MAGYAR NEMZETI BANK

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Occasional Papers

42.

2005

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The microstructure approach to exchange rates: a survey from a central bank's viewpoint

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September 2005

Occasional Papers 42.

The microstructure approach to exchange rates:
a survey from a central bank's viewpoint
(A devizaárfolyamok mikrostruktúra-megközelítése:
a szakirodalom áttekintése jegybanki szemmel)

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Budapest, September 2005

Published by the Magyar Nemzeti Bank
Publisher in charge: Gábor Missura
Szabadság tér 8–9. Budapest 1850

www.mnb.hu

ISSN 1787-5293 (on-line)

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Contents

Abstract

The application of the market microstructure theory to foreign exchange markets in the last few years has introduced a new approach to the analysis of exchange rates. The most important variable of the microstructure analysis, the so-called order flow has proven to be suitable for explaining a significant part of exchange rate changes, not only for high frequency data, but also at longer time horizons that are relevant for macro-economic analysis. Microstructure theory is thus extremely successful from an empirical point of view, especially when compared to traditional exchange rate models. The aim of our study is to provide an introduction to the microstructure-based analysis of exchange rates, emphasising those aspects which may be the most relevant for central banks. In addition to an introduction to the theoretical background of the microstructure approach and the presentation of the key empirical results, we also intend to cast light upon the questions which are important for central banks and which can be tackled successfully using this framework. On the basis of the literature's findings, we present the answers given by the microstructure approach to, among others, questions concerning the efficiency of central bank intervention, the effects of economic news on exchange rates, and the role of different currency market participants in exchange rate developments.

JEL: F31, G15.
Keywords: exchange rate, order flow, microstructure.

Összefoglalás

A piaci mikrostruktúra-elméletnek a devizapiacokra való alkalmazása az elmúlt néhány évben új szemléletmódot honosított meg az árfolyamok elemzésében. A mikrostruktúra-elemzés legfontosabb változója, az ún. order flow az árfolyammozgások jelentős részét képes megmagyarázni nemcsak rövid távon, hanem makrogazdasági szempontból releváns, hosszabb időhorizonton is, így – különösen a hagyományos árfolyammodellekhez képest – a mikrostruktúra-elmélet empirikus szempontból rendkívül eredményes. Tanulmányunk célja, hogy a jegybanki alkalmazhatóság szempontjait kiemelve bevezetést nyújtson az árfolyamok mikrostruktúra alapú elemzésébe. A mikrostruktúra-megközelítés elméleti hátterének bemutatása és az empirikus adatokon végzett tesztek eredményeinek ismertetése mellett elsősorban arra kívánunk rávilágítani, hogy milyen, a jegybankok számára fontos kérdésekben alkalmazható sikerrel ez az elemzési keret. Így a szakirodalom eredményei alapján megmutatjuk, milyen választ ad a mikrostruktúra-megközelítés többek között a jegybanki intervenció hatásosságának, a makrogazdasági hírek árfolyamra gyakorolt hatásainak, az eltérő devizapiaci szereplők árfolyam-alakulásban játszott szerepének kérdéseire.

JEL: F31, G15.
Kulcsszavak: árfolyam, order flow, mikrostruktúra.

1. Introduction

Explaining and forecasting exchange rate developments has been an important field of study for academics, participants of the foreign exchange market – market analysts, FX traders, portfolio managers, etc. – as well as for central banks. Despite its practical importance, for a long time research into exchange rates was not able to find a theoretical model of exchange rate dynamics that was successful in empirical applications.

Since traditional exchange rate models based on macro-economic fundamentals generally fail in practical applications, in recent years the microstructure-based analysis of exchange rate movements has gained growing attention in the literature.

This methodology has already been popular in the analysis of equity markets for a long time. The application of the microstructure theory to foreign exchange markets has became widespread since the seminal study of Martin Evans and Richard Lyons (Evans and Lyons, 2002b). Evans and Lyons introduced a new way of thinking in exchange rate analysis by successfully applying a framework that had been used until then almost exclusively to describe intraday exchange rate movements to longer time horizons, which are more relevant for macro-economic analysis. As opposed to the macro-based approach to exchange rates, microstructure theory rejects the perfect markets hypothesis, and emphasises the process of trading and price determination. In addition to – and partly instead of – the fundamental variables explaining the exchange rate, special attention is devoted to the examination of the structure of the market, the rules of trading and the activities of the different types of market participants.

Instead of the macro variables of traditional models, the most important explanatory variable of microstructure analysis is the so-called order flow. The order flow is a 'signed' measure of trading volume, the net balance of buyer-initiated and seller-initiated foreign exchange market transactions. It can be considered as an indicator of buying and selling pressure on a given currency. In microstructure models, exchange rate dynamics is heavily influenced by the order flow. Empirical analyses show that order flows are able to explain a significant part – one half to two-thirds – of the exchange rate fluctuations.

Given the evidence to date, the microstructure approach seems empirically more successful in explaining actual exchange rate developments than the earlier models. Traditional exchange rate models based on macro fundamentals, as shown by the oft-cited study of Meese and Rogoff (1983) and the subsequent empirical research, are mostly unable to outperform the random walk model in explaining exchange rate dynamics out of sample. In practical applications, therefore, they usually fail. Microstructure models, on the other hand, are able to explain a significant part of exchange rate movements, and – despite widespread beliefs – in relation not only to intraday, but also to longer time horizons as well (Evans and Lyons, 2002b).[1]

Although the most important explanatory variable of microstructure models is the order flow, it must be emphasised that, at a deeper level, it is the macro-economic fundamentals that determine the exchange rate in microstructure theory, too. The order flow can be considered as a link between the exchange rate and the underlying factors, i.e. the macro fundamentals. The key innovation of the microstructure theory concerns the way in which the order flow transmits the information on fundamentals via the mechanism of trading. Therefore, the microstructure approach can be considered as a supplement, rather than an alternative, to macro models.

In recent years several summaries and literature surveys have been published on the microstructure approach to exchange rates. The rapid development of the field is illustrated by the fact that some of the studies considered to be of key importance today had yet not been included in the survey by Sarno and Taylor, published in 2003. Similarly, since the appearance of the truly seminal book by Lyons (2001a), important new results have been published. In addition to a brief, well-structured summary of the main findings of the microstructure approach to the exchange rate, Vitale (2004)

[1] A large number of studies – covering almost the complete literature– on the microstructure theory of exchange rates can be downloaded from the websites of Martin Evans and Richard Lyons (http://www.georgetown.edu/faculty/evansm1 and http://faculty.haas.berkeley.edu/lyons, respectively).

attempts to identify key areas where future research is likely to – or should be – directed. Numerous studies by Martin Evans and Richard Lyons also contain summaries of the field (Lyons, 2001b, Evans and Lyons, 2002b).

The goal of this study is to present, without aiming at completeness, the microstructure-based analytical framework of exchange rate dynamics, including the basic models and the most important empirical results. In addition, we wish to highlight those aspects and potential applications that may be of importance for central banks.

Section 2 provides a general overview of the microstructure approach to exchange rates. Thereafter, in Section 3, we outline two key theoretical models of FX microstructure theory. In addition to the relatively abstract model of Kyle, we also discuss the model of Evans and Lyons, which was designed explicitly to describe the foreign exchange market, and thus it is more realistic. In Section 4 we present some of the most important empirical results, which explore the relationship between order flow and exchange rates. Section 5 then looks at some of those applications of the microstructure theory that may be of particular importance from a central banking aspect. The issues covered include how central bank interventions, international capital movements and macro-economic news affect the exchange rate, and we also discuss the role of the different types of FX customers in influencing exchange rates. Section 6 presents the conclusions.

2. Key concepts of the microstructure approach to exchange rates

In the following paragraphs we briefly outline the analytical framework of the microstructure approach to exchange rates. We highlight those special characteristics of spot foreign exchange markets that may play a role in the determination of exchange rates. We compare the features of traditional macro-based and microstructure models and briefly describe the processes through which the order flow may affect the exchange rate. The explanation has been kept non-technical, with a view to providing an introduction for readers not familiar with this novel application of microstructure theory, which provides a more realistic description of the operation of foreign exchange markets.

2.1. THE MACRO-BASED APPROACH TO EXCHANGE RATES

According to the traditional, macro-based exchange rate models, the exchange rate is determined by macro-economic variables, or 'fundamentals'. Money supply, interest rates, capital flows and other macro-economic indicators are included in the models as variables explaining the exchange rate. In line with data availability, the empirical versions of the macro models typically use monthly or lower frequency data. Macro models of the exchange rate can be represented by a general formula given below:

$$\Delta s_t = f(\Delta i, \Delta m ...) + \varepsilon_t$$

where Δs_t is the (monthly) percentage change in the exchange rate, and the function $f(\Delta i, \Delta m, ...)$ includes the macro fundamentals, which may be different from model to model. The most popular families of macro models[2] are the monetary approach to the exchange rate and the portfolio-balance model. In these models the money supply, aggregate income, interest rates, or domestic and foreign portfolio holdings feature as explanatory variables. In addition to the current values of macro fundamentals, expectations on their future values are also often assumed to affect the exchange rate. The impact of other factors, which may affect the exchange rate but are not modelled explicitly, is included in the ε_t residual term.

Two important assumptions of the macro models are that (1) all the information which is relevant for the determination of the exchange rate is publicly known; and (2) the process through which new information influences the exchange rate and determines its new equilibrium level is also known by all participants of the market. It follows from these two assumptions that all new information is included in the exchange rate immediately after becoming public, and the actual process of trading is thus irrelevant in the determination of the exchange rate.

Despite their appealing logical structure and wide-spread use, macro models are unable to explain some key empirical properties of real-world exchange rate developments. These empirical facts include the followings.

1) Excess turnover. The traditional macro-economic approach cannot justify the enormous turnover observed on the global foreign exchange markets: the turnover of these markets is significantly higher than that which could be explained by developments in the macro-economic fundamentals.

2) Excess volatility. Most freely floating exchange rates are far more volatile than what would be justified by the fundamentals.

3) The exchange rate determination puzzle. In practice, the relationship between exchange rates and the above-mentioned fundamental variables has so far proven to be weak. Most empirical analyses have come to the conclusion that these models are able to explain only a small fraction of exchange rate changes, and their forecasting ability is unable to surpass that of random walk (Meese and Rogoff, 1983; Frankel, 1993; Frankel and Rose, 1995). The relationship

[2] Vitale (2003) provides an overview of the macro-economic exchange rate models.

between the fundamentals and the exchange rate can only be detected empirically on a rather long time horizon (see, for example, Mark, 1995).

In view of the modest empirical success of traditional macro models, research has taken new directions. Since the late 1990s electronic platforms of FX trading have become widespread, and databases allowing the testing of market microstructure theory on the foreign exchange market have become available to researchers .

Based on the results to date, this new direction of research seems to be promising. On the one hand, microstructure theory provides an empirical model that can successfully explain exchange rate developments at shorter time horizons. On the other, it can also facilitate a better understanding of the relationship between exchange rates and fundamentals.[3]

2.2. THE CHARACTERISTICS OF SPOT CURRENCY MARKETS

The subject of market microstructure theory is "the process and outcomes of exchanging assets under explicit trading rules" (O'Hara, 1995). The theory assigns pivotal roles to market features that may influence prices: the rules of trading, the key players, the structure, the state of the market, etc. Microstructure-based analyses aim to explore the mechanism through which the prices of the different assets are determined. The key question is whether prices are driven solely by public information without any impact from the trading process itself, or the price dynamics is somehow influenced by the trading, as the transactions themselves transmit information which otherwise would not be observable. Microstructure analyses typically rely on the theoretical foundations elaborated by Kyle, Glosten and Milgrom in the 1980s (e.g. Kyle, 1985; Glosten and Milgrom, 1985).

The theory is thus not new, which is also shown by the fact that microstructure-based analyses of equity markets have been around for a while (Glosten and Harris, 1988; Madhavan and Smidt, 1991). There are several microstructure-based studies of derivatives markets, and such analyses also exist in relation to fixed income markets (e.g. Brandt and Kavajetz, 2004). However, economists have only recently started to investigate the effect of the foreign exchange markets' structural features on exchange rate determination, following the lack of success of the exchange rate models applying a macro approach.

As the structure of the market plays a key role, both in theoretical models and in empirical applications, it is useful to discuss briefly the key properties of the foreign exchange markets before proceeding any further.

The global FX market is the largest financial market of the world. Its turnover exceeds the turnover of even the largest stock exchanges. The market itself is completely integrated in a global sense. Trading is continuous, spreading over time zones throughout the day. The total daily FX turnover is estimated to be 1,200 billion dollars, and it is concentrated in the three largest financial centres: Tokyo, New York and London. Spot transactions constitute approximately 30 per cent of the total volume, forward transactions account for around 10 per cent, while the swap and options market constitute more than 50 per cent. According to certain estimates, trading among currency dealers themselves accounts for approximately 50-60 per cent of the turnover. Nearly 50 per cent of these inter-dealer transactions is intermediated through brokers, while the other half of the trades happens through direct, bilateral deals (Galati, 2002).

By its nature, the foreign exchange market does not have a physical trading floor, unlike some stock exchanges, for example. It is scattered around in numerous financial centres in different countries. As a consequence, there is only a very limited possibility of imposing rules and regulations on its operation and its participants. The rules of trading in foreign exchange markets, therefore, are the result of a natural evolution, and they are not governed or administered by an external supervisory authority.

[3] In recent decades, in addition to the microstructure approach, numerous alternative theories and models emerged to explain – and overcome – the empirical shortcomings of the traditional theories of the exchange rate. These include, among others, the consumption CAPM models (where the premium, stemming from the relationship between the consumption and the exchange rate and from risk aversion, diverts the exchange rate from the value determined by the uncovered interest rate parity), models based on deviations from the rational expectations, models of exchange rate bubbles, the peso problem, etc. Discussing these alternative theories is beyond the scope of this study. Sarno (2005) provides an exhaustive summary of the competing explanations and their empirical performance.

