant of exchange rate movements.

4 Fundamentals, Order Flow and Exchange Rates

Froot and Ramadorai (2002) try to assess the relation which exists between order flow, exchange rate returns and fundamentals. With respect to the studies of Evans and Lyons (2002) and Payne (2003) there are two major differences in their approach.

Firstly, they employ a data-set of more than 6 million FX transactions obtained from State Street Corporation, a very large global asset custodian. This data-set contains records of all foreign exchange transactions for 111 currencies by more than 10,000 funds over the period between January 1st 1994 and February 9th 2001. Secondly, they try to investigate the long-run effects of international flows on exchange rates and their relation to fundamentals. Since these are hard to observe Froot and Ramadorai employ Campbell's decomposition of permanent and transitory components of asset returns.

As a starting point Froot and Ramadorai repeat the analysis of Evans and Lyons considering the following regression:

$$r_{t+1,j}(P) \; = \; \alpha \; + \; \beta_{z,j} \, z_{t,j}(P) \; + \; \epsilon_{t,j},$$

where $r_{t+1,j}(P)$ is the P-period cumulative excess return on currency j,

$$r_{t+1,j}(P) = \sum_{i=1}^{P} r_{t+1-i,j},$$

and $z_{t,j}(P)$ is the corresponding cumulate for the signed trade size.

Because of the lack of enough observations, Froot and Ramadorai do not consider simple bilateral rates: $r_{t+1,j}$ represents the excess return on currency j against a basket of major currencies; likewise, $z_{t,j}$ is the value in US dollars of all currency j inflow in the interval $(t, t+1]$.

The regression slopes, i.e. the coefficients β_{zj}^{h}'s estimated by Froot and Ramadorai indicate that even over very long time horizons international inflow and excess returns are positively correlated. In particular, for most currencies the values of these coefficients are significantly larger than zero and relative stable across various time horizons. On average the values of the β_{zj}^{h}'s indicate that a \$100 million dollar net inflow results in a appreciation of 11.5 basis points (i.e. 0.115%) of the corresponding currency.

The correlation coefficients between aggregate flows and excess returns reported by Froot and Ramadorai also present some very interesting regularities. These coefficients take positive values with maxima reaching values ranging from 0.3 to 0.6. In addition, they tend *first* to increase with the time horizon between the 1-day and the 20 day horizon and *then* to decrease as horizons pass

beyond 20-60 days.

Froot and Ramadorai suggest that these results do not show a stable causal relation from flows to exchange rates, as the impact of order flow on excess returns is transitory. The positive correlation observed over short horizons is not related to fundamentals and could be the consequence of trend chasing activity on the part of investors.

To verify their conjecture Froot and Ramadorai combine a VAR model of excess returns, fundamentals and order flow with a decomposition of the excess returns *à la* Campbell. The VAR specification is *de facto* an extension of the formulation proposed by Payne, as it includes interest rate differentials and inflation differentials alongside order flow and excess returns, while the decomposition of the excess return allows to distinguish between innovations in exchange rates due to shifts in expected interest rate differentials (i.e fundamental shifts) and innovations due to changes in expected future returns.

In order to investigate how international flows interact with returns and fundamentals both in the short- and in the long-run, Froot and Ramadorai consider the following VAR model for the vector $x_t = (r_t, z_t, i_t - i_t^*, \pi_t - \pi_t^*)'$:

$$x_t \; = \; \Gamma \, x_{t-1} \; + \; \epsilon_t.$$

Because of the limited number of observations a unique VAR specification is estimated for all currencies. This means that all observations are stacked together in a single series. This requires a standardisation of the order flow measure, z_t, where single currency j observations, $z_{t,j}$, are normalised by dividing all purchases of assets denominated in currency j by its standard deviation for the entire period.

Since Froot and Ramadorai concentrate on the short- and long-run interaction between order flow, fundamentals and returns, the impulse response functions associated with this VAR specification play a paramount role in their analysis. Given its matrix form representation, it is not difficult to invert the transition matrix Γ (obtaining hence the VMA representation) and derive the following cumulative innovation matrix

$$\Phi(p) \; \equiv \; (\Gamma \, - \, \Gamma^{p+1}) \, (I \, - \, \Gamma)^{-1},$$

which allows to determine the expected cumulative change in the vector x_t *up to period* $t + p$ induced by the shock ϵ_t, $\Phi(p)\epsilon_t$. The expected cumulative innovation to the excess return induced by a shock ϵ_t is given by $e1' \, \Phi(p)\epsilon_t$, where $e1' = [1\, 0\, \cdots\, 0]$ isolates the first component of vector x_t. The total impulse response of the exchange rate to shock ϵ_t is given by the expected cumulative

innovation in the exchange rate, $e1'\Phi(p)\epsilon_t$, plus the shock itself, $e1'\epsilon_t$, i.e.

$$e1'\Psi(p)\epsilon_t = e1'\left(\Phi(p) + I\right)\epsilon_t.$$

Analogously we can identify the effects of a perturbation on order flow by substituting the vector $e1'$, with $e2' = [0\,1\,0\,\cdots\,0]$. This allows to isolate the order flow shock, $e2'\epsilon_t$, the expected cumulative innovation in the order flow due to shock ϵ_t, $e2'\Phi(p)\epsilon_t$, and its total response function from an order flow shock, $e2'\Psi(p)\epsilon_t$. For the analysis of the infinite horizon impulse responses the following cumulative innovation matrices apply:

$$\Phi = \Phi(\infty) = \Gamma\,(I - \Gamma)^{-1}, \quad \text{and} \quad \Psi = \Psi(\infty) = \Phi(\infty) + I.$$

Short- and long-run effects of perturbations can then be identified via the following matrices:

$$\Phi(p) \quad \text{and} \quad \Psi(p) \quad \text{vs} \quad \Phi - \Phi(p) \quad \text{and} \quad \Psi - \Psi(p).$$

An economic interpretation of these functions can be derived from the following excess return decomposition derived by Froot and Ramadorai:

$$r_{t+1} - E_t\,(r_{t+1}) = \sum_{i=1}^{\infty} E_{t+1}\,(d_{t+i} - r_{t+1+i}) - \sum_{i=1}^{\infty} E_t\,(d_{t+i} - r_{t+1+i}),$$

where d_t is the real interest rate differential between time $t-1$ and t, $d_t = i_{t-1}^* - \pi_t^* - (i_{t-1} - \pi_t)$.