Three types of participants can be distinguished on the FX market: market makers, brokers and customers. Market makers 'operate' the market by providing two-way quotes. They are at each other's and at their customers' disposal by being ready to buy or sell the given currency at the quoted buying and selling rates. Market makers are usually large banks, and the main customers are usually large corporations, non-marketmaking banks or other financial institutions.

Inter-dealer order flow covers a major part of the foreign exchange market's turnover. Inter-dealer trades can be performed directly or through brokers. Brokers only make deals commissioned by their customers, for a fee. They match the best selling and buying orders, but they do not make proprietary trades on their own account. Accordingly, the two main trading mechanisms are often distinguished in the literature as the direct market, where the market makers trade among themselves bilaterally, and the indirect market, where trading is performed via orders given to brokers.

On the direct market deals result from bilateral negotiations. The actual conversations were traditionally done over the phone, but nowadays deals are initiated and discussed through electronic trading systems. An example of such an electronic solution, capable of direct trading, is the Reuters 3000 Dealing System, and its predecessor, Reuters D2000-1. The market maker, who initiates the deal, contacts another market maker through a text-based electronic messaging service, and requests a quote for a given amount of currency. The market maker, who was contacted, gives both a buy and a sell offer for the given amount. Finally, the customer, if he is satisfied with the quotes, accepts the price and reveals whether he wants to buy or sell.

The direct market is decentralised and is often characterised as being 'opaque', since the participants carry out the deals bilaterally; thus other participants are unable to monitor directly the prices and quantities of these transactions. Due to the global and decentralised nature of the market, there exists no regulation to report or publish this information.

The indirect market is order-driven, with trade prices and quantities being determined simultaneously. The participants do not communicate with each other directly – the broker mediates between the two parties. He trades on behalf of his customers, and not on his own account. A broker may receive limit orders and market orders. In the case of limit orders, the broker's client specifies the amount of the given foreign exchange he intends to buy (sell), and the maximum (minimum) price he is ready to pay (accept). In the case of market orders, the clients wish to buy or sell the given amount immediately, at the best price available at that particular point in time.

Indirect trading used to happen over the phone, and the broker's subscribers could follow the offers with the best limit prices through loudspeakers. Today, however, electronic systems are the standard on this market, too. The two popular systems are the Reuters 3000 Spot Matching – previously called Reuters D2000-2 – and the EBS (Electronic Broking Services).[4]

In electronic broking systems, every participant can monitor the best current limit buying and selling orders on a screen. Limit orders other than the best actual bid and offer cannot be seen until the actual best offer is withdrawn, or removed by a transaction. Then the list is updated with the addition of the next best limit order. Users of the trading system can accept the orders – by hitting the bid, or taking the offer – at any time. They can also submit new orders themselves.

Due to these features, the electronic indirect trading can be characterised as centralised to a certain extent. There are, however, limits to the transparency of the market. The names of participants making the deals, for example, do not appear on the screen; thus they can preserve their anonymity.

Although it is true in general that the decentralised trading is slowly losing its importance to the more efficient centralised trading platforms, both forms still play an important role in foreign exchange trading. This is often attributed to the different demands of market participants. Most traders use the direct and indirect markets in parallel, always choosing the form that is most adequate for the given transaction or trading strategy.

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[4] The EBS Ltd. was established in September 1993 by leading market makers of the largest foreign exchange markets.

2.3. FOREIGN EXCHANGE TRADING, ORDER FLOW AND INFORMATION

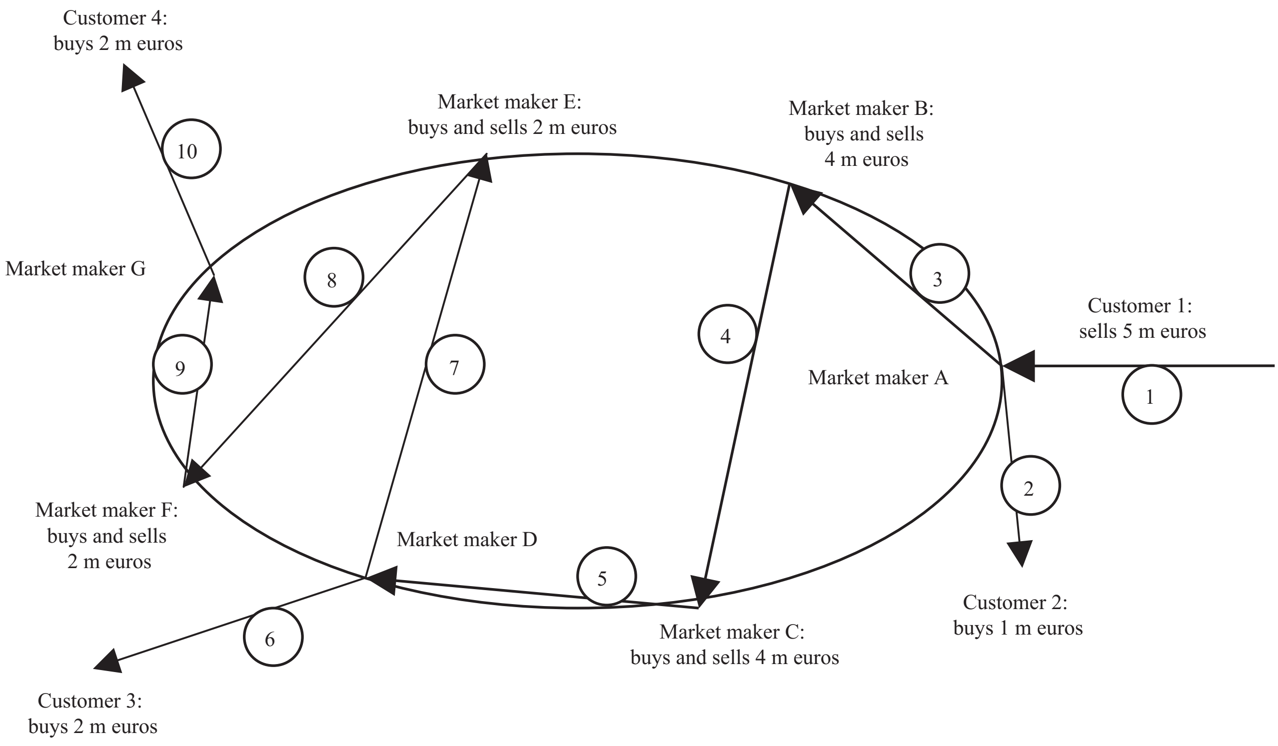
The application of microstructure analysis to foreign exchange markets in the mid-1990s is connected to, among others, the name of Richard K. Lyons. Lyons became interested in the microstructure theory when he visited an FX dealing room at Merrill Lynch. He noted that the traders of the foreign exchange market make their trading decisions using a completely different pool of information to the one assumed in the macro-based models of exchange rate dynamics.

According to Lyons's observations, trading in the foreign exchange market happens in the following manner (Lyons, 2001a). A customer contacts a market maker and carries out a foreign exchange transaction of a given amount. After the deal with the customer, the market maker is left with an open foreign exchange position, which he would like to close. If he is lucky, he can make an opposing customer trade, provided that another customer shows up with an intention to make a deal of different direction compared to the previous one. If the market maker does not have such a customer, he can 'pass the parcel' of the open position to another market maker.

This initiates a process whereby a number of chain-linked market makers are passing the unwanted foreign exchange position to each other. This is the so-called 'hot potato effect'. Of course, if one of them can find an appropriate customer, he can close the exposure through a customer transaction. By the end of the circle market makers shift the risk on to their customers. (see Chart 1).

Chart 1

The trading process on the foreign exchange market



Source: Marsh and O'Rourke (2005).

Inter-dealer order flow, i.e. the 'hot potato effect', provides an explanation for the large trading volume of foreign exchange markets, as a single customer transaction may initiate a turnover much higher than its own value. In the example shown in Chart 1 – which we have borrowed from a study by Marsh and O'Rourke (2005) – an initial sale of 5 million euros generates a total turnover of 28 million euros (see Table 1).

An important feature of the trading process described above is that although the 'one buyer – one seller' relationship is true for each transaction, it is possible to distinguish an initiating and a passive party for each deal. In Chart 1, for example, customer 1 initiated selling the euro to market maker A; customer 2 initiated buying the euro from market maker A, market maker A initiated selling the euro to market maker B, etc.

The identification of the initiating and passive parties of a given trade allows us to derive the so-called order flow, which is the most important explanatory variable in microstructure models. The order flow is the net balance of buyer-initiated and seller-initiated foreign exchange transactions. It is an indicator of the buying pressure (positive order flow) or selling pressure (negative order flow) on the given currency. The order flow is a signed indicator and it is not identical with the turnover or traded volume, which is an unsigned quantity (see Table 1).

Table 1

Order flow and turnover in the course of trading

Transaction	Initiating party	Passive party	Order flow (m €)	Cumulative order flow (m €)	Total turnover (m €)
1	Customer 1	Market maker A	-5	-5	5
2	Customer 2	Market maker A	+1	-4	6
3	Market maker A	Market maker B	-4	-8	10
4	Market maker B	Market maker C	-4	-12	14
5	Market maker C	Market maker D	-4	-16	18
6	Customer 3	Market maker D	+2	-14	20
7	Market maker D	Market maker E	-2	-16	22
8	Market maker E	Market maker F	-2	-18	24
9	Market maker F	Market maker G	-2	-20	26
10	Customer 4	Market maker G	+2	-18	28

The concept of order flow must also be distinguished from demand. In macro models, favourable macro-economic news increases the demand, which results in an increase in prices. However, if the participants are rational and the market is perfect, no one needs to trade at intermediate prices – the change in demand leads to an immediate shift to the new equilibrium. Macro-economic news is publicly available, and price adjustment takes place immediately as the new information appears, without a single trade or transaction being carried out. In this respect, order flow does not have a role in price determination.

If either of the two assumptions of the macro approach – which asserts that both the information and the process of its incorporation into the exchange rate are well-known – is violated, then the order flow transmits information about the market-cleaning exchange rate to the participants of the transaction. Since the price and quantity traded in any customer transaction is known only by that market maker who made the deal, market makers get access to private information. Only they know the magnitude and the direction of the transactions initiated by their customers. The larger a market maker's clientele, the more private information he learns from the order flow of the customers.

However, in the course of inter-dealer trading, each market maker receives indirect signals, 'impulses', of other market makers' customer trades, and learns about the prevailing selling or buying pressure. As the 'hot potato trading' goes on, and the trades among market makers are made, the initially private information from customer trades becomes partly and gradually known by the active market makers. Simultaneously, the information will also be incorporated into the exchange rate.

In the case of the example above (see Chart 1 and Table 1), let us assume that *Customer 1* is well-informed, and learns that the euro is overvalued. To convert this information to monetary profit, he initiates a euro sale, creating an order flow with negative sign. At the beginning, only *Market maker A* can see and read this order flow. He obtained some inside information and he is using it to trade on its basis. In the meantime he generates additional (negative) euro order flow. As the other market makers receive the information through the hot potato effect, they also follow the example. Meanwhile, as a result of the negative order flows, the euro's exchange rate depreciates gradually until reaching the new equilibrium level. At the end of the trading round, Customer 4 buys the euro at this new equilibrium price. Customer 2 and Customer 3, in the middle of the process, however, purchase at higher-than-equilibrium prices. It is assumed that these customers trade on the basis of liquidity needs and not on the basis of private information.

According to this logic based on microstructure theory, trading on the foreign exchange market can be considered as a process of learning. Certain pieces of information, relevant from the aspect of exchange rate developments, are scattered around the economy and are not immediately available in an aggregate form for any of the participants. In this environment, market participants are continuously striving to aggregate the scattered pieces of information.

Order flow may be informative, as private information may be hidden behind the transactions of customers. The existence of private information is hardly questionable on the stock markets, where only a few analysts monitor certain individual stocks. On the FX markets, however, fundamental information regarding future exchange rate developments rarely can remain hidden for long periods of time. One exception is the order flow resulting from central bank intervention, which is a typical example of flows carrying private information.

Probably more important than private information is the fact that differences exist in the interpretation of public macroeconomic data by individual market participants. Different interpretations may, in turn, result in different trading strategies. Presumably, market makers can recover most information from the order flow of market participants with strong and reliable analytical background, better information sources, or large capital stock or market share. This is likely to be reflected in exchange rate developments.

We can presume that the trading of those participants that do not have extra information happens randomly. This means that their order flow is expected to be zero on average. As a result, the larger the order flow is in one direction, the more probable it is that it stems from orders by participants having private information. The evaluation of a new piece of information, or macro-economic data can also be considered as an investment decision. The order flow, in this sense, indicates market participants' and final investors' judgements of the given financial asset.

2.4. THE ROLE OF ORDER FLOW IN MICROSTRUCTURE MODELS

Theoretical models of market microstructure are derived from the market participants' individual optimisation problems. The models' relationship describing exchange rate developments can be represented with the following generic formula:

$$\Delta s_t = g(\Delta x \ldots) + \nu_t \,,$$

where Δs_t is the (percentage) change in the exchange rate between two transactions, while the $g(\Delta x, \ldots)$ function encompasses the explanatory variables from the area of microstructure, of which the most important is the order flow, Δx.