Thus, the unexpected exchange return can be decomposed in the difference between *cash-flow* news, $\nu_{cf,t}$, and *expected-return* news, $\nu_{er,t}$, i.e.:

$$r_{t+1} - E_t\,(r_{t+1}) = \nu_{cf,t} - \nu_{er,t}, \quad \text{where:} \tag{2}$$

$$\nu_{cf,t} = \sum_{i=1}^{\infty}\left(E_{t+1}\,(d_{t+i}) - E_t\,(d_{t+i})\right),$$

$$\nu_{er,t} = \sum_{i=1}^{\infty}\left(E_{t+1}\,(r_{t+1+i}) - E_t\,(r_{t+1+i})\right).$$

In other words, an exchange rate shock might be the consequence of either a fundamental shock, $\nu_{cf,t}$, or a shock in expected returns, $\nu_{er,t}$. In the former case the foreign currency appreciates if there is an increase in the present value of future interest rate differentials. In the latter it appreciates if there is a reduction in future required rates of return.

Given the excess return decomposition in equation (2) it is possible to calculate these two components of the excess return from the VAR model. The unexpected exchange return is equal to the exchange rate shock, $r_{t+1} - E_t(r_{t+1}) = e1'\epsilon_t$, whilst the expected-return news, i.e. the innovation in the present value of future excess returns, is equal to the expected infinite-horizon cumulative innovation induced by shock ϵ_t, $\nu_{er,t} = e1'\Phi\epsilon_t$. This implies that cash-flow news, i.e. the innovation in the present value of future interest rate differentials, is equal to total infinite-horizon impact of shock ϵ_t: $\nu_{cf,t} = e1'\Psi\epsilon_t$.

Froot and Ramadorai's estimates of the comovement between the short- and long-run components of flows and returns propose very interesting results. They show that the contemporaneous comovement between order flow and excess returns, $e1'\Sigma e2$ (where $\Sigma = E[\epsilon_t\epsilon_t']$), is as expected larger than zero. In addition, the comovement between order flow and expected short-term *future* excess returns, $e1'\Phi(p)\Sigma e2$, is also positive. This indicates that order flow *positively* anticipates short-term (1-month ahead) movements in exchange rates. Anyhow, over longer horizons this anticipation effect changes sign, as the comovement between order flow and expected long-term *future* excess returns, $e1'(\Phi - \Phi(p))\Sigma e2$, is negative.

Froot and Ramadorai's results also show that the covariance between expected short-term cumulative innovations in order flow and current excess returns, $e1'\Sigma\ \Phi(p)'e2$, is positive. This indicates that some traders employ positive feedback rules over short horizons. On the contrary, the covariance between expected long-term cumulative innovations in order flow and current excess returns, $e1'\Sigma\ (\Phi - \Phi(p))'e2$, is strongly negative. In brief, these results seem to indicate that some traders employ positive feed-back rules over short-term horizons and then unwind their speculative position. As a consequence they appear to follow negative feed-back trading rules over long horizons. Such interpretation is also consistent with the different signs of the short- and long-term anticipation effects of order flow described before.

Finally, Froot and Ramadorai show *insignificant* values for the covariance between fundamental news and: i) flow surprises, $e1'\Psi\Sigma e2$; ii) expected short-term innovations in order flow, $e1'\Psi\Sigma\Phi(p)'e2$; iii) expected long-term innovations in order flow, $e1'\Psi\Sigma(\Phi - \Phi(p))'e2$; and iv) total innovations in order flow, $e1'\Psi\Sigma\Psi'e2$. In synthesis, Froot and Ramadorai conclude that: i) there is no clear link between order flow and the permanent components of exchange rates; and ii) the positive impact of order flow on exchange rate is a *transitory* phenomenon *not* necessarily related to fundamental information.

Froot and Ramadorai also analyse the short-run and long-run covariances between excess returns and interest rate differentials, and between order flow and interest rate differentials. Their results partially vindicates order flow. In fact, they suggest that returns are positively correlated with expected short-term future changes in interest rates, while order flow is *positively correlated* with

expected short-term future changes in interest rates. Thus, we can differ from Froot and Ramadorai and suggest that order flow is at least related to some short term fundamental information.

5   Heterogeneous Information, Order Flow and Exchange Rates

Bacchetta and van Wincoop (2003) have offered a possible rationale for the empirical evidence outlined by Evans and Lyons, Payne, and Froot and Ramadorai. Their basic idea is that in FX markets if risk averse traders i) possess heterogeneous beliefs over exchange rate fundamentals and ii) observe imperfectly correlated signals on fundamentals, transitory liquidity shocks will have a persistent impact on exchange rates. This is due to: i) the usual *risk-sharing* mechanism, when investors need to be compensated for any extra risk they are forced to bear as a consequence of purchases and sales of foreign currencies, and; ii) an *information-based* mechanism, when, in the face of the opaque structure of FX markets, investors confuse an appreciation (depreciation) of the exchange rate due to a liquidity shock with that induced by fundamental information.

In the case in which such confusion concerns fundamental information that becomes public in the *distant* future the impact of order flow on exchange rates due to this information-based mechanism is *magnified* by the *infinite regress* of investors' individual beliefs. In fact, if investors receive private signals on fundamental variables, such as interest rates or monetary aggregates, whose realisations are not imminent but distant in the future, they will try to learn from prices and quantities they observe (i.e. exchange rates and order flow) not only the fundamental value of foreign currencies, but also other investors' forecasts. This attempt to learn other investors' forecasts exacerbates the confusion between liquidity and fundamental shocks, amplifying the impact of order flow on exchange rates.

The magnification effect is absent if private signals concern *imminent* shifts in fundamentals. This is because in the case in which private information is short-lived the knowledge of other investors' forecasts is redundant and hence the confusion between liquidity and fundamental shocks subdues. More precisely, when private signals concern next period realisations of fundamental variables investors know that very soon they will all share the same fundamental information. If they are aware that changes to the fundamental variables to which their private signals pertain will become of public domain in the near future, investors realise that they will not be able to exploit any information they can extract from other investors' forecasts and hence will not seek to learn these forecasts.

We now briefly discuss the basic elements of Bacchetta and van Wincoop's model. First we present a simplified analytical framework which represents their basic argument. We then discuss

the properties of their model analysing the confusion between fundamental and liquidity shocks and the magnification effect. Finally we present the empirical implications of this model in the face of the empirical evidence discussed in the previous Sections.

5.1   A Simple Structural Model

According to this simplified framework in the market for foreign exchange a single foreign currency is traded for the currency of a large domestic economy. Trading in this market is organised according to a sequence of Walrasian auctions. When an auction is called agents simultaneously submit either market or limit orders for the foreign currency and then a clearing price (exchange rate) for the foreign currency is established.