Microstructure models can be classified into two main 'schools', depending on how they explain the effect of the order flow on the exchange rate. According to the *information models*, order flow affects the exchange rate because participants have heterogeneous information. In these models the market maker usually knows that some of his customers have some private information. These informed clients buy when the given foreign exchange is underpriced and sell when it is overpriced. They may also decide not to trade if the price is not suitable for them. The market maker often makes losses when making trades with the informed customer. To compensate, he has to generate profit on transactions with non-informed participants, or on the fee charged for the transactions. It is typical for the information-based models that the effect of information – order flow – on the exchange rate is permanent.

The other main class is the *inventory approach*. The key question of the inventory approach is how risk-averse market makers adjust their quoted prices in a manner that helps to close unwanted, risky open foreign exchange positions that result from liquidity shocks. In these models there is no information asymmetry. The market makers do not take speculative positions: the market maker's exposure – hence the uncertainty – stems from the random differences in the arrival of buying and selling orders. If market makers' open currency position moves from the desirable level due to a transaction, they will try to adjust their quoted prices in a way to induce deals that help to square the position. In inventory models, order flow has only a temporary effect on the exchange rate.[5]

Naturally, there is an overlap between the approaches. More sophisticated models take account of the effects of both factors, with a view to better approximating real-world foreign exchange markets, where, presumably, the motives deriving from information asymmetry and inventory aspects are present simultaneously.[6]

Although the order flow is the key explanatory variable in microstructure-based models of the exchange rate, it must be emphasised that order flow is only a proximate cause of exchange rates dynamics, not its underlying reason. Order flows only transmit pieces of information on fundamental determinants of the exchange rate that are aggregated by the market. Microstructure theory does not deny that fundamentals determine the exchange rate; the difference is that in the mechanisms through which fundamentals affect the exchange rate a key role is assigned to the trading process. From this aspect, microstructure theory can be considered as a complement to, rather than a competitor of, the macro-economic approach.

Empirical results seem to confirm the relationship between order flow and exchange rate. Econometrically estimated versions of microstructure models show that the relationship between exchange rate and order flow is strong – order flow typically explains one half to two-thirds of the daily exchange rate variations. This is stronger than the explanatory power of other models of exchange rate developments. (See Section 4 on the empirical models of market microstructure).

Several potential explanations of the better explanatory power of the order flow models compared to the ones based on macro variables exist. In exchange rate models, expectations of macro variables cannot be measured accurately; therefore substituting them with the order flow can be fruitful. This, of course, does not mean that fundamentals are not the key determinants of exchange rates; it may only be that the more standard methods of measuring the expectations on future fundamentals are less reliable. As opposed to the questionnaire-based survey of expectations, an order for a foreign exchange transaction reflects the fact that the initiating party is ready to put real money behind his opinion and expectations. Order flow thus also can be interpreted as a money-backed estimate of future fundamentals, and in models it can be considered as a variable describing the expected value of fundamentals.

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[5] Inventory models are not identical with the portfolio-balance approach to the exchange rate, although the two theories are related to each other. In the portfolio-balance approach, securities denominated in various currencies cannot be perfectly substituted with each other. As a result, portfolio reallocations by the holders of these assets have an impact on the exchange rates. Exchange rates, therefore, react to capital flows, and the impact is permanent. In the inventory models, final savers are able to accommodate portfolio shocks without a change in the exchange rate. The model only limits the position-absorbing ability of the risk-averse market makers, who therefore charge a premium for taking risky positions. The exchange rate impact is only temporary, as sooner or later market makers shift their open positions upon the customers, who do not request additional premium for absorbing the excess liquidity. Of course, the two approaches can be combined. Evans and Lyons (2000) provide an extensive discussion of the subject.

[6] Several empirical studies have examined whether the co-movement of the exchange rate and the order flow is caused by inventory or information motives. An argument supporting the information approach is that order flows from different customers have different effects on the exchange rate, which would be inconsistent with the pure inventory approach.

3. Theoretical models of market microstructure

In this section we present two theoretical models that are often mentioned when discussing the market microstructure theory of exchange rates. Our aim is to provide an intuitive insight into the theoretical toolkit of the microstructure approach; therefore we have kept the mathematical rigour to a minimum.

One of the models examined, originally from Albert Kyle, is one the simplest yet intuitive 'workhorse' models in the literature. The logic of the microstructure-based approach can be presented in an expressed and clear manner through the Kyle model. The model is far from being realistic, i.e. its structure does not directly correspond to the foreign exchange market or to stock markets. By preserving its basic philosophy, however, it can be adopted in a relatively flexible manner to real-world market structures.

The second model presented below, by Richard K. Lyons and Martin D. D. Evans, is the core model of the microstructure theory of exchange rate. This model is specific to the foreign exchange market: the 'opaque' nature of the market, and the pivotal role of the inter-dealer order flow are of key importance. The significance of the Evans-Lyons model is also justified by the fact that most econometrically estimated equations describing the link between order flows and exchange rates have been derived from this model or its versions.

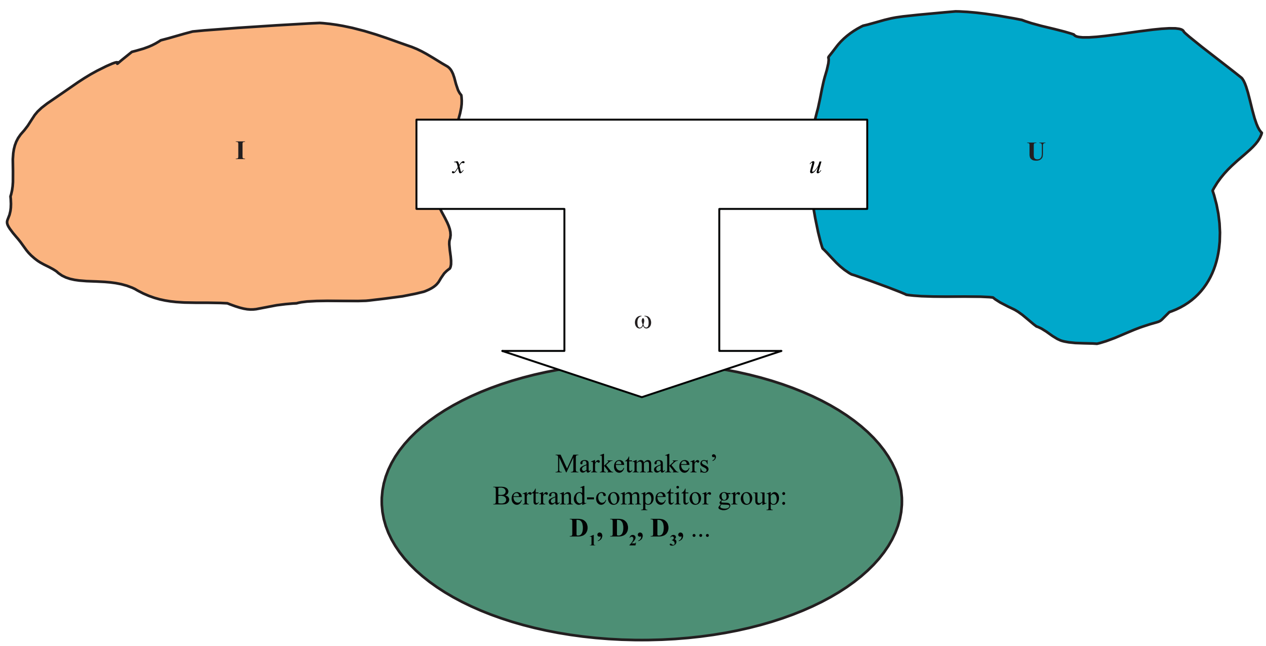
3.1. THE KYLE MODEL

Equilibrium models usually distinguish three participants: the seller, the buyer and the 'Walrasian' auctioneer. This perfectly informed auctioneer is a fictitious agent, whose role in the model is to ensure that sellers and buyers, ordered by their reservation prices, exchange the equilibrium quantity at the equilibrium price. No trade is made outside the equilibrium.

Compared to the equilibrium models, the cast in the Kyle model is different (see Chart 2). Kyle defines three types of market participants: the market maker (D), the informed trader (I) and the liquidity trader (U).

Chart 2

Market microstructure of the Kyle model



The less well-informed substitute for the Walras' market maker is a group of *risk-neutral market* makers who operate in a competitive market, where competition is defined as a Bertrand-oligopoly. They quote prices knowing that informed participants – who possess private information – and non-informed participants are both present on the market. When they quote a price, they face the risk of their customer having private information on the value of the asset.

The second type of player is the *informed trader*, who has the most information about the subject of trading. In the simplest version of the model he knows exactly its value. The informed trader enters the market with the purpose of making profit using the additional information he has.

The third participant, the *liquidity trader*, is a passive player. He is on the market because he experienced an exogenous liquidity shock, which forces him to sell or buy the asset.

The exact value of the traded asset is unknown for both the market maker and the liquidity trader during the course of the trading. They only know the *a priori* probability distribution of this value. The informed trader also knows this distribution, but he receives some additional inside information before the beginning of the trading session, and learns of the actual value of the asset, which is one realisation from the *a priori* distribution.

The trade process in the model is sequential, i.e. individual participants make their trading decisions one after the other. In the *first round of trading*, the informed trader learns the additional private information. Having this information, and some assumptions regarding the market maker's reactions and pricing behaviour, he decides what amount of the asset he wishes to sell or buy, maximising the expected profit. In this same phase, the liquidity trader experiences a random liquidity shock, which induces him to enter the market with an exogenous supply or demand. His trading is thus a consequence of individual optimisation.

In *the second round* the market maker learns the net amount of buy and sell orders of the whole market; in other words the net order flow. He does not know the share of the order flow coming from the informed participant. However, from the direction and magnitude of the net order flow he can make a guess about the amount of inside information.

As the expected value of the liquidity shock is zero, the positive (negative) order flow most probably means that the informed trader has received a signal indicating that the asset is more valuable (less valuable) compared to the mean of the a priori probability distribution. Therefore, the higher positive (negative) order flow the market maker sees, the higher (lower) price he will quote, compared to the expected value of the *a priori* distribution. If the market maker was certain that no informed trader is present on the market, he would not modify the prices at all, and the instrument would trade at the *a priori* expected value.

The fact that market making is not a monopoly is also important for price setting. As our market maker operates on a competitive market, prices have to be as favourable as possible given the available information. If a market maker quoted less favourable prices compared to other market makers, nobody would make deals with him. Consequently, market makers' expected profit cannot be higher than zero.

In *the third round of trading* the 'true', final value of the instrument becomes public, which was known only by the informed trader before. Accordingly, each trader can evaluate his profit made in the course of trading.

The process of trading can formally be described as follows.[7] The final value of the asset, s, is a random variable following a normal distribution:

$$s \approx N\left(s^{*}, \sigma_{s}^{2}\right).$$

[7] For the sake of consistency with the other parts of the study we slightly departed from the notation system of the original Kyle model, and we use the notations of the exchange rate microstructure literature.

The net balance of the shocks to liquidity traders, u, is also a normally distributed random variable:

$$u \approx N\left(0, \sigma_u^2\right).$$

Probability distributions describing *s* and *u* are independent. Their parameters are known by all market participants.

The informed participant, learning the true value of the instrument *(s)*, chooses his trading strategy by deciding how much of the asset he sells or buys. He formulates the function *x(s)*, which describes the relationship between the value (s) and the quantity he is bringing on the market *(x)*, to maximise expected profit:

$$\max_x \mathrm{E}\left[x(s)(s - p(\omega)) \middle| s\right] \tag{1}$$

In the above maximisation problem, *p(ω)* denotes the market maker's pricing function, which assigns the optimum price for the market maker to any given value of the order flow *(ω)*. The order flow is defined as the sum of the informed and non-informed traders' demand: *ω=x(s)+u*. Since, as was mentioned, the market makers are (Bertrand) competitors, their expected profit is zero. This is equivalent to setting the price equal to the asset's expected value, conditional on all available information.

$$p(\omega) = \mathrm{E}\left[s \middle| \omega\right] \tag{2}$$

Both the market maker and the informed participant are aware of each other's possible strategies. This situation can be considered as a two-player game. To characterise the Nash-equilibrium strategies of this game, one has to determine the *x(s)* and *p(ω)* reaction function pair that meets the two conditions mentioned above: the informed customer's profit-maximising condition, and the market maker's zero profit condition. Kyle assumes that both reaction functions are linear:[8]

$$x(s) = \beta s + \alpha \tag{3a}$$

$$p(\omega) = \lambda\omega + \mu \tag{3b}$$

Parameter β indicates how aggressively the informed participant exploits his private information, i.e. how many additional units he buys or sells for a unit shift in the asset's final value. Parameter λ shows how much the market maker reacts with his prices to non-zero order flows.

If the market maker's reaction function is substituted in the relationship describing the informed participant's profit maximum (1), the following relation between λ and β can be derived:

$$\frac{1}{2\lambda} = \beta.$$ [9]

[8] As we shall see later, if we reduce the search for equilibrium only to linear functions, the equilibrium exists and it is unique. Showing that the linear function is optimal even in a broader space of possible reaction functions is beyond the scope of our study.

[9] The informed participant's expected profit can further be broken down as

$$E[\Pi_I(x(s))] = E\left[x(s)(s - p(\omega)) \middle| s\right] = x(s)(s - \mu - \lambda x(s))$$

Then from the informed participant's first-order condition it follows that

$$\frac{\partial \mathrm{E}[\Pi_I(x(s))]}{\partial x(s)} = s - \mu - 2\lambda x(s) = 0 \quad \Rightarrow \quad x(s) = \frac{1}{2\lambda}s - \frac{\mu}{2\lambda}$$

The first-order condition can only be met for any realisation of s if the coefficients in the informed participant's reaction function (3a) and in the above equation are identical. The relationship between λ and β follows from this.