FX markets are more complex than the simple Walrasian market we envisage here, in that several trading platforms coexist and traders can either complete private bilateral transactions or execute their orders through centralised electronic limit order books, such as Reuters Dealing 2002 and EBS systems. Anyhow, since a growing share of all FX transactions has been conducted via these centralised trading platforms, our simplification is partially justified. Moreover, our framework allows to capture the lack of transparency of the market for foreign exchange, in that all transactions are anonymous.[4]

In the market for foreign exchange we distinguish two classes of traders: FX dealers and customers. Dealers are risk averse investors which absorb any imbalance in the flow of customers' orders. They are rational investors which select optimal portfolios of domestic and foreign assets. They are supposed to be short-sighted in that their investment horizon is just one period long. This assumption is introduced for tractability but also captures a quite well known feature of the behavior of FX dealers, which usually unwind their foreign exchange exposure by the end of any trading day.

All domestic FX dealers share the same CARA utility function of their end-of-period wealth. At time t they can invest in three different assets: a domestic production technology, which depends on the amount of real balances possessed, domestic bonds that pay period-by-period interest rate i_t and foreign bonds that pay period-by-period interest rate i_t^*.

Under these conditions the optimal demand for foreign bonds (foreign currency) on the part of

---

[4]See BIS (2002) and Rime (2003).

the population of domestic FX dealers is:

$$d_t = \frac{1}{\gamma \sigma^2} \left(\bar{E}_t(s_{t+1}) - s_t + (i_t^* - i_t) \right), \tag{3}$$

where s_t is the log of the spot exchange rate (i.e. the number of units of the domestic currency for one unit of the foreign one), $\bar{E}_t(s_{t+1})$ is the average of the conditional expectations for next period spot rate on the part of all domestic FX dealers, s_{t+1}, given the information they possess in t, σ^2 is the corresponding conditional variance and γ is the coefficient of risk-aversion of all FX dealers' CARA utility functions.

FX dealers's clients provide all the supply of foreign currency. Thus, in equilibrium at time t the total demand for foreign currency on the part all FX dealers is equal to the total amount of foreign currency supplied by their clients, x_t:

$$d_t = x_t. \tag{4}$$

These customers comprise a population of liquidity and informed traders.[5] The amount of foreign currency these customers supply changes over time in order to meet their liquidity needs and/or exploit their private information. If o_t represents the amount of foreign currency liquidity and informed traders collectively desire to sell at time t, the total supply of foreign currency changes according to the following expression:

$$x_t = x_{t-1} + o_t. \tag{5}$$

Signed order flow o_t can be decomposed in the number of units of foreign currency traded respectively by the liquidity, b_t, and the informed customers, I_t:[6]

$$o_t = b_t + I_t. \tag{6}$$

Since order flow usually presents some evidence of serial correlation we assume that its liquidity component, b_t, follows an AR(1) process,

$$b_t = \rho_b b_{t-1} + \epsilon_t^l, \tag{7}$$

where the liquidity shock ϵ_t^l is normally distributed, with mean zero and variance σ_l^2, and is serially uncorrelated (i.e. $\epsilon_t^l \perp \epsilon_{t'}^l$),

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[5]By introducing informed customers we depart from Bacchetta and van Wincoop's original set up.

[6]Differently from the usual convention a positive o_t indicates a net sale of foreign currency. If instead o_t is negative, FX dealers' clients collectively place an order to purchase the foreign currency.

At time t the amount of foreign currency offered for sale by the informed traders, I_t, is instead correlated with the innovation in the fundamental value, f_t, i.e. the variable that in equilibrium determines the value of the foreign currency. This fundamental value is given by $f_t \equiv m_t - m_t^*$, where m_t represents the log of the domestic money supply at time t and m_t^* the equivalent aggregate for the foreign country. We assume that the fundamental value follows a simple AR(1) process with serial-correlation coefficient ρ_f,

$$ f_t = \rho_f f_{t-1} + \epsilon_t^f, \tag{8} $$

where the fundamental shock ϵ_t^f is normally distributed with mean zero and variance σ_f^2 and is serially uncorrelated ($\epsilon_t^f \perp \epsilon_{t'}^f$).

Whilst the fundamental process is observable, at time t all informed traders possess some private information on its next period shock, ϵ_{t+1}^f, and place a collective market order to gain speculative profits. We assume that this order is equal to

$$ I_t \equiv -\theta \epsilon_{t+1}^f, \tag{9} $$

where θ is a positive constant that measures the intensity of their trading activity. This assumption indicates that some insiders collect information on future shifts in interest rates before these become of public domain.

To close the model equilibrium conditions are imposed for the monetary markets in the domestic and the foreign country. Given the production functions introduced by Bacchetta and van Wincoop, the two following equilibrium conditions in the domestic and foreign country prevail:

$$ m_t - p_t = -\alpha i_t, \tag{10} $$
$$ m_t^* - p_t^* = -\alpha i_t^*, \tag{11} $$

where p_t and p_t^* represent respectively the log of the domestic and foreign price level. As in both countries a unique common good is produced, the purchasing parity condition holds:

$$ s_t = p_t - p_t^*. \tag{12} $$

Using equations (10), (11), (12), the definition of the demand for foreign currency on the part of domestic FX dealers (equation (3)) and the FX market equilibrium condition (equation (4)) we find that:

$$ s_t = \frac{1}{1+\alpha} \sum_{k=0}^{\infty} \left(\frac{\alpha}{1+\alpha}\right)^k \left(\bar{E}_t^k (f_{t+k}) - \alpha \gamma \sigma^2 \bar{E}_t^k(x_{t+k})\right), \tag{13} $$

where $\bar{E}_t^k(f_{t+k})$ is the order k average rational expectation across all FX dealers of period $t+k$ fundamental value, f_{t+k}, i.e. $\bar{E}_t^k(f_{t+k}) = \bar{E}_t\bar{E}_{t+1}\ldots\bar{E}_{t+k-1}(f_{t+k})$. Similarly, $\bar{E}_t^k(x_{t+k})$ is the order k average rational expectation across all FX dealers of period $t+k$ supply of foreign currency, x_{t+k}.

In this simplified version of Bacchetta and van Wincoop's model we assume that: i) all FX dealers possess symmetric information; and ii) all FX dealers at time t can only receive signals over next period fundamental shock, ϵ_{t+1}^f. These two assumptions allow to circumnavigate the infinite regress problem Bacchetta and van Wincoop study and hence obtain simple closed form solutions for the exchange rate equation (13). In practice, this amounts to impose the conditions that $\bar{E}_t^k(f_{t+k}) = E(f_{t+k} \mid \Omega_t)$ and $\bar{E}_t^k(x_{t+k}) = E(x_{t+k} \mid \Omega_t)$, where Ω_t corresponds to the information set FX dealers possess at time t. Thus, the order k average rational expectations of period $t+k$ fundamental value and supply of foreign currency are simply equal to all FX dealers' conditional expectations of the same variables.