From the market maker's zero profit condition (2), using the properties of the normal distribution and Bayes' theorem, a similar relation can be derived:

$$\frac{\beta\sigma_s^2}{\beta^2\sigma_s^2+\sigma_u^2}=\lambda\ .$$[10]

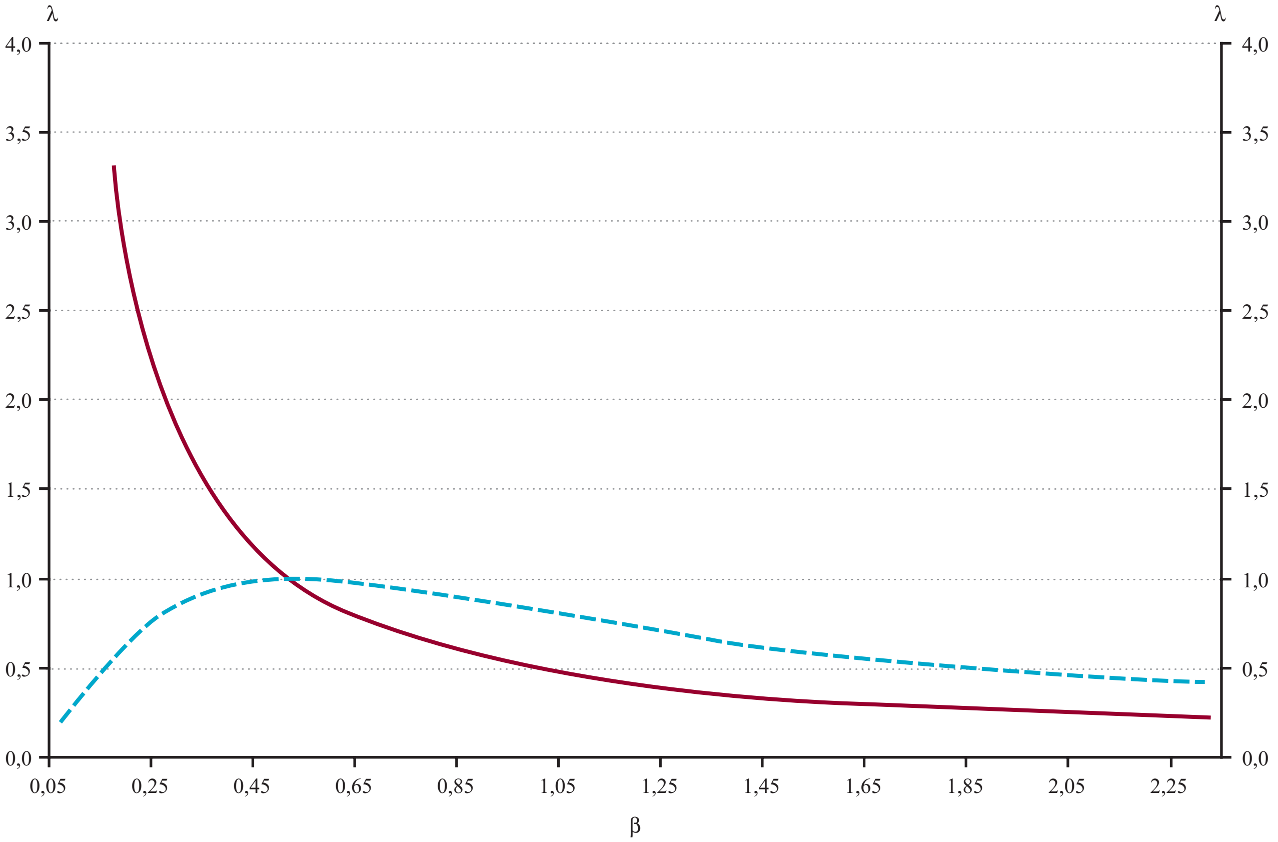
The optimum value of the informed participant's 'trading aggressiveness' *(β)* and the sensitivity of the market maker's reaction *(λ)* will be determined by these two equations. The equilibrium values are as follows:

$$\beta=\frac{\sigma_u}{\sigma_s};\quad \lambda=\frac{\sigma_s}{2\sigma_u}\ .$$

In equilibrium, the trading aggressiveness of the informed customer and the pricing sensitivity of the market maker depend uniquely on the relative size of the two shocks in the model: the liquidity shock and shock affecting the asset's final value. Chart 3 plots the equilibrium that develops at $\sigma_s=2\sigma_u$. The blue line plots the informed customer's optimal strategy for any given *λ*, while the green line, derived from the market maker's zero profit condition, shows the market maker's optimal reaction for any specific *β* value.

Chart 3

Equilibrium in the Kyle model



[10] We used the finding that the conditional probability derived from two random variables (X,Y) following a bivariate normal distribution with a correlation coefficient follows a normal distribution with the following parameters:

$$Y|X=v\approx N\left(\mu_Y+\rho\frac{\sigma_Y}{\sigma_X}(v-\mu_X),\sigma_Y^2(1-\rho^2)\right).$$

Accordingly, $E[s|\omega]=\bar{s}+\frac{Cov(s,\omega)}{\sigma_\omega^2}(\omega-\mu_\varpi)$, In addition, using that $\omega=\beta s+\alpha+u$, we can show that $p(\omega)=\frac{\beta\sigma_s^{\ 2}}{\beta^2\sigma_s^{\ 2}+\sigma_u^2}\omega+\ddot{s}+\frac{\beta\sigma_s^{\ 2}}{\beta^2\sigma_s^{\ 2}+\sigma_u^2}(\beta\ddot{s}+\alpha)$. The parameters of the market maker's reaction function (3b) can then be identified from this equation.

The Kyle model describes how price setting is affected by heterogeneous information in an easily tractable framework. Compared to traditional models with a Walrasian auctioneer, several significant differences emerge. In the Kyle model, the market maker learns some of the information about the asset value – the 'fundamentals' – indirectly, through the order flow. Furthermore, the market maker cannot differentiate between informed and non-informed participants, which is exploited by the former to generate profit.

Another significant difference is that as long as the participants do not have equal information, the market price does not necessarily reflect the fundamental value of the asset. The price in the third stage of the Kyle model will differ from the asset's final, true value, even in terms of expected value.

Moreover, the informed customer's private knowledge is not completely revealed during the trading circle – it is only partially incorporated in prices. Let us imagine the Kyle model in a repeated, dynamic framework, where the true value of the asset is not fully revealed at the end of the trading round. In such a setting we would need numerous trading rounds and transactions to incorporate a particular piece of information into the price.

Although the Kyle model is highly intuitive and easily tractable, it is rather abstract relative to the structure of real-world FX markets. In contrast, the Lyons-Evans model described below explicitly attempts to highlight some key characteristic features of foreign exchange markets.

3.2. THE LYONS-EVANS MODEL

The Lyons-Evans model's market structure is far more intricate than in the Kyle model. It corresponds to the decentralised, multi-layered and opaque trading system of foreign exchange markets. In this framework, private information is not explicitly assigned to a single participant, but it is scattered among the individuals. The pieces of information are then aggregated in the course of trading. We will not provide a formal presentation of the model here. Instead, we will show the most significant differences relative to the Kyle model, the model's basic structure, and some of the lessons it yields.

Chart 4

Market microstructure of the Lyons-Evans model

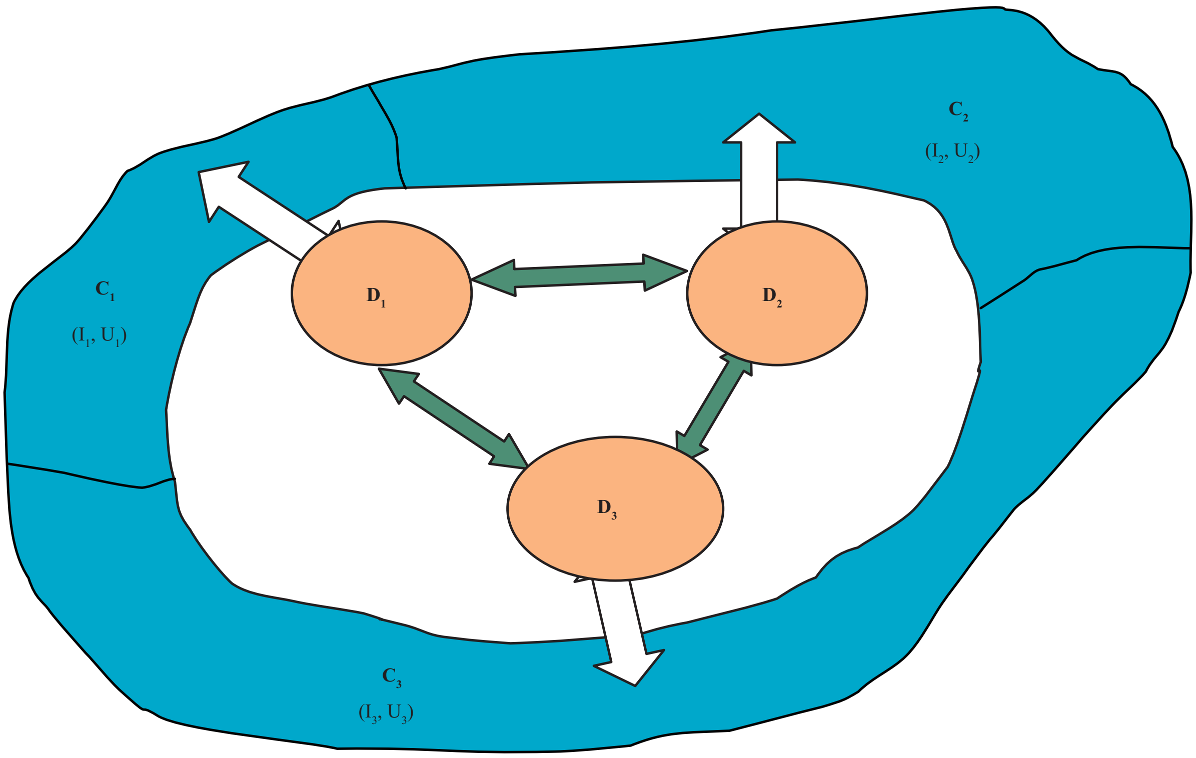


Chart 4 is a sketch of the market structure of the Lyons-Evans model. The market comprises a finite number of market makers (D), and an infinite number of customers (C), all being risk averse. Each particular market maker has his own clientele, and each of them obtains a partial picture of the market conditions through the order flow received from his own customers.

However, customer trades leave market makers with open foreign exchange positions. As they are risk averse, they wish to close these exposures. This can be done by trading with the other market makers. In the course of inter-dealer 'hot potato' trading, market makers pass the open positions among each other, and in the meantime they learn the aggregate order flow affecting the market as a whole. In the course of this trading, the information from this aggregate order flow becomes incorporated into the exchange rate. At the end of the process, the exchange rate is just enough to make the customers willing to buy back the market makers' net open position.

In this model the trading process also involves three rounds. In the first round, every participant obtains some public information by observing the interest rate differential for the two currencies for the period ahead. As a reaction to this information, customers shift their portfolios and provide the market makers with orders, who accept these at prices formed on the basis of the public information.

In the second round of trading, market makers trade with each another. In this stage, each transaction is public; thus the market makers can learn the net order flow on the market.

In the third round, the market makers trade again with their customers. With the knowledge of the aggregate order flow, market makers set an exchange rate in a manner that induces their customers to mop up the open positions accumulated during the earlier stages of trading.

One can derive from the model the following relationship between the change in the exchange rate, public information – the interest rate differential – and the order flow:

$$\Delta s = \beta_1 \Delta(i - i^*) + \beta_2 \omega \,,$$

where Δs denotes rate changes, $\Delta(i\text{-}i^*)$ changes in interest rate spread, and ω denotes the order flow of trade between market makers. The above equation is the one most frequently used in the empirical exchange rate microstructure literature.

While in the Kyle model the value of the fictitious asset is fully revealed in the last round of trading, in real-world foreign exchange markets the true value of the currency is extremely difficult to grasp. In their interpretation of the model, Lyons and Evans offer a foothold – the exchange rate may be considered as the expected discounted value of future interest rate differentials. This value can change either by a shift in the expected interest rates, or by a shift in the discount factors.[11] As the bulk of public information provides only indirect information on shift in the expected interest rate differentials and the discount factors, the way how market participant's interpret and process this information also constitutes significant information in itself.

The order flow of customers in the Lyons-Evans model communicates exactly this type of information. These bits and pieces of knowledge, divided among the individual market makers, are aggregated in the course of inter-dealer trade, and then incorporated in the exchange rate. In contrast to the Kyle model, which focuses on the order flow received from customers, the Evans-Lyons model discusses the role of market makers' trading in the flow of information and exchange rate developments.

We mentioned above that the Lyons-Evans model can describe foreign exchange markets more realistically than Kyle's asymmetric information model. This is definitely true for the trading structure itself. However, to make the model analytically tractable and solvable, a few relatively restrictive constraints had to be incorporated.

[11] Implicitly, this is equivalent to assuming that the *uncovered interest parity (UIP)* holds.

One of them is the no-arbitrage logic applied to the inter-dealer market, which prevents individual market makers from attempting to sell private information. The no-arbitrage principle is a key tool in financial modelling. However, it seems to be somewhat artificial when it is applied in a market microstructure framework. This is because the no arbitrage condition claims that once different prices are observed on the market, the natural forces of arbitrage come into play and close the price gap by increasing the demand for the cheaper and the supply for more expensive product. Microstructure models describe exactly this mere process of volumes pushing differing prices towards an equilibrium. The reason behind arbitrage is that volumes shift differently priced products towards a uniform price. In a microstructure model, which analyses the impact of order flows on pricing, it may not automatically be assumed at any point of the model that on a specific sub-market the market makers quote equal prices on the basis of the no-arbitrage condition. The other strong assumption is that quoted prices are valid for potentially infinite volumes in the individual rounds of trading.