Under equation (9) equation (13) simplifies to:

$$
\begin{aligned}
s_t \;=\; & \frac{1}{1 + \alpha(1 - \rho_f)}\, f_t \;+\; \frac{\alpha}{(1 + \alpha)}\, \frac{1}{1 + \alpha(1 - \rho_f)}\, E\left(\epsilon_{t+1}^f \mid \Omega_t\right) \\[2ex]
& - \alpha\,\gamma\,\sigma^2\, x_t \;-\; \gamma\,\sigma^2\, \frac{\alpha^2\,\rho_b}{1 + \alpha(1 - \rho_b)}\, E\left(b_t \mid \Omega_t\right).
\end{aligned}
\tag{14}
$$

To derive a rational expectation equilibrium and obtain a closed form solution for the spot rate we need to establish how FX dealers formulate their predictions of: i) the shock in the fundamental value, ϵ_{t+1}^f; and ii) the liquidity order flow, b_t. With respect to the former task we assume that at time t all FX dealers observe the following common signal:

$$
v_t \;=\; \epsilon_{t+1}^f \;+\; \epsilon_t^v,
\tag{15}
$$

where once again the error term ϵ_t^v is normally distributed with mean zero and variance σ_v^2. Clearly, the error terms are uncorrelated overtime (i.e. $\epsilon_t^v \perp \epsilon_{t'}^v$) and with the fundamental shock (i.e. $\epsilon_t^v \perp \epsilon_{t'}^f$). In practice, the signal v_t represents all the information which FX dealers can readily obtain from various official sources and publicly available data, such as newswire services, newsletters, monetary authorities' watchers and so on.

Alongside this signal all FX dealers can observe the flow of transactions that are completed in the market for foreign exchange. This is possible because in centralised platforms such as EBS and Reuters Dealing 2002 all transactions are immediately published on the system's computer screens. Therefore, we can assume that in any period t all FX dealers observe the signed order flow, o_t. However, given that on these centralised platforms trades are anonymous, the average

dealer cannot distinguish between liquidity orders and informative ones, i.e. between b_t and I_t.

It is then possible to show that under these assumptions in a stationary equilibrium the variation in the exchange rate respects the following expression:

$$
\begin{aligned}
s_t - s_{t-1} \quad = \quad & \lambda_{s,-1}\,(s_{t-1} - s_{t-2}) \; + \; \lambda_f\,(f_t - f_{t-1}) \; + \; \lambda_{f,-1}\,(f_{t-1} - f_{t-2}) \; + \; \lambda_x\,o_t \; + \\
& \lambda_{x,-1}\,o_{t-1} \; + \; \lambda_o\,(o_t - o_{t-1}) \; + \; \lambda_{o,-1}\,(o_{t-1} - o_{t-2}) \; + \; \lambda_v\,(v_t - v_{t-1}), \quad (16)
\end{aligned}
$$

where the closed form solutions for the coefficients λ's depend on the parameters of the model (see Breedon and Vitale (2004)).

5.2 Model Interpretation

From equation (16) we see that four factors enter into the equilibrium relation for the variation in the spot rate: i) the first lag of the spot rate variation, $s_{t-1} - s_{t-2}$; ii) the variation in the fundamental variable, $f_t - f_{t-1}$, and its first lag, $f_{t-1} - f_{t-2}$; iii) the order flow, o_t, and its first and second lag, o_{t-1} and o_{t-2}; and iv) the public signal, v_t, and its first lag v_{t-1}. While the presence of lags in equation (16) is basically due to serial correlation in the liquidity component of order flow, more clout on the link between these explanatory variables and exchange rate dynamics can be obtained by a detailed inspection of the coefficients λ's.

The sign of the fundamental coefficient λ_f is positive. This is not surprising given that an increase in the fundamental value, f_t, corresponds to a rise in the relative money supply, i.e. in the interest rate differential $i_t^* - i_t$. In other words, an increase in f_t augments the excess return on the foreign currency and hence determines its appreciation. A similar result holds for the public signal coefficient, λ_v.

The total supply coefficients λ_x and $\lambda_{x,-1}$ are also quite straightforward to explain. The former is negative because an increase in the supply of foreign currency depresses its value via a liquidity effect. FX dealers will be willing to hold a larger quantity of the foreign currency only if they are compensated for the increased risk they bear. Thus, a larger x_t forces a depreciation of the foreign currency as this corresponds to a larger excess return FX dealers expect from holding foreign bonds. When $\rho_b > 0$ the latter coefficient is positive, because persistence in the liquidity component of order flow induces mean reversion in the liquidity effect of the total supply of foreign currency. When ρ_b is negative such mean reversion turns into magnification, in that $\lambda_{x,-1} < 0$.

The order flow coefficients λ_o and $\lambda_{o,-1}$ are particularly interesting. The former is negative, because of the aforementioned liquidity effect and because order flow possesses an information

content. When some customer orders are informative (i.e. for $\theta > 0$) an excess of sell orders might indicate an impending negative fundamental shock ($\epsilon_{t+1}^f < 0$) and hence induces rational FX dealers to expect an exchange rate depreciation. Consequently, FX dealers will be willing to hold the same amount of the foreign currency only if a reduction in s_t re-establishes the expected excess return foreign bonds yield.

For $\rho_b > 0$ the sign of $\lambda_{o,-1}$ is positive given that persistence in liquidity trading forces mean reversion in the effect of order flow on the spot rate. In fact, FX dealers learn over time the realisations of the fundamental process and can eventually disentangle the informative and the noisy components of order flow. Such mean reversion is in any case only partial, in that $|\lambda_o| > |\lambda_{o,-1}|$, and hence we can conclude that the effect of order flow on exchange rates is *persistent*.

Importantly, this result holds even when customer trades do not carry any information, i.e. when $\theta = 0$, suggesting that the impact of liquidity shocks on exchange rates is not transitory. Such conclusion contrasts with the generally held view that any transitory imbalance between buy and sell orders possesses only a short-lived effect on exchange rates if order flow does not carry any information.

5.3 Extensions and Empirical Implications

When, differently from the formulation we have presented here, FX dealers observe correlated *but* different signals of the fundamental process, the impact of the order flow on exchange rates is amplified. If any domestic FX dealer, h, observes a private signal on the fundamental shock, $v_{t,h} = \epsilon_{t+1}^f + \epsilon_{t,h}^v$, other things being equal, the order flow coefficient in the equilibrium spot rate equation (16), λ_x, is *larger*, indicating that the impact of non-fundamental shocks, b_t, is *magnified*.