4. The relationship between order flows and exchange rates: What does the data reveal?

The theoretical models presented so far highlight some significant and essential features of the foreign exchange markets, and they help us to understand their basic operation. However, the main reason behind the success of the microstructure approach is its excellent performance in empirical terms. In this chapter we provide an overview of the most relevant empirical results.

We focus mainly on those studies that we deem as most interesting for monetary authorities. The overwhelming majority of the works we present analyse the relationship between the exchange rate and order flow. Those microstructure studies that focus on other variables such as bid-ask spread, volatility, turnover, etc. are not discussed here. From the literature on the link between exchange rates and order flows, we discuss primarily those analyses where the data series are comparable in terms of length and frequency to 'traditional' empirical exchange rate models, i.e. studies using high frequency data and short time series are not discussed extensively.

4.1. SOURCES OF ORDER FLOW DATA

One obstacle analysts often face when attempting to empirically apply market microstructure theory is the restricted availability of order flow data. Early analyses of the relationship between order flow and exchange rates relied on high frequency data spanning short periods only, and generally covering the order flow of a single dealer or bank. It is only in the past few years that researchers have gained access to databases allowing the quantification of various types of order flow indicators on longer time spans, and ones that represent whole markets, or at least considerable segments of them.

A large part of the literature analysing the link between order flow and exchange rate focuses on inter-dealer order flow. The significance of *inter-dealer order flow* in empirical analysis follows partly from the unique structure of foreign exchange markets. The overwhelming majority of foreign exchange turnover involves inter-dealer trading, and as the market is decentralised, this is likely to have a key role in pricing as well. Inter-dealer order flow is also in the focus of the workhorse model of Evans and Lyons, described in the previous chapter.

Another reason why empirical research has been focusing on this market segment is that in the past few years, due to the increasing popularity of electronic trading platforms (such as Reuters and EBS), inter-dealer order flow data has become relatively easy to access in a concentrated form. Direct, bilateral trading, which covers a large part of inter-dealer turnover, is carried out almost completely via the Reuters Dealing 3000 Direct (earlier Reuters Dealing 2000-1) platform. Several studies use order flow data obtained from this system. Another, increasing segment of the inter-dealer market includes the electronic platforms of indirect, brokered trading (EBS and Reuters Dealing 3000 Spot Matching, earlier Reuters Dealing 2000-2). In the past few years, deal data transacted this way also has become available for research purposes. Due to the concentration and quasi-monopoly of the trading platforms, these databases comprise a considerable part of inter-dealer order flow, and thus the order flow indicators calculated from them represent quite adequately the entire market of the specific currencies.

As customer trading is more decentralised and given the lack of a common electronic trading platform, order flow data for the market between market makers and customers *(customer order flow)* is not so easy to access. For the purposes of empirical research, customer order flow indicators are sometimes generated from transactions data from large FX trading banks – some studies calculate order flow from historical databases of the most active market making banks. One problem with this type of data is that even for the largest participants we can only presume that their customer orders are representative of the aggregate, market-level order flow. In addition, the confidential nature of this customer data makes the market makers relatively reluctant to provide this information for external researchers.

Certain central banks, such as Sweden's Riksbank, Norway's Norges Bank and The Bank of Canada, collect data on foreign exchange transactions from the main market making banks of their own currencies. Using certain assumptions, this data source allows the calculation of customer order flow indicators.[12] Compared with the data of individual banks, these databases provide a relatively comprehensive picture of specific foreign exchange markets. However, it should be born in mind that in some cases only resident banks report to central banks; thus the data do not necessarily include off-shore trading. Unfortunately, no such collections are made for the foreign exchange pairs with the highest turnover (dollar/euro and euro/yen).

4.2. EMPIRICAL RESULTS

Most studies in the field refer back to the work by Evans and Lyons (2002b). Although it was not the first econometric analyses on the relationship between order flow and exchange rates,[13] the Evans-Lyons study was the first to analyse the co-movement of these two variables using a series that a) covers a significant part of the market for a certain currency pair, and b) covers a relatively long time span (four months).

Their econometric analysis is an empirical test of the Evans-Lyons model described above in Chapter 2. This model suggests that the exchange rate changes in a specific period depend on changes in the interest rate differential and the inter-dealer order flow in the period under review. Evans and Lyons tested this by estimating the following regression:

$$\Delta s_t = \beta_1 \Delta\left(i_t - i_t^*\right) + \beta_2 z_t + \eta_t ,$$

where Δs_t denotes exchange rate changes, $\Delta(i_t\text{-}i_t^*)$ indicates the changes in the interest rate differential between the two currencies examined, z_t is the order flow, and η is the error term. (Most of the analyses in the subsequent empirical literature concerning the impact of order flow on exchange rates use similar techniques, although some authors apply co-integration models or vector auto-regressions.)

The database they used contains all the deutschmark/US dollar and yen/dollar transactions made through the Reuters Dealing 2000-1 electronic trading system between May and August 1996. It involves approximately one million transactions per day.[14] The transaction-level data was aggregated to a daily frequency, and the estimation was carried out on this daily time series.

For both currencies, the estimation yielded positive values for the β^2 parameter representing the order flow's coefficient, with the levels of significance exceeding 99 per cent. Both equations had high explanatory power: the R^2 value in the deutschmark/US dollar equation was 0.64, and the one in the yen/dollar equation was 0.45.

The model's high explanatory power is exclusively due to the order flow. Although as expected, the interest rate differential's regression coefficient is positive, this is significant only for the Japanese yen. When the order flow was omitted from the equation, the R^2 dropped to 0.01, and the interest rate differential lost its significance, even in the Japanese yen equation.

Evans and Lyons also investigated the model's out-of-sample forecasting power. They used the method suggested by Meese and Rogoff (1983) in their classic study, which analysed the forecasting power of the traditional models of the exchange rate. The Meese-Rogoff test cannot be considered as a genuine 'forecast' test, as they used the actual realised out-of-sample values of explanatory variables. It is more appropriate to think about this method as a test of out of sample model fit.

In view of this fact, the forecasting power of the order flow model does not seem so impressive at first glance. If, however, one considers that, under similar conditions, traditional exchange rate models usually cannot outperform a simple random walk model, the results of the microstructure approach are remarkable.

[12] The data collected by the Magyar Nemzeti Bank from the daily reports of Hungarian banks on their FX transactions can also be used for such purposes.
[13] See, for instance, Lyons (1993), or Goodhart, Ito and Payne (1995).
[14] Records of the data obtained through the Reuters Dealing 2000-1 system contained the price, the time and an indicator showing whether it was originated by the seller or the buyer. However, it did not include the size of the transactions. Evans and Lyons calculated the daily order flow by deducting the number of seller-initiated transactions from the number of buyer-initiated transactions. As in the course of the inter-dealer trading the transaction size does not vary too much, the loss of information resulting from the fact that the accurate amounts are unknown could be considered as relatively small.

Evans and Lyons estimated the equation from the first 39 days of their sample, and then used the remaining 50 days to analyse the out-of-sample 'forecasting' power on one-day, one-week and two-week horizons. They compared the order flow model's forecasting performance with the random walk benchmark. The results were radically different from the negative results obtained by Meese and Rogoff. The order flow equation outperformed the random walk on every forecast horizon, although its advantage declined with the length of the horizon.

Overall, the key achievement of the empirical analysis by Evans and Lyons was that they demonstrated that, unlike macro fundamentals, inter-dealer order flow can appropriately explain exchange rate developments in practical applications, and not only for intraday data, but for longer periods, too.

Subsequent studies successfully reproduced this result on other data sets. Killeen, Lyons and Moore (2001) analysed another segment of the inter-dealer order flow, namely the transactions mediated by brokers. Their data were taken from the EBS electronic trading platform, and also contained transaction volumes. This allowed them to quantify the order flow properly. The currency pair they analysed was the German mark/French franc. Their results suggest strong co-integration between the order flow and the exchange rate.

Daníelsson, Payne and Luo (2002) tested the impact of the order flow on exchange rates using data from the other market leading electronic broker platform, Reuters Dealing 2000-2. They examined four currency pairs (the euro/dollar, the euro/sterling, the sterling/dollar and the yen/dollar) on a sample covering 10 months. A particularly interesting feature of this study is that they analysed the impact of the order flow at various frequencies, from 5 minutes to 1 week. At intraday frequencies each foreign exchange pair showed strong co-movement. In the case of the euro/dollar and euro/yen, this increased as frequency declined – the highest R^2 values were obtained when the regressions were run on one-day and one-week changes. One of the most significant results of the analysis is precisely the fact that the explanatory power of the order flow is not limited to data at transaction level; it is also significant in the longer term.

Another interesting result is that, in the case of sterling, the explanatory power of the estimated equation considerably increased once the euro/dollar order flow was also included in the regression. This led the authors to the conclusion that the order flow of major currency pairs may carry information relevant to the exchange rate development of foreign exchanges with smaller turnover.[15]

Reproducing the Meese-Rogoff forecasting test, Daníelsson and his colleagues confirmed the Evans and Lyons results. The forecasts provided using the order flows performed better than the random walk in every currency pair examined, even at the one-week forecast horizon.

Although customer order flow plays a key role in market microstructure theory, the studies mentioned so far analysed only inter-dealer order flows. The reason for this is that the data from electronic trading systems does not include trades with external, non-market-making customers.

In most models of microstructure theory, such as the Kyle model presented in Section 3, or the model of Glosten and Milgrom (1985), customer order flow has a pivotal role. It is the customer items through which the private information reaches the market makers and becomes incorporated into prices. Besides theory, the importance of customer order flow is also highlighted by the questionnaire-based surveys carried out by Cheung and Chinn (1999) and Gehrig and Menkhoff (2004). These studies showed that most foreign exchange market traders considered customer order flow as a top-priority information source before making buy or sell decisions.

[15] Lyons and Moore (2005) offer an elegant explanation for the fact that the order flows of a specific foreign exchange pair carry information about the exchange rate of another foreign exchange pair. They extend the Kyle model to three instruments representing three foreign exchange pairs. In this model, a trader who has some private information about one of the pairs may decide whether he wishes to utilise the information through trading directly with the pair in question, or indirectly, with the insertion of another intermediate currency. If the 'noise' resulting from liquidity trading is higher on the market of this other currency, he has a better chance to conceal the transaction, and the exchange rate will shift less as a result of his order flow. In such cases informed traders transact at least some of their transactions through some intermediate currencies. In such a model, the order flow of a foreign exchange naturally affects the exchange rate of the other foreign exchange in the pair. The model also provides an explanation for the fact that trading for some currency pairs is restricted exclusively to trading through intermediary currencies

Due to the lack of appropriate databases, the empirical analysis of customer order flows has begun only in the past few years. Based on three years' weekly data on the foreign exchange transactions of Norwegian banks, collected by Norges Bank, Rime (2000) found that customer order flow had a strong explanatory power regarding the exchange rate of the krone. By using a similar data set for the Swedish kronor, Bjønnes, Rime and Solheim (2004) confirm these results. They also find that the order flows from various different customer groups have different impacts on the exchange rate.

In addition to data from central banks, some researchers use customer transactions data from major market-making banks. Based on the analysis of a data-set spanning seven years and 19 currency pairs, obtained from StateStreet, Froot and Ramadorai (2002) found that the order flow explained exchange rate developments even for time series with monthly frequency. However, they also found that order flow had only a temporary impact on exchange rates, and in the long run macro fundamentals offered a better explanation for exchange rate dynamics. Based on five years' yen/dollar and euro/dollar data obtained from Citibank, Fan and Lyons (2002) concluded that the co-movement between the customer order flow and the exchange rates can be clearly observed, even when the data is aggregated at monthly or annual frequencies.

Using data covering two years of customer transactions from the Royal Bank of Scotland, Marsh and O'Rourke (2005) analysed the impacts of the customer order flow on exchange rates for the sterling, the dollar, the yen, and the euro. The order flow and the exchange rates showed close co-movement at both one-day and one-week frequencies. They were the first to demonstrate that customer order flow for one currency pair may have an impact on the exchange rate of other currency pairs, too.

Evans and Lyons (2005) analysed the forecasting power of customer order flows. They found that on time horizons ranging from one day to one month, their empirical microstructure model based on customer order flow provided better forecasts than either the random walk model or the uncovered interest parity model. It must be noted that in this study the authors performed a true out-of-sample forecast, unlike Meese and Rogoff and the subsequent literature. In other words, they forecast future exchange rate developments using past order flow. In this respect, their results are outstanding, and suggest that besides its contemporaneous impact on exchange rates, customer order flow also reflects information about future exchange rates.

Due mainly to the lack of data, hardly any empirical analyses have been made on emerging market exchange rates. It is important to highlight the study by Scalia (2004), which uses three months' data taken from the Reuters 2000-2 electronic trading platform on the Czech koruna, the Hungarian forint and the Polish zloty, and which demonstrated the impact of order flow on exchange rates. Menkhoff and Schmeling (2005) analyse order flows from Russian interbank foreign exchange market trading. These results suggest that the co-movement between order flows and exchange rates is not only a feature of more mature markets, but a characteristic observable on emerging markets, too.

Causality running from the order flow to the exchange rate may not be the only reason for the co-movement between the two variables. If traders reacted to exchange rate movements by opening speculative positions of the same direction *(positive feedback trading)*, regression estimates would provide similar results, even if order flow had no impact on the exchange rate. Thus, in the presence of a positive feedback trading, the results confirming the microstructure logic may be misleading and questionable.