Bacchetta and van Wincoop show that the impact of these non fundamental shocks is *very large* if traders possess long-lived information. This is the case if at time t either informed customers observe period $t+T$ fundamental shock, ϵ_{t+T}^f (with $T > 1$), or domestic FX dealers observe private signals on the same shock, $v_{t,h} = \epsilon_{t+T}^f + \epsilon_{t,h}^v$. In both cases in equation (13) we cannot impose the simplifying assumption that $\bar{E}_t^k(f_{t+k}) = E_t(f_{t+k})$ and $\bar{E}_t^k(x_{t+k}) = E_t(x_{t+k})$ and as a consequence the impact of non fundamental shocks, b_t, on exchange rates is *greatly* magnified.

The empirical implications of Bacchetta and van Wincoop's model are very interesting. In particular, the fundamental shock, ϵ_{t+1}^f, presents a *persistent* effect on the value of the foreign currency. However, its initial impact is *smaller* than its total effect. In fact, when a positive shock hits the fundamental process, $\epsilon_{t+1}^f > 0$, because of the rational confusion between liquidity and fundamental shocks, FX dealers need several observations of the spot rate to realise the extension

of this shock.

Bacchetta and van Wincoop show that under heterogeneous information: i) order flow variability accounts for a large share of the spot rate volatility over the short-run; ii) the amount of exchange rate volatility explained by fundamental variables augments over time; and iii) the spot rate is a good *predictor* of future changes in fundamentals over short horizons.

6 News, Order Flow and Exchange Rates

In the previous Sections we have seen that at least over the short run order flow is an important determinant of exchange rate dynamics. From Bacchetta and van Wincoop's analytical framework we have learnt that order flow can affect exchange rates via either a liquidity channel, as FX dealers need to be compensated for the risk they bear when they hold foreign currencies, or an information channel, if order flow conveys information on fundamental shifts which affect the value of currencies. In the second scenario order flow is related to news arrivals, i.e. to information on macroeconomic variables which FX traders obtain from various official sources and publicly available data, such as newswire services, newsletters, monetary authorities' watchers and so on.

The analysis of the effects of news arrivals on spot rates dates back to the debate over the exchange rate disconnect puzzle stimulated in the early 1980s by Meese and Rogoff's influential results. Since then researchers have tried to verify whether macroeconomic variables influence exchange rates, studying the effects of macro announcements on exchange rates. Earlier contributions (Hardouvelis (1985), Ito and Roley (1987)), that concentrated on the analysis of *daily* data, have partially vindicated the role of fundamentals, showing that news arrivals on variables such as output, price levels, etc., do affect exchange rates. Recently researchers (Goodhart (1992), Andersen *et al.* (2003)) have studied the effects of news arrivals at *high frequencies*, also trying to explore the relation between news and order flow (Evans and Lyons (2003), Love and Payne (2003)).

Data on macro variables are continuously released by official and unofficial sources. According to the efficient markets paradigm prices reflect *all* available information, so that only the *unexpected* component of these macro announcements should affect exchange rates. Thus, let $A_{k,t}$ represent a macro announcement variable. This is equal to the announced value of a macro indicator k, such as US GDP or German unemployment level, in the interval $(t, t+1]$ in which a public announcement is released and zero in any other interval. Let $E_{k,t}$ indicate the corresponding value expected by market participants at time t. According to the efficient markets paradigm only the unexpected component, $A_{k,t} - E_{k,t}$, of the announcement variable should influence exchange rates.

Andersen *et al.* (2003) have studied the effects on six major exchange rates (CHF/USD, DEM/USD, EUR/USD, GBP/USD and JPY/USD) of the unexpected components of announcements on 41 macro variables for the United States and Germany over the period between January 1992 and December 1998, employing Reuters data on exchange rate returns, r_{t+1}, observed at *5-minute* intervals and MMS data on money managers' *expectations* of the 41 macro variables, $E_{k,t}$.

For any indicator, k, a *standardised* news variable is defined as follows:

$$N_{k,t} \equiv \frac{A_{k,t} - E_{k,t}}{\sigma_k},$$

where σ_k is the sample standard deviation of the unexpected component of the announcement $A_{k,t}$. The effect of the news variables $N_{k,t}$'s on exchange rates is evaluated estimating the following linear regression of the 5-minute return, r_{t+1}, on its own lags and on contemporaneous and lagged values of the news variables:

$$r_{t+1} = \alpha_0 + \sum_{i=1}^{p} \alpha_i \, r_{t+1-i} + \sum_{k=1}^{K} \theta_{k,j} \, N_{k,t-j} + \epsilon_t. \tag{17}$$

From this linear regression Andersen *et al.* (2003) find that both for US and German indicators *unexpected* fundamental shocks significantly *affect* exchange rates. Moreover, exchange rates react *quickly* to fundamental shocks, with an immediate jump and very little movement thereafter. For example, a positive (negative) one standard deviation US payroll employment shock, $N_{e,t} > 0$ ($N_{e,t} < 0$) appreciates (depreciates) the US dollar against the German currency by 0.16%. Adding the announcement indicators, $A_{k,t}$, to the linear model (17) they also find that the *expected* components of macro announcements do *not* affect exchange rates.

Most of the econometric fit in equation (17) comes from the lagged values of the dependent variable and the contemporaneous news variables, $N_{k,t}$'s. Indeed, most of the effect of news $N_{k,t}$ on the spot rate is felt within a 5-minute interval. Given the number of macro announcements, this amounts to a sub-sample of less than 0.2% of all observations. However, within this small sub-sample news variables show strong explanatory power, as documented by the following linear regression:

$$r_{t+1} = \theta_k \, N_{k,t} + \epsilon_t, \quad \text{for } k = 1, \dots, 41, \tag{18}$$

where the sample is restricted to the intervals, $(t, t+1]$, in which a value for $N_{k,t}$ is observed. While the coefficients of multiple correlations are very small for all currency pairs in the case of equation (17), in the 41 estimations of equation (18) the coefficient of multiple correlation, R^2, often takes values around 0.3 and at times approaches 0.6.

Love and Payne (2003) extend the analysis of the effects of news arrivals on exchange rates by

studying the interplay between order flow, spot rates and macro news. They study: i) the effect of news arrivals on exchange rates and order flow *separately*; ii) the impact of order flow on exchange rates *around* announcement dates; and iii) the effect of news arrivals and order flow on exchange rates *simultaneously*.

They employ transaction data which consist of all inter-dealer trades completed via Reuters Dealing 2000-2 system in the EUR/USD, EUR/GBP and GBP/USD spot markets over several months in 1999 and 2000. Exchange rate returns are sampled at the 1-minute frequency, so that several thousands observations are available for the three spot rates. Only the *direction* of individual trades is available, whilst no information on their size is accessible. We have already seen that this lack of information is inconsequential for the study of the effects of order flow on spot rates.

Their macro news data consist of announcements on several macro indicators for the three listed economic areas alongside the corresponding market expectations collected by Standard and Poors. Since very few announcements per any macro indicator are available, for any economic area a *unique* macro news variable is obtained consolidating the data for the individual indicators. This is done in two stages: firstly, in the economic area C the news variable for the individual indicator k is standardised according to the familiar formulation, $N_{k,t}^C \equiv (A_{k,t}^C - E_{k,t}^C)/\sigma_{k,C}$; secondly, this standardised news variable is *signed* according to its effect on the value of the currency of the area.

To give a sign to the news variable $N_{k,t}^C$ a simple linear regression of the return for currency C on the news variable $N_{k,t}^C$ is estimated via OLS over the entire sample period. If the coefficient of this linear regression is positive (negative), positive unexpected shocks in the indicator k tend to appreciate (depreciate) currency C. The news variable $N_{k,t}^C$ is then signed by pre-multiplying its value by the sign of this linear coefficient.

For any economic area C a single news variable is then obtained by aggregating (i.e. summing together) the *signed* standardised news variables, $N_t^C = \sum_{k=1}^{K} \text{sign}(N_{k,t}^C) N_{k,t}^C$. Hence, the impact of macro news on exchange rates and order flow is studied separately. Returns are regressed on leads and lags of macro news variables:

$$ r_{t+1}^C \;=\; \alpha \;+\; \sum_{i=-p}^{p} \theta_i^C \, N_{t-i} \;+\; \epsilon_t^C, $$

where N_t is the vector of the three economic areas news variables, while θ_i^C is the corresponding vector of coefficient for lag (or lead) i. Order flow is regressed on leads and lags of macro news variables:

$$ z_t^C \;=\; \lambda \;+\; \sum_{i=-p}^{p} \gamma_i^C \, N_{t-i} \;+\; \eta_t^C, $$

where z_t^C indicates the flow of orders moving funds into currency C in the interval $(t, t+1]$, i.e. the difference between the number of buy and sell orders for currency C.

Love and Payne find that news arrivals affect exchange rates. Even at this very high frequency (1-minute) the reaction of the exchange rate is immediate, as the contemporaneous coefficients θ_0^C's are all significantly different from zero. Only the very first lag for the GBP/USD rate is significant, confirming the tremendous *pace* of FX markets. Surprisingly, news arrivals *also* affect order flow, with both immediate and delayed effects. In particular, all nine contemporaneous coefficients γ_0^C's are statistically significant. Moreover, some of the lag coefficients are also significantly different from zero.

To investigate the possibility that news arrivals alter the impact of order flow on exchange rates, Love and Payne consider the following non linear regression of returns on leads and lags of order flow:

$$r_{t+1}^C = \alpha + \beta z_t^C + \sum_{C'} \sum_{i=-p}^{p} \delta_i^{C'} z_t^C \cdot I_{t-i}^{C'} + \epsilon_t^C,$$

where $I_{t-i}^{C'}$ is an indicative variable which takes the value 1 if there is a macro announcement in period $t-i$ for the economic region C'. Results for these non-linear regressions show that around periods of news arrivals exchange rates are *more* sensitive to order flow than during calmer times. Contemporaneously to the release of US (UK) news, order flow presents a significantly larger effect in the determination of the US dollar (British pound). Specifically, the coefficient δ_0^{US} in the regression for the US dollar shows that the impact of order flow on exchange rates more than *doubles* with respect to normal times. Similar results hold for the corresponding coefficients of the British currency.

To test whether exchange rate response to news arrivals is mediated by order flow, Love and Payne estimate a simple bivariate VAR model for each spot rate:

$$\begin{bmatrix} r_{t+1}^C \\ z_t^C \end{bmatrix} = \begin{bmatrix} \alpha_r \\ \alpha_z \end{bmatrix} + \begin{bmatrix} \beta \\ 0 \end{bmatrix} z_t^C + \sum_{i=1}^{p} \Gamma_i \begin{bmatrix} r_{t+1-i}^C \\ z_{t-i}^C \end{bmatrix} + \sum_{j=1}^{q} \Theta_j N_{t-j} + \epsilon_t.$$

This specification assumes that while the contemporaneous value of the order flow, z_t^C, enters into the return equation the opposite is not true. This identification restriction is justified by the 1-minute frequency at which variables are observed. Over such short periods of time a causality link from returns to flows is improbable.

Results from the estimation of this VAR specification indicate that, as seen elsewhere, flow variables, z_t^C, possess a large and highly significant positive impact on exchange rates. A net purchase of euros in the EUR/USD and EUR/GBP markets brings about a rise in the value of the

euro. Similarly, a net purchase of US dollars in the EUR/USD and GBP/USD markets produces a rise in the value of the dollar.

News variables, N_t^C, also have a significant impact on exchange rates and flows. A positive news shock in the euro area ($N_t^{EU} > 0$) appreciates the euro against the US dollar and generates positive order flow from the United States and the United Kingdom. Likewise, a positive value for N_t^{US} appreciates the US dollar against the euro and the British pound and generates positive order flow from Euro-land and the United Kingdom. Interestingly, news in one area also conditions the performance of the market between the other two areas. A positive news shock in the US ($N_t^{US} > 0$) provokes an outflow from Euro-land toward the United Kingdom and a corresponding depreciation of the euro against the British pound.

Since news variables provoke order flow and this on its turn moves exchange rates, information conditions the values of currencies both via a direct channel, as exchange rates immediately adjust after an informative shock, and via an indirect channel, as exchange rates react to imbalances between buy and sell orders.

Studying the impulse response functions of the VAR model Love and Payne are able to isolate the two components. For different horizons these are found by: i) calculating the cumulative return generated by a positive news shock in area C; ii) repeating the same calculation under the restriction that order flow is not affected by news, i.e. by introducing zeros in the second row of all the matrices of coefficients Θ_j; and iii) by subtracting the latter from the former.

Results of this decomposition show that 30-60% of the simultaneous impact of news on exchange rates is mediated by order flow. Love and Payne conclude that nearly 50% of public information simultaneously released to all market participants is impounded into exchange rates via order flow. This implies that efficient markets theory, according to which public information should be immediately transferred to prices with *no role* for trading, is violated.

A difficulty with the analysis of Love and Payne is that their methodology is prone to a circularity issue. In fact, the direction of news is defined on the basis of the effect of announcements on exchange rates. $N_{k,t}^C$ is positively (negatively) signed if an unexpected positive announcement $A_{k,t}^C$ augments (reduces) the value of currency C. The effect of news arrivals on the first moment of order flow and exchange rate is then investigated. Since Love and Payne use the same sample of observations to sign the variables $N_{k,t}^C$ and to study their effects on spot rates, their results are *biased* in favour of a positive effect of news on returns.