Evans and Lyons discuss the possibility of positive feedback already in their original analysis (Evans and Lyons, 2002b). They provide several arguments supporting their view that it is unlikely for positive feedback trading to lie behind the empirical success of the order flow regressions. First, empirical evidence suggests no significant positive feedback trading on the foreign exchange market. In addition, some studies found that intraday changes in the exchange rate are not positive autocorrelated, thus positive feedback trading would not be profitable. Finally, it can be shown that that the parameter values estimated for the order flow could only be explained by unrealistically large and aggressive positive feedback trading.

Subsequent studies analysed positive feedback trading in detail (see, for example, Evans and Lyons 2003, Daníelsson and Love 2004). These results seem to reveal that there may be some small positive feedback trading within intraday foreign exchange transactions. However, econometric estimations that were corrected for the impact of this positive feedback show that it does not invalidate the original results. On the contrary, the impact of order flow on the exchange rate becomes even more pronounced in these corrected estimates.

In addition to spot market order flows, some studies also include *derivative market order flows* in the empirical analyses. According to Rime (2000), customer order flow to FX derivative markets does not significantly improve the explanatory power of the regression explaining the Norwegian krone's exchange rate. Tien (2002) finds the contrary – according to the results of his study on data covering five currency pairs and covering 15 years, futures market order flows can help explain exchange rate developments. Another analysis of futures market data, by Klitgaard and Weir (2004), confirms these results.

These studies are rather unique in the literature. Most analyses do not mention the possible impact of futures market order flows on exchange rates. This is due to several reasons. One is related to data – consistently comparable spot and futures order flow data are difficult to generate. Another reason is that although the microstructure theory does not exclude the possibility that, in addition to the spot market, futures order flow may also carry information, and thus affect the exchange rate, the overwhelming majority of studies in the microstructure literature explicitly or implicitly consider the spot market as the only channel of exchange rate determination. Those who give reasons for this assumption argue that the spot market makes up the majority – approximately 80 per cent – of the foreign exchange turnover, not counting swap transactions[16] (Lyons, 2001a).[17] Nevertheless, the role of derivative order flows in exchange rate determination is yet to be established.

To summarise, the most important achievements of the empirical literature on the co-movement between order flow and exchange rates are the following:

- Both inter-dealer and customer order flows have high explanatory power with regard to exchange rate dynamics. This result has proven to be robust on time series with diverse frequencies – one day to one month – and for numerous foreign exchange pairs.

- The order flow model performs significantly better in the Meese-Rogoff out-of-sample forecasting tests than the traditional macro-models.

- Co-movement between order flows and exchange rates is due chiefly to the impact of the order flow on exchange rates, rather than to positive feedback trading.

- The order flows of the different currency pairs are interrelated with one another, and the order flow of a currency pair may affect the exchange rate of other currency pairs, too.

- The studies published so far have not paid much attention to derivative market order flows; little is known of their role.

[16] As a swap transaction is a combination of a spot and an opposing forward foreign exchange transaction, its net order flow impact thus equals to zero.
[17] Due to the 'hot potato effect', the small size of the derivative turnover is not a sufficient argument for excluding derivative order flows from the analyses. It may be that open foreign exchange positions might be easier – technically simpler, cheaper and less risky – to maintain using derivative transactions. In this case, derivative order flow may have a higher share relative to the entire market than derivative turnover.

5. Potential applications of the microstructure approach

In the light of the empirical performance of traditional exchange rate models, an approach that can successfully explain exchange rate developments on real-world data is significant and interesting in itself. The microstructure approach is, in addition, suitable for analysing a number of practical issues related to currency markets and exchange rates. In the following we will highlight a few areas of application that may be of interest for monetary policy purposes

5.1. THE EFFECTS OF MACRO-ECONOMIC NEWS

Macro-economic news and the exchange rate reactions following its announcement play an important role in the empirical analysis of exchange rates. Public information about fundamentals reaches the market through macro-economic news. We can expect, therefore, the publication of macro-economic news to affect the exchange rate. It is important, however, whether the effects of news are immediately and fully incorporated in the exchange rate, or the market needs time to completely process and 'digest' the news.

The microstructure approach can be useful in understanding the effects of news on exchange rates. Microstructure theory often refers to the heterogeneous nature of the information available to various market participants as the underlying reason behind order flow's impact on exchange rates. Information asymmetry may arise from the fact that news and information are not equally accessible for everyone, or from the fact that the various participants interpret news in different ways.

It follows from the above that the information content of macro-economic news[18] can be divided into two components (Evans, 2002). The first is often referred to as *common knowledge*. All market participants learn this information at the same time, and everybody interprets it in the same way. In other words, opinions regarding its impact on the exchange rate do not differ. Traditional macro-models only consider this type of information. As a consequence, in these models the exchange rate changes immediately upon news announcements, and no trading is done at intermediate prices.

The other type of information is *non-common knowledge*. This is either not known to everyone, or it is known to everyone, but can be interpreted in several ways. Non-common information is built into the exchange rate through the trading process, and it takes time to incorporate it fully into the price.

By analysing the activity of foreign exchange traders following news announcements, Omrane and Heinen (2003) provide empirical evidence for the existence of these two kinds of information. They examine the behaviour of individual market makers and they demonstrate that the reactions of the individual market makers to the same macro-economic news item can be largely different. The market makers' differing reactions indicate that they interpret the very same news items differently; in other words, part of the information included in an announcement is non-common knowledge.

The role of order flow in the processing of news by the market can be explained as follows. Market makers learn about a change in the value of a certain macro-economic variable. Each of them individually makes a guess regarding the new information's expected impact on the exchange rate, and adjusts the quoted prices. It is not sure, however, that every market participant assesses the news in a similar manner. The trading that develops upon publication of the news carries information to the individual market makers about how their fellow market makers and their customers have assessed the news. The information revealed in the course of trading can generate further changes in the exchange rate. Some impact of the news is thus incorporated in the price only indirectly, in the course of trading.

In their analysis of the impact of news announcements, Evans and Lyons (2003) differentiate three driving forces behind exchange rate developments. One of these is the *direct effect of news*. This is the factor known from traditional macro-

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[18] The information content of macro-economic data announcements is their 'surprise content' – i.e. their difference from the market expectations – rather than their absolute value (Kiss M. 2004). We use the terms 'news', 'news value' and 'information' in this sense.

economic models, which is built in the price without delay. The order flow does not play any role in its impact. The second factor includes *the indirect effects of news through order flows*. This factor becomes incorporated into the exchange rate during the trading process, and the order flow has a role here in spreading the non-common knowledge. They also distinguish a third factor – the *shocks to the order flow that are unrelated to macro-economic news*.

The analysis of the deutschmark/dollar exchange rate and order flow data revealed that roughly two-thirds of the effects of the news on the exchange rate are transmitted through the order flow, while the remaining one-third is the direct impact. Both daily and intraday data point towards the rejection of the hypothesis that the direct impact of news exceeds the indirect impact exercised through the order flow.

Altogether, the combined effect of news explains roughly 30 per cent of exchange rate changes. This result is highlighted by the fact that traditional analyses that assume only a single, direct effect of news transmission explain merely 1 to 5 per cent of all exchange rate fluctuations.

Overall, according to the study, 10 per cent of all exchange rate fluctuations are due to the direct impacts of the announced macro-economic news, 20 per cent results from indirect impacts through order flows, while 40 per cent may be related to order flow unrelated to macro-economic news. Thus the model offers an explanation for about 70 per cent of exchange rate volatility.

These results are confirmed by Love and Payne (2002), who analysed ten months of data on three currency pairs (the dollar/euro, the sterling/euro and the dollar/sterling). Depending on the time horizon and the currency pair, roughly half to two-thirds of the impact of news is incorporated into the exchange rate through the order flow. The direct impact shows up in prices practically without delay, while the indirect impact is also revealed within a few minutes. They also confirm another result from Evans and Lyons, namely the explanatory power of the order flow with respect to the exchange rate increases considerably when macro-economic news is announced. The exchange rate seems to be more sensitive to the order flow in such periods than at other times.

The case study by Carlson and Lo (2003) uses a single event to demonstrate the transmission of new information into the exchange rate through transactions. They analyse a sudden interest rate increase by the Bundesbank on 9 October, 1997, to illustrate the way news appears in the dynamics of trading and then in the exchange rate.

Traditional – portfolio equilibrium – models of exchange rates suggest that such an interest rate rise would increase the demand for financial assets denominated in German marks. As a consequence, a strengthening in the German mark could be expected. According to traditional models, at such times the market makers withdraw their price quotes, the consensus value of the new exchange rate is determined without a single trade being carried out, then finally trading is resumed at the new price.

In contrast, the real-world events that followed the interest rake rise were more in line with the earlier results of the empirical microstructure literature. The first reaction was an extremely large increase in trading volumes, which the authors attributed to the closing of speculative positions. Subsequently, traders having long US dollar positions initiated the dollar sales in large volumes at the best available bid prices, creating a negative dollar order flow. Those traders who were short in dollar waited until their – increasingly favourable – bid prices were hit. As a consequence, the dollar's exchange rate dropped rapidly until it reached the level considered consistent with the new market environment. The entire process took about two hours before the exchange rate stabilised at a new value. The event is a colourful illustration of how individual participants' portfolio shifts can trigger a wave of market orders, and finally generate changes in the exchange rate.

Evans and Lyons (2004a) analyse the impact of news on the transactions of final customers. They differentiate three customer types: (1) 'corporations', which include non-financial institutions, (2) 'investors' comprising unleveraged financial institutions, and (3) 'traders', which are leveraged financial institutions. They find that news changes the trading activity of all three kinds of ultimate customers, and the change is maintained for several days. They also find that the news and the transactions they trigger have a permanent effect on the exchange rate.

While the analyses of market makers' behaviour have concluded that news is built in the order flow within a maximum of one or two hours, ultimate customers' reaction to macro-economic news seems to take longer time. News may be responsible for customer transactions even several days after it has been announced. Evans and Lyons suggest that the delayed reaction may be traced to the fact that the ultimate customers have different exchange rate risk management possibilities than market makers.

They found that it is the categories labelled as 'corporations' and 'investors' that are characterised by slower decision-making. Decision-making bodies responsible for FX exposure management often meet rarely in these types of companies; therefore they cannot react promptly to news. The continuous monitoring of foreign exchange markets would require more research capacity than is available for these firms. Only few of them perform intraday or more frequent portfolio adjustments and exchange rate risk management. Although developments in the fundamentals have a significant role in their trading, a particular piece of news triggers less activity in the customer segment than among market makers. Undoubtedly, firms in the 'trader' category have the most flexible exchange rate strategy. However, even for most of them the active intraday management of foreign exchange exposure is not worthwhile.

The bottom line is that as final customers react to news with significant lags, a few minutes are insufficient for the exchange rate to reflect the full impact of the news. 'Digesting' the news fully requires longer time, often several days.

5.2. WHO INFLUENCE THE EXCHANGE RATES?

One question which may be relevant for central banks is how the behaviour of the different agents in the economy affects the exchange rate. In other words, can we identify market participants who are able to exercise dominant influence on exchange rate movements? We can translate the issue into the language of the microstructure approach by asking the question whether order flows from different market players affect the exchange rate to the same extent, or in a different manner? The issue can be analysed by disaggregating customer order flows.

The first studies of customer order flow already consider the possibility of the various types of customer order flow having different influences on the exchange rate. A logical way to disaggregate the order flow for currencies of small, open economies could be the separate examination of order flows from *foreign* and *domestic customers*. Rime (2001) showed in his study that for the Norwegian krone/German mark exchange rate, the order flow of non-Norwegian customers had slightly different impact on the exchange rate than that of domestic customers. Other studies conducted on other markets, however, have not shown any difference between the effects of domestic and foreign customers' order flow (see, for example, Bjønnes, Rime and Solheim, 2004, for the case of the Swedish kronor).

In most studies, customer order flows are disaggregated according to the customers' activities. It is quite common to differentiate between financial and non-financial (corporate) customers. Using trading data from a large Australian commercial bank, Carpenter and Wang (2003) found that the order flow from financial institutions is positively related to the exchange rate. The impact of non-financial customers' order flow, however, was not significant. Transaction-level data from a medium-sized German bank, examined in a study by Mende and Menkhoff (2003), showed that while the order flow of financial customers is positively related to the exchange rate, the effect of order flow from non-financial corporate customers is negative. Similar results were found by Marsh and O'Rourke (2005) on an extensive database from the Royal Bank of Scotland, one of the most active participants of the global foreign exchange market.

The most extensive discussion of this issue so far was provided by Bjønnes, Rime and Solheim (2004). Their starting point is the empirical observation that market makers usually close their open foreign exchange position at the end of the day, thus they provide only intraday liquidity to the market. The aim of the study by Bjønnes, Rime and Solheim is to identify market participants who provide liquidity to the market on a longer horizon.

On the basis of the Evans-Lyons model, they derive two co-integration equations, which they estimate using a database compiled by the Riksbank covering 10 years of daily foreign exchange transactions of the Swedish banking system.

Their most important findings are the following. The order flow from financial customers is positively related to the exchange rate, while the order flow from non-financial corporations shows a negative correlation. This is similar to the findings of the other studies mentioned above. Through Granger causality tests, they also showed that the order flow of financial corporations plays an active role in price setting, while the role of non-financial ones is passive. Based on all this they concluded that financial corporations are dominant in influencing the exchange rate, while the role of non-financial corporations was to ensure liquidity for the market's operation.

Certain authors further differentiate within financial customers and examine the order flow of *traditional* and *highly leveraged institutions* separately. The first category can include smaller, non-marketmaking banks, insurance companies, pension funds, etc., while the second one usually contains hedge funds and the proprietary trading units of investment banks. Fan and Lyons (2002) found that the order flows of traditional and highly leveraged financial institutions have a very different impact on the exchange rate. They point out that during the LTCM crisis, despite common beliefs, hedge funds provided liquidity to the market, and it was the capital withdrawal by investment funds and other 'traditional' institutional investors that generated the weakening of the yen/dollar exchange rate.