The contradictory results of the empirical analysis of traditional models of exchange rate determination make it hard to sign news. For example, an unexpected rise in the growth rate of

monetary aggregates in one country can lead to either a depreciation of the domestic currency, if this process brings about inflation and devaluation expectations, or an appreciation of the domestic currency, if, in the presence of a central bank reaction function, nominal interest rates are set to rise. In other words, any empirical study of the effects of news on exchange rates and order flow is plagued by the issue of the *indeterminacy* of news direction.

In the face of these difficulties one could just concentrate on the effects of news arrivals on the second moments of exchange rates and order flow. That is the route followed by Evans and Lyons (2003). In their study they employ data on all bilateral transactions between FX dealers via Reuters Dealing 2000-1 system in the spot DEM/USD and JPY/USD markets between May 1st and August 31st 1996 and data on macro announcements for US and German indicators derived from Reuters' newswire services. From these sources they construct daily observations for the order flow imbalance, z_t, the exchange rate variation, Δs_{t+1}, and the number of news releases, A_t.

Evans and Lyons study the effects of news arrivals on the volatility of exchange rates and of order flow, considering the following simple extension of their original model of exchange rate determination:

$$\Delta s_{t+1} = \alpha\, z_{1,t} + N_{C,t} + \epsilon_t, \quad \text{where}$$

$$z_t = z_{1,t} + z_{2,t}, \quad \text{with} \quad z_{2,t} = \gamma\, \Delta s_{t+1} \quad \text{and} \quad z_{1,t} = N_{P,t} + \eta_t.$$

Here order flow can be both informative, $z_{1,t}$, and induced by exchange rate movements, $z_{2,t}$, as a consequence of feed-back trading rules. Moreover, exchange rate movements can be the consequence of public information, $N_{C,t}$, or private information contained in order flow, $N_{P,t}$.

Evans and Lyons propose a different role for public information with respect to that advocated by Love and Payne, in that public information does not affect order flow and is immediately incorporated in currency values. Only the private component of information alters exchange rates via order flow. Their notion of private information is also different from the usual one, as FX traders do not share a common model of exchange rate determination and give different interpretations to macro news. Hence, a general consensus on the implications of an unexpected shock to a macro variable can be obtained only via trading. Thus, $N_{C,t}$ refers to the common knowledge component of news while $N_{P,t}$ subsumes all the rest.

Evans and Lyons do not attempt to identify $N_{C,t}$ and $N_{P,t}$. Rather, they simply assume that the corresponding variances, $\sigma^2_{C,t}$ and $\sigma^2_{P,t}$, are increasing in the pace of news arrivals:

$$\sigma^2_C = \sigma_C \cdot A_t, \quad \sigma^2_P = \sigma_P \cdot A_t.$$

Using GMM estimators they find that news arrivals significantly increase the volume of trading. The

arrival of news also augments the volatility of exchange rates via both a direct public information channel and an indirect order flow one. In line with the results of Love and Payne, Evans and Lyons calculate that roughly 70% of daily exchange rate variance due to news arrivals is via order flow and 30% is via the direct effect. In addition, they find that exchange rate movements have a *negative* feed-back effect on order flow. Note that this clearly contradicts the conjecture of Froot and Ramadorai.

7 Central Bank Intervention in Foreign Exchange Markets

We now turn to central bank intervention, as this is an important component of order flow. Central banks routinely buy and sell currencies in spot FX markets. Often the declared intention of these operations is that of conditioning currency values. In this respect, their success depends on the impact that order flow has on exchange rates and its information content. Some have suggested that *foreign exchange (FX) intervention* can be effective because it carries information. In other words, central banks are like informed agents which trade on superior information and consequently alter securities prices. In this sense, order flow in foreign exchange markets condition exchange rates because some traders, notably central banks, possess private information.

When we mention FX intervention we intend *sterilised intervention*, in that when monetary authorities buy and sell currencies, the consequent change in the money supply is usually *offset* through an immediate open market operation. In effect, FX intervention represents an independent instrument of policy-making as long as it does not change the money supply, since otherwise it would be a different and less convenient way of implementing the monetary policy.

According to a traditionally held view sterilised intervention alters currency values via a *portfolio balance effect*, for it modifies the ratio between domestic and foreign assets held by the private sector. More specifically, domestic and foreign assets are imperfect substitutes, since investors have a preference for assets denominated in their own currency. A purchase (sale) of foreign currencies by the central bank, which reduces (augments) the ratio between domestic and foreign assets held by the private sector, induces a depreciation (appreciation) of the national currency, because investors require a greater risk-premium to hold a larger quantity of this currency.

In the early 1980s a controversy over the effectiveness of sterilised intervention emerged. Members of the G-5 debated if sterilised purchases and sales of foreign currencies could influence exchange rates through this *portfolio balance effect*. Critics of this hypothesis challenged it on the ground that either domestic and foreign assets are perfect substitutes or that the effect of sterilised intervention on the risk-premium is irrelevant. The Jurgensen Commission (1983), alongside other

investigations (Frankel (1982), Frankel and Engle (1984), Loopesko (1984), Neumann (1984) and Rogoff (1984)), suggested that sterilised intervention had a very *small*, if any, effect on exchange rates.

In the first part of the 1980s, in line with the general opinion of the ineffectiveness of sterilised intervention, the Federal Reserve followed a "hands-off" stance, refraining from intervening in FX markets. Nevertheless, the excessive overvaluation of the US dollar in 1985 led the monetary authorities of the United States and other leading industrial countries, notably Germany and Japan, to co-ordinate intervention operations to try to bring down the value of the US currency. At the Plaza meeting of September 1985 members of the G-5 inaugurated a new period of co-ordinated and individual operations to manage exchange rates.

The period 1985-1990 witnessed a *reduction* in the fluctuations of the US dollar with respect to the large movements of the previous five years. This reduction has been interpreted as confirmation of the positive results of the new intervention policy (Dominguez and Frankel (1993a)). The reappraisal of large-scale operations in FX markets by the main central banks and their relative success have given new life to the analysis of sterilised intervention. Empirical studies based on more recent and accurate data conclude that central bank intervention has a *significant* short-term impact on exchange rates and is *useful* to stabilise their values. In particular, Dominguez and Frankel (1993b) and Gosh (1992) vindicate the portfolio balance effect, showing that intervention operations influence risk-premia.

Nevertheless, in the 1990s scholars have started giving more weight to a new channel of transmission of central bank intervention to exchange rates. According to the *signalling* hypothesis (Mussa (1981)) operations in FX markets by a central bank may signal changes in future monetary policy more *credibly* than just a simple announcement. By purchasing (selling) foreign assets the central bank stakes its own capital in support of the future policy and hence "buys credibility". Sterilised intervention affects market expectations and hence the exchange rate.