Besides the order flow, there exist some other indicators that provide information regarding the role of the various types of FX market participants. A study by Mende, Menkhoff and Osler (2004), for example, shows that market makers quote smaller bid-ask spreads to financial corporations than to their non-financial customers. They suggest that market makers are able to extract private information from transactions with financial corporations, and thus are willing to trade with them under more favourable conditions. The smaller bid-ask spread could also be interpreted as the price that market makers pay for the information from the financial corporations.[19]

In addition to the nature of their activity, the impact of customers' order flow is also dependent on their market size. Carpenter and Wang (2003) examined separately the order flow from customers with the largest turnover, finding that it has a larger impact on the exchange rate. This suggests that the order flow of well-known customers with large turnovers either carries more information, or that market makers can obtain information more accurately from these trades.

As pointed out by Marsh and O'Rourke (2005), among others, the fact that the order flow of different participants influences the exchange rate in a different manner may help to answer one of the long-disputed questions of microstructure literature, namely whether the order flow affects exchange rates due to the inventory effect or to the information effect. The different impact of different participants indicate the relevance of the information effect, as it would not be logical for the inventory effect to be dependent on the type of customer.

For monetary policy-making, perhaps the most relevant issue in this area is whether and how intervention – i.e. the order flow from the central bank – affects the exchange rate. Some of the above-mentioned studies examine the impact of the central bank's order flow. Due to its pivotal role, we present the findings of the microstructure-based studies on central bank intervention in a separate subsection below.

5.3. THE MICROSTRUCTURE-BASED ANALYSIS OF CENTRAL BANK INTERVENTION

Central bank intervention is an important issue for both the FX microstructure literature and the practice of monetary policy. The microstructure approach is particularly suited for studying the efficiency of central bank interventions. Besides the impact of interventions on the exchange rate, it also helps with analysing the effect of interventions on bid-ask spreads, market liquidity and the activities of market makers, etc. The microstructure framework may also help us to understand the varying efficiency of interventions under different circumstances.

To begin with, we can establish that, in contrast to the mixed findings of 'traditional' analyses on the efficiency of central bank interventions, the majority of microstructure-based research found that interventions may be an efficient tool for influencing exchange rates over the short term, if it is conducted properly (see Payne and Vitale, 2001; Fatum and King,

[19] Different spreads may serve as instruments of market segmentation. The market maker may make use of the fact that the search for the market maker with the best quote is costly for non-financial corporations; thus they are willing to accept a less favourable price. At the same time, however, the logic of the Kyle model would justify higher spreads quoted for financial corporations. If we assume that financial corporations conduct their trading mainly on the basis of private information, then market makers, on average, make losses on transactions conducted with them. If they suspect that their customer is a well-informed participant, they could defend themselves from this with wider quoted spreads.

2005; Scalia, 2004; Dominguez, 2003; Fischer and Zurlinden, 1999). Most studies also characterise how intervention works under different circumstances.

The key question about central bank intervention – or, in terms of microstructure, the order flow from the central bank – is whether it has an impact on exchange rates, and if so, to what extent. Some of the studies analysing the order flows from different customers treat central bank order flow separately. Rime (2001), Carpenter and Wang (2003) and Bjønnes, Rime and Solheim (2004) all suggest that of all customer types it is the central bank whose trading activity has the greatest impact on the exchange rate.

The above studies examine the issue in general terms and do not differentiate between the different types of central bank interventions. Before examining the effect of different types of interventions empirically, it is worth looking at what theoretical models of market microstructure can tell us about the efficiency of interventions.

Traditional research concerning central banks' role on the foreign exchange markets differentiates between two possible channels through which (sterilised) interventions can influence exchange rates. Firstly, central bank can use interventions to indicate future changes of fundamentals – e.g. the level of interest rates and inflation – through the *expectations channel*. The operation of this mechanism is based on the perceived information asymmetry between the central bank and market participants. Intervention is a mechanism to alleviate this information asymmetry. Secondly, if assets denominated in different currencies are not perfect substitutes, the central bank can influence the exchange rate by intervention through the *portfolio balance channel*. In his literature survey, Kiss M. (2005) found that, according to the consensus of the day, the exchange rate is predominantly influenced by the expectations channel, while the impact of the portfolio balance channel is marginal.

We can distinguish secret and open interventions. Secret interventions are not good at sending signals to the market. They exclude the expectations channel. Therefore, on the basis of the traditional theory, it is difficult to justify their use, as opposed to open interventions.[20] The assertions of traditional research into intervention efficiency are somewhat in contrast with both central banks' practice and the opinions of market participants and central bankers, who usually claim that secret interventions are efficient.

The application of the microstructure approach can resolve this contradiction. It can be used to show that secret interventions – due to the existence of informational asymmetry, the adjustment of market makers' open positions and the effects of the order flow – may also be efficient.

In more recent studies, the *microstructure channel* has been gaining more ground as a third possible channel through which intervention may influence the exchange rates. This channel is also assumed to work through asymmetric information, but here the asymmetry is between the information available to the various market participants, which the central bank may use to influence the market. The information flow takes place more gradually and in a dispersed manner relative to the expectations channel.

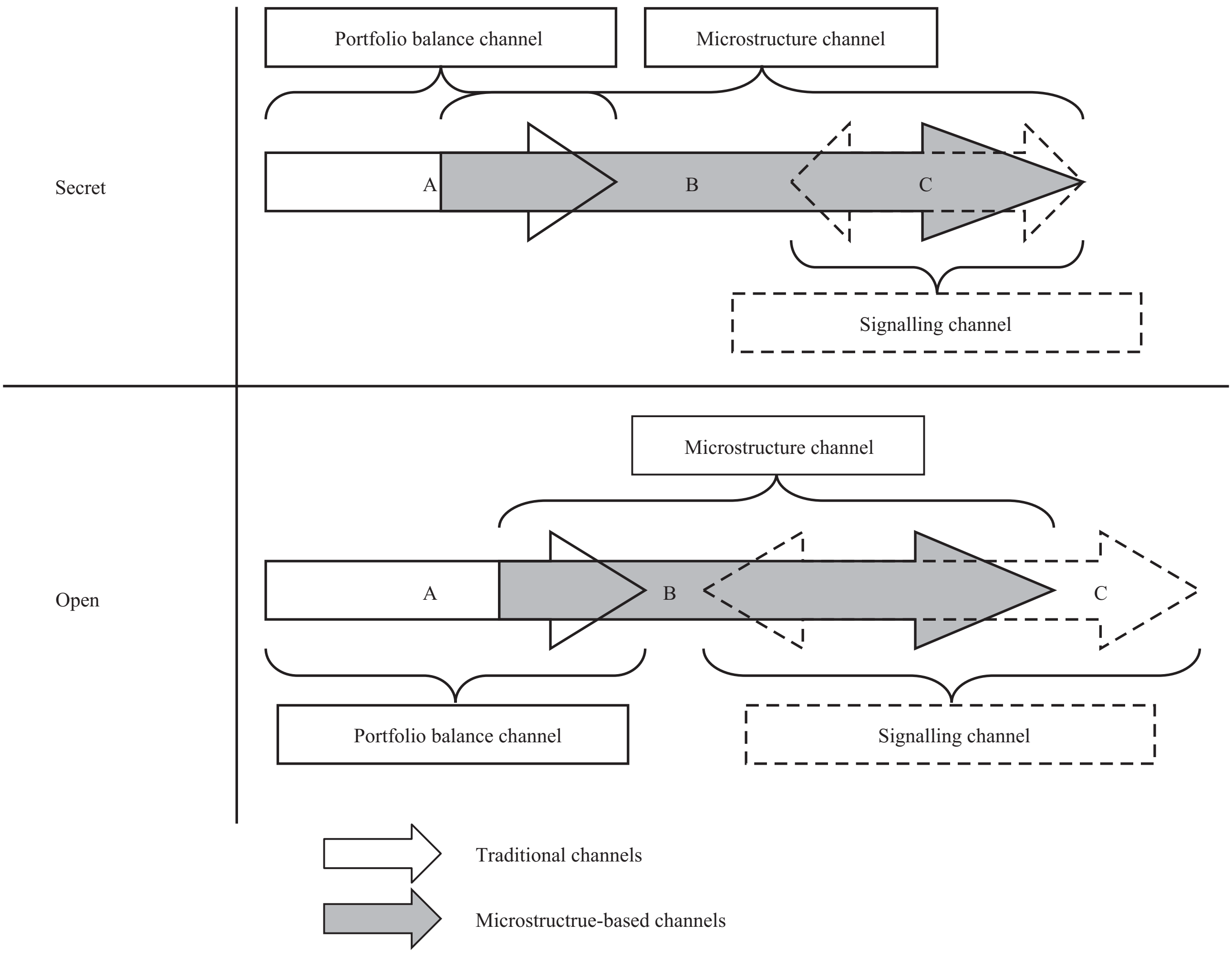
The operation of the microstructure channel is not entirely independent of the other two possible channels of the intervention, and is partly based on them. If market participants deduce information from the central bank order flows on future fundamentals or portfolio shifts, the microstructure effects can reinforce the operation of channels identified by traditional approaches.

If the central bank intervenes secretly, and does not reveal itself, market makers cannot differentiate the order flow from the central bank from the orders coming from other participants, whether they are informed or not. In this case – in addition to the fact that the portfolio shift may also influence the exchange rate (Chart 5, Area 'A') – the order flow generated from the intervention itself also has an impact on the exchange rate (Chart 5, Area 'B'). This impact would be the same as for transactions by any other participant. It is just a part of the order flow observed by market makers.

[20] Views on this issue are divided. Certain central banks claim that they apply secret intervention in order to reach maximum impact on the exchange rate, while others do the same to minimise the influence (Neely, 2001).

Chart 5

The impact of central bank interventions in a microstructure framework



If the central bank reveals itself to its trading partners (and only them), then the order flow resulting from the intervention represents additional information to those market makers who take part in the transactions. Due to the special role of the central bank, this piece of information has a different impact on market makers' quotes than the regular customers' order flow. The market makers involved in the deal can use this additional information when making trading decisions, unlike the others who do not know about the intervention. A market maker who learns that he is trading with the central bank gets a private signal on the expected stance of monetary policy. If the signal is credible, it may influence his behaviour. This means that the effect of intervention may be reinforced by an influence on expectations.

In the case of an open intervention the mechanism is slightly different. The announcement of the intervention may have an effect on the exchange rate in itself. Furthermore, the announcement influences the expectations of all market participants, not only those of the given market makers.

If the intervention signal is not consistent with the fundamentals, does not transmit clearly the intended message, or is just not well understood by the market, there is a risk that it has an opposite effect to that intended. In such cases, openness can decrease the efficiency of the intervention (Chart 5, Area 'C').[21] Openness thus introduces a volatility into the effect of the intervention signal. Depending on the credibility of the signal, it may either strengthen or weaken the other channels, making the combined effect uncertain. The central bank must also take into account the risk to its reputation

[21] Even in the case of a secret intervention, the information transmitted to the partners may have unintended effects. However, the probability and the size of the expected 'damage' is significantly lower.

when deciding on the method and the transparency of the intervention, i.e. whether it is willing to take a greater reputational risk in order to achieve a greater impact on the exchange rate.[22]

To summarise, order flow from the central bank carries information in itself and can lead to a portfolio shift. If the market interprets the central bank's intervention as new information about the fundamentals, the announcement of the central bank's intervention will lead to an additional change in the traders' expectations, which will result in further changes in the exchange rate.

Therefore, one of the reasons behind the impact of central bank interventions may be the fact that the market considers the central bank a 'well-informed' participant, whose transactions carry important information regarding the future value of the currency. It follows that the intervention's impact is dependent on the market participants' awareness of the central bank's market presence. This assertion is confirmed by Scalia (2004), who, having examined the activities of the Czech central bank, found that the market effect of the intervention is greater if the market senses the presence of the central bank behind the transactions with a high enough probability.

According to studies of the inter-dealer order flow following central bank interventions, the impact is largely dependent on the extent of the inter-dealer order flow generated by the intervention. This suggests that inter-dealer order flow is a necessary part of the price-formation process (Chari, 2002, D'Souza, 2001). The inter-dealer order flow following the intervention is significantly influenced by the changes in the distribution of expectations. A number of studies state that the volatility of the exchange rate is directly related to how traders interpret intervention signals, and how the central bank can modify the heterogeneous expectations of the market participants (Chari, 2002; Dominguez, 2003; Payne and Vitale, 2001; Scalia, 2004; Baillie, Humpage and Ostenberg, 2000). The deals that ensure the efficiency of the intervention are done by those FX dealers who think that the information content of the central bank's operations is greater than that of the transactions by other customers.

Differences in market makers' expectations stem from two factors: (1) market makers have different opinions – and private information – about the actual and the expected macro-economic picture; (2) this difference can be accentuated by the different interpretations of the signals sent by the central bank (Chari, 2002, Dominguez, 2003). Due to these two factors, market uncertainty may temporarily or permanently increase as a result of the intervention.

A number of studies found that central bank interventions may – albeit temporarily – increase market uncertainty[23] and thus the short and long-term effects of the intervention may differ. Research by Dominguez (1999, 2003) on interventions by G3 countries between 1987 and 1995 confirms these findings. Intervention operations – mainly if they were coordinated – resulted in an increase of intraday and daily volatility, while they did not influence long-term volatility. The effect of the intervention could be detected already one hour before the announcement, and certain traders knew about the intervention before the publication of the news by Reuters.[24]

The results were not dependent on the amounts – small and large-scale interventions had similar effects. In contrast, the interventions had larger effects when performed at the same time as macro-economic data announcements. This could be attributed to the fact that when important news is published, market participants react to any information more sensitively, including interventions. The impact of intervention is also larger during heavy trading hours. Central bank transactions seem to carry more information at these times.[25]

[22] The most active large central bank in terms of intervention, the Bank of Japan, shifted its emphasis towards secret interventions recently. This trend may be interpreted as the Japanese central bank trying to influence the exchange rate by using the microstructure effects of the intervention as opposed to the expectation channel (Beine and Lecourt, 2004).