In the 1990s a series of empirical studies has attempted to assess the signalling role of sterilised intervention (Dominguez and Frankel (1993a, 1993c), Klein and Rosengren (1991), Dominguez (1992), Watanabe (1992), Lewis (1993), Kaminsky and Lewis (1996) and Catte *et al* (1994)). The conclusions of these investigations tend to support Mussa's hypothesis, as sterilised intervention is related in some way to the monetary policy and seems to condition investors' expectations. A survey of this strand of research is contained in Edison (1993).

7.1 A Transaction Level Study of Foreign Exchange Intervention

All cited authors have considered either daily or monthly observations of sterilised intervention. Payne and Vitale (2003) instead employ transaction data on the intervention operations of the Swiss National Bank (SNB) and conduct an event study of the effects of foreign exchange intervention on exchange rates at high frequency.[7] Their data-set consists of all *customer* and *intervention* operations, time-stamped to the minute, conducted by the SNB in the USD/CHF market and are recorded for the period covering 1986 to 1995. The data-set also contains tick-by-tick indicative exchange rate quotes on the USD/CHF rate over the same period.[8]

Payne and Vitale consider simple linear regressions of the 15 minute percentage return on the USD/CHF rate on leads and lags of a signed intervention operation indicator, I_t, and a signed customer operation indicator, C_t:

$$r_{t+1} \;=\; \alpha \;+\; \sum_{j=8}^{-8} \beta_j \, I_{t+j} \;+\; \gamma_1 \, r_t \;+\; \gamma_2 \, r_{t-1} \;+\; \epsilon_t, \tag{19}$$

$$r_{t+1} \;=\; \alpha \;+\; \sum_{j=8}^{-8} \beta_j \, C_{t+j} \;+\; \gamma_1 \, r_t \;+\; \gamma_2 \, r_{t-1} \;+\; \epsilon_t. \tag{20}$$

Here I_t (C_t) is +1 in any 15 minute interval where the SNB purchased dollars, within an intervention (customer) operation, -1 in intervals when the SNB sold dollars and zero otherwise.

Payne and Vitals's results indicate that interventions have *significant* and *persistent* effects on exchange rate levels. On the contrary, customer trades do not alter exchange rates, as at no point is the cumulative effect of a customer trade on the USD/CHF rate significantly different from zero. These results suggest that the exchange rate reaction to the SNB intervention activity is not the consequence of a *liquidity* or *portfolio-balance* effect. Rather, it is evidence that intervention operations "carry" information.

As a further check of the signalling hypothesis, Payne and Vitale consider two new regressions. In the first r_{t+1} is regressed on leads and lags of the signed intervention indicator, I_t, alongside those of the signed intervention *quantity*, z_t. In the second the leads and lags of the signed indicator

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[7]Dominguez (2003) has also offered a high frequency study of FX intervention. However, she does not have access to actual transaction data and makes use of newswire reports of central bank activity in FX markets.

[8]The distinction between *customer* and *intervention* operations is crucial: whilst the former are triggered by the need of the Swiss government for foreign currency, the latter are aimed at influencing the value of the Swiss franc.

are substituted with corresponding leads and lags of the *signed, squared quantity*:

$$r_{t+1} = \alpha + \sum_{j=8}^{-8} \beta_j I_{t+j} + \sum_{j=8}^{-8} \delta_j z_{t+j} + \sum_{j=1}^{2} \gamma_j r_{t-j+1} + \epsilon_t, \tag{21}$$

$$r_{t+1} = \alpha + \sum_{j=8}^{-8} \delta_j z_{t+j} + \sum_{j=8}^{-8} \theta_j \, \text{sign}(z_{t+j}) \, z_{t+j}^2 + \sum_{j=1}^{2} \gamma_j r_{t-j+1} + \epsilon_t. \tag{22}$$

Equation (21) allows to assess the relevance of the *size* of intervention, while equation (22) indicates if the relationship between intervention size and the USD/CHF return is non-linear.

Results for the first regression indicate that the size of the intervention operation is important as the coefficient on current intervention, δ_0, is significantly positive, suggesting that the larger the magnitude of intervention, the larger its immediate impact on the exchange rate. Thus, the estimated impact on the exchange rate of an intervention purchase of \$50 million by the SNB (nearly 30 basis points) is *very very* large. This impact is an order of magnitude larger than the lower bound estimated by Evans and Lyons (2002) for the impact of central bank intervention in the DEM/USD market (5 basis points for operations of \$100 million).

To investigate the persistence of these effects Payne and Vitale also examine the results from regressions of *temporally aggregated exchange rate return* data on *aggregated intervention activity*. They consider the following two sets of linear regressions:

$$r_{t+1}^k = \lambda_0 + \sum_{i=1}^{2} \lambda_i r_{t-i+1}^k + \lambda_3 I_t^k + \epsilon_t, \tag{23}$$

$$r_{t+1}^k = \kappa_0 + \sum_{i=1}^{2} \kappa_i r_{t-i+1}^k + \kappa_3 z_t^k + \epsilon_t, \tag{24}$$

where r_{t+1}^k is the return aggregate across k observations, while I_t^k and z_t^k are the corresponding aggregated intervention indicator and quantity.

Results from these regressions indicate that the effect of SNB intervention operations is significant and *persistent*. The quantitative impact of these operations *falls* with the time horizon. In brief, at least over the short-run, the signalling hypothesis seems confirmed. Intervention operations in FX markets represent an *expensive* instrument of policymaking. Because of their potential cost, they can be employed by monetary authorities to credibly convey information to market participants and hence condition market sentiment and currency values. Moreover, since large operations are potentially more expensive they have a bigger impact on exchange rate returns than small ones.

Concluding Remarks

With this survey we have offered a guided tour of the recent market micro structure approach to exchange rate determination. We have not attempted to offer a comprehensive overview of a large and growing body of literature. Rather, we have tried to isolate the most important and innovative aspects of this literature focusing our attention on some key research papers.

In this way we have outlined the main message of this new approach to exchange rate economics: signed order flow is an important determinant of exchange rate dynamics in the short, and possibly even in the medium term. The explanatory power of order flow is associated to two different channels of transmission, due respectively to liquidity and information effects. Anyhow, it is too early to say how important these two channels of transmission are. Only via the estimation of structural model of exchange rate determination containing the key micro-structural aspects of FX markets will it be possible to disentangle the liquidity and information effects of order flow.

We believe that the formulation and estimation of such a structural model represents the most important challenge for this new strand of research. In particular, only when the issues of the simultaneity between exchange rates and order flow and the indeterminacy of liquidity and information effects will be solved the market micro structure approach will overcome the general skepticism that it has met among several international finance scholars.

Clearly, this new approach would have a larger impact if it could offer valid exchange rate forecasts. So far no empirical study has shown any supporting evidence, but this is an issue of such importance that a definitive answer cannot be given yet.

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