[23] The growth of market uncertainty can be detected through sharp increases of (historical) volatility, the widening of spreads (Chari, 2002), the increase of implied volatility derived from option prices (Galati and Melick, 2002), or the variability of questionnaire-based surveys (Beine, Quere, Dauchy and MacDonald, 2003).

[24] In other words, the Reuters news items on interventions were published about an hour after the interventions.

[25] Easley and O'Hara (1992) attempt to explain why transactions could be more informative when trading is intensive. They assume a given information structure, in which new information that is observable to the traders emerges with a probability p. The probability of no new information is thus $1-p$. If at a certain point in time trading activity is low, then rational market makers increase the subjective probability of the state of no new information. Traders will consider it less probable that an incoming order will be informative. As a result, new trades will not generate large adjustments in the expectations. When trading is intensive, the appearance of new information on the market is more probable. This results in more frequent and larger-scale re-evaluations of the market makers' expectations.

According to Dominguez, the long-term behaviour of the exchange rate is dependent on fundamentals, and trading on the market can be either information-based or non-information-based. Depending on the market's ability to differentiate between noise and information, non-fundamental trading can also have an effect in the short run. By providing additional information through intervention, central banks may help participants in differentiating between the two types of transactions. If the intervention contains real information, the market 'learns' from its announcement, and after some time only information-based transactions will have an effect on the exchange rate. As a result, uncertainty will decrease after a temporary increase. In the opposite case, interventions may only increase trading noise and may contribute to a permanent increase in volatility.

Based on intraday exchange rate data between 1986 and 1995, Payne and Vitale (2001) showed that the intervention of the Swiss central bank had a significant effect on the level and the volatility of the exchange rate. On the other hand, the central bank's FX transactions that were conducted without the explicit aim of influencing the exchange rate had negligible effect. They also found that the effect was stronger and more permanent if (1) the intervention was coordinated and carried out with the U. S. Federal Reserve or the Bundesbank, and (2) the aim was to reinforce, and not to counteract, the underlying trend in the exchange rate. To a certain extent, the market could predict interventions – the exchange rate had often started to move in the desired direction already minutes before the intervention. Interventions had an impact on volatility, and market liquidity as well. The findings confirm that during the intervention market uncertainty increases, which can be measured by larger volatility and wider spreads. However, once the information transmitted by the intervention has extended throughout the market, the uncertainty decreases.

Fatum and King (2005) examined the intervention activities of the Canadian central bank between 1995 and 1998. This period included two different regimes of intervention.[26] Results suggest that the interventions had a strong impact on the intraday exchange rate. Surprisingly, however, the findings show that the impact was independent of the regime. The Canadian dollar reacted to the frequent and predictable rule-based interventions in a very similar manner as to the discretionary ones. This supports the view that the immediate impact of the intervention happens mainly through the microstructure channel, as opposed to the expectations channel, and that the order flow and the portfolio shifts by market participants play a decisive role. It should be noted, however, that these results are valid for short-term exchange rate developments and may not be necessarily true on the longer run.

In microstructure-based studies of central bank interventions, the use of Reuters news announcements as a tool to detect interventions is widely accepted. However, it is questionable whether such news, often drawn from unofficial sources, is able to capture the fact, the timing and the amount of intervention with adequate accuracy. The analyses generally assume that the time of publication of Reuters news items is close to the time of interventions. In contrast to this – based on the actual intervention data from the Swiss central bank – Fisher (2004a) found that published news items do not grasp well the time, the size and intensity of interventions. Although we should not draw general conclusions using data from a single country (and the communication of interventions by central banks often varies), the bias resulting from possible data inaccuracies must not be ignored when interpreting the results.

To recapitulate, the followings are the most important findings of the microstructure-based analysis of central bank interventions:

- Due to microstructure effects, central banks' order flows, in themselves, have an impact on the exchange rate, similarly to the transactions by any other market participant. In addition, the microstructure channel may reinforce the operation of both the portfolio balance channel and the expectations channel.

- The market's reaction to the intervention is largely dependent on the heterogeneity of market participants' expectations and on how well intervention is able to shape these expectations.

- If foreign exchange market traders consider interventions as transactions with a high information content, the impact of an intervention may be increased by revealing it to the market.

[26] The former, rule-based regime, where interventions were frequent and easily predictable was replaced by a more flexible system in April 1995, in which discretionary decision-making gained importance.

- Open interventions can help the central bank to achieve a larger impact on the exchange rate, but they also increase the risk of failure and loss of reputation.

- The presence of the central bank on the foreign exchange market may increase market uncertainty. However, in the case of informative and credible interventions, volatility usually decreases after a temporary increase, once the information is 'digested'.

- The impact of the intervention may be stronger and more permanent if it is conducted (1) at a time of macro-economic data announcements, (2) during periods of heavy trading, (3) in coordination with another central bank, or (4) to reinforce the current trend of the exchange rate.

5.4. MARKET MICROSTRUCTURE AND INTERNATIONAL CAPITAL FLOWS

As discussed in detail earlier, one of the motivations behind the microstructure-based modelling of the exchange rate was that economic models based solely on macro-economic fundamentals were not successful in an empirical sense. The initial studies of the microstructure-based modelling, however, left open the question of how fundamentals influence the exchange rate over the long run.

The attempts to combine the macro-economic and microstructure approaches led to two competing theories. Works by Lyons and Evans (2002a, 2002b, 2003) emphasise that order flow plays a pivotal role in the interpretation and the processing of the dispersed information on the future value of the fundamentals. Order flow can, therefore, be used to forecast both the exchange rates and the fundamentals as well. Froot and Ramadorai (2002), however, consider the order flow as a carrier of information independent of fundamentals, which is related only to short-term liquidity shocks.

There is another segment of the literature that also aims at revealing the links between order flow and fundamentals. This literature relies heavily on the portfolio balance approach to exchange rates. In the portfolio balance models, individual investors may allocate their assets in domestic and foreign instruments. Assets denominated in the foreign and the domestic currency are not perfect substitutes, and thus shocks can result in portfolio shifts, generating exchange rate adjustments.

This segment of the microstructure literature examines the relationships between international capital flows, asset returns, currency order flows and exchange rates. In most cases, the literature examines the links between FX and equity markets, but ignores the other elements of the international portfolio diversification, such as fixed income markets, or FDI.

Why do most studies restrict the examination of net foreign assets and international capital flows to the study of equities? One of the reasons for this is that in the case of equities we find turnover, order flow and price data of sufficiently large frequency, whereas on the other markets such data are usually not available. Another reason is described by Siourounis (2003). He also examined the fixed income markets in his study and found that portfolio shifts on bond markets do not carry important information regarding exchange rate developments. Accordingly, he concluded that, in contrast to investments in equity, for fixed income investments the foreign investors hedge the exchange rate risks. Therefore, fixed income order flows do not necessarily generate currency order flows.

An article by Francis, Hasan and Hunter (2003) examines the links between the currency returns and returns on the equity markets corresponding to those currencies. They found that the two markets have strong influences on each other. Innovations in certain segments – primarily in the exchange rate – quickly disperse to the other markets as well. The close relationship between the exchange rate and equity returns is true for both the expected returns and their volatility.

Besides the links between markets and the dissemination of information, the authors also examined the impact of order flow. When completing their model with unexpected – or unpredictable – order flows, they found that the impact of certain variables on each other decreased significantly. At the same time, however, the information carried by the order flow explained a significant part of the dynamics, in accordance with the portfolio balance approach to exchange rates.

The model by Hau and Rey (2004) differentiates among three types of shocks – asset price shocks, shock to the order flows (liquidity shocks), and direct shocks to the exchange rates. Their hypothesis is that in a dynamic model, these shocks behave according to the portfolio balance approach. Changes in the relative returns of foreign and domestic portfolio elements are the main drivers in portfolio balance models, as global investors repatriate the excess returns on their foreign investments. Hau and Rey tested the behaviour of the three shock components for a number of currency pairs in a VAR framework. Their findings confirmed that the dynamics corresponds to the portfolio balance approach. An unexpected but permanent increase in the relative returns on foreign assets is generally accompanied by the sale of foreign instruments and a consequent strengthening of the exchange rate from a domestic point of view. A similar accommodation takes place in the case of shocks affecting the order flow of the assets.

The authors found that, having taken into account the above mechanisms, about 10-20 per cent of the variance in the exchange rate can be attributed to shocks to the stock returns and equity portfolio reallocations.

5.5. MICROSTRUCTURE IMPACTS IN TRADITIONAL MACRO MODELS

One of the latest and most promising directions of FX microstructure related research involves the incorporation of the findings of the microstructure approach into traditional macro models. The theoretical models of FX market microstructure – e.g. the Evans-Lyons model – do not link the foreign exchange market to other segments of the economy. Shocks affecting the fundamentals and the order flow are considered to be exogenous from the point of view of the model. The traditional macro models, however, cannot reproduce a number of empirical observations regarding exchange rate developments.

The combination of the two approaches enables the creation of macro models with more realistic exchange rate dynamics. At the same time they are also able to perform tasks usually done by general macro models as well, e.g. policy simulations, forecasting, welfare analysis, etc. For the time being, there have been only a few studies published on this topic. From this point of view, the work by Bacchetta and Wincoop (2004) can be considered as groundbreaking. Their starting point is a two-country, general equilibrium model of the exchange rate, which is based on the building blocks of the monetary approach of the exchange rate, i.e. money market equilibrium, purchasing power parity, and uncovered interest rate parity. At the same time, however, they reject the homogeneity of economic agents, and assume that the investors present in the economy have different items of information at their disposal. With this condition, the model can describe the links between the order flow and the exchange rate, arising from the microstructure.

The model has not been tested on empirical data, but it was successful in reproducing a number of stylised facts on the exchange rates, the fundamentals and the order flow. In the model there is no strong co-movement between the fundamentals and short-term and medium-term exchange rate developments. However, in the long run it is the fundamentals that determine the value of the exchange rate. All this coincides with the facts derived from actual data. Similarly, the exchange rate predicts the future developments of fundamentals only to a small extent, and the exchange rate and the order flow move closely together.

The study by Evans and Lyons (2004b) also attempts to formulate a hybrid model containing microstructure elements. Their dynamic model departs from the framework of traditional macro models – the risk-averse agents in the model have heterogeneous information, the market is not complete and the participants learn over time. Similarly to the model by Bacchetta and Wincoop, it can also explain a number of stylised facts and puzzles. These include the fact that the FX volatility is much higher relative to that of the fundamentals, and that the order flow can explain exchange rate fluctuations better than the fundamentals. Some relationships derived from a simplified variation of the model have been tested on actual data (Evans and Lyons, 2004c).

As yet, it is difficult to judge whether the combination of the microstructure-based approach and general equilibrium modelling will provide usable exchange rate models, yielding relevant answers for policy applications. The complicated structure of the models, which is difficult to handle from an analytical point of view, and the joint use of micro-level and macro-economic data will most certainly present constraints for empirical applications. Nevertheless, this direction of research carries the possibility, through the potentially successful application of these hybrid models, of fundamentally changing our views in many respects on the links between the macro-economy and exchange rates.

6. Conclusions

Our study has presented an overview of the microstructure-based approach to exchange rates. This non-comprehensive survey has provided an insight into the roots and origins of the microstructure approach, to its theoretical background, to the most important empirical findings and to those applications that are most relevant for monetary policy. At the end of our study we would like to summarise those aspects of the literature that we consider the most important.

The market microstructure theory describes the way in which exchange rates behave when we depart from the assumptions of a perfect market and assume that market participants possess heterogeneous information, or that at least they interpret the same information in different ways. In such a set-up, items of private information reveal themselves in the course of trading. Order flow, calculated as the balance of bid and ask orders, may help market participants to infer the information scattered among other traders and to optimise their price quotes using this knowledge. Order flow, therefore, has an impact on prices.

This result of the microstructure theory is confirmed by the data from real-world foreign exchange markets. Both inter-dealer order flow, and the order flow from customers, have strong explanatory power regarding exchange rate dynamics. The empirical success is emphasised by the fact that other, traditional macro-based exchange rate models can only explain exchange rate developments in practice to a negligible extent, except on very long time horizons. Furthermore, the impact of the order flow on the exchange rate is not temporary. As a result, despite the use of high frequency data, the microstructure approach not only explains intraday exchange rate movements, but the impact of the order flow is also relevant on the longer time horizons used in macro-economic analyses.

One of the uses of the microstructure approach – perhaps the most relevant from the point of view of central banks – is the study of the efficiency of central bank interventions. In contrast to the mixed results of the traditional literature on intervention efficiency, most microstructure-based research has found that intervention may be an efficient tool for influencing the exchange rate over the short term, if applied appropriately by the central bank. The research also characterises the circumstances under which interventions have a stronger impact on the exchange rate. Open and coordinated interventions which are in line with the fundamentals are usually more successful. At the same time, interventions – especially if they contrast with the fundamentals expected by the market – may increase uncertainty on foreign exchange markets.

In addition to issues of central bank interventions, the microstructure toolkit can be used to answer a number of other questions of practical importance. These include the study of the transmission of macro-economic news announcements to exchange rates, the role of the various FX market participants in exchange rate determination, or the links between international capital flows and exchange rate developments.

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September, 2005

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