

Norbert Kiss M.–Klára Pintér: How do macroeconomic announcements and FX market transactions affect exchange rates?

In this paper we analyse the relation between the EUR/HUF exchange rate, economic fundamentals and FX market transactions. Our results are in line with international experiences: the effect of macroeconomic announcements is transmitted to the exchange rate partly directly, with an immediate change in the exchange rate, and partly indirectly, via the information revealed through the FX market transactions, triggered by the news. We found that macroeconomic news, as well as the buying/selling pressure originating from one-way transactions both affect the level of the exchange rate and volatility. Our results also show that around pre-scheduled data releases the one-way transactions move the exchange rate more than under normal circumstances. Furthermore we broadened the commonly used set of macroeconomic news, such as data on GDP, inflation etc., to include the communications of central bankers. The model including central bank communication can explain a considerable part of exchange rate changes.

INTRODUCTION

Several times during the last few years extreme events took place on the Hungarian FX market and focused attention on the EUR/HUF exchange rate. Extreme exchange rate movements made the importance of the exchange rate and its role in everyday life clear for the wider public too, as a result of which the exchange rate and the factors affecting it attract increased attention.

This paper describes the relationship between macroeconomic announcements, order flow¹ and the exchange rate on the EUR/HUF market. Over the last decade, there has been a generally observed tendency that central banks are moving towards greater transparency. As a result of these efforts to enhance transparency, central bank communication has become increasingly important and a new area of literature assessing and analysing central bank communication has emerged in recent years. Similarly, there has been a growing body of literature on the microstructure theory of currency exchange rates and special related areas. This paper is novel in that it represents the first attempt at a microstructure-based analysis of the effects of central bank communication and macroeconomic news in the Hungarian market.²

The relationship between news and the exchange rate, and a better understanding of the driving forces behind the currency markets are interesting for a broad audience.

Practically everyone who follows the formation of the EUR/HUF exchange rates in some form is concerned with them. First of all, this group includes market participants directly involved in the operation of the currency FX (market makers, dealers, brokers, bank treasuries, mid-offices, risk management employees) whose daily work, profitability and efficiency are related to trading. Apart from them, corporates and most households are also affected by exchange rate fluctuations, even if they are less sensitive to it. The topic may also be of interest to foreign central banks, international financial institutions, academics and the Hungarian economic media, university lecturers and students.

The purpose of this study is to identify the mechanisms, through which recently published macroeconomic information on the future monetary policy stance or economic fundamentals influences the exchange rate and the trading process on the FX market. Our analysis shows that new information is only partly reflected in the prices directly and immediately, i.e. its effect is only partly shown by the change in the quotes of market makers without entering into any deals following the announcement. Macroeconomic news or MNB communications influence the trading and deals between FX market participants, may trigger a buying or selling wave, and therefore have an indirect effect on prices as well through the trading processes or, more precisely, changes in the order flow.

¹ The order flow is a key variable in the microstructure literature: it is a buying or selling pressure on a particular currency, the difference between the purchase and sales transactions during a particular period. According to the microstructure theory, the market processes the new information through the order flow and the order flow has a major role in the development of the exchange rate. For more details of the microstructure approach of currency exchange rates, see Gereben, Gyomai and Kiss M. (2005)

² The analysis presented in this article is based on the paper by Frömmel, Kiss M. and Pintér (2007), containing a more in depth analysis of the issues discussed here.

Our empirical analysis aims at identifying the impact of the disclosure of new information (in the form of central bank communication or macroeconomic news) on the quoted prices, orders and activity of the market makers and, indirectly, on the exchange rate, factors shaping the order flow, and whether or not the order flow has any information content in its own right or if it only transmits information about fundamentals.

NEWS, ORDER FLOW AND THE EXCHANGE RATE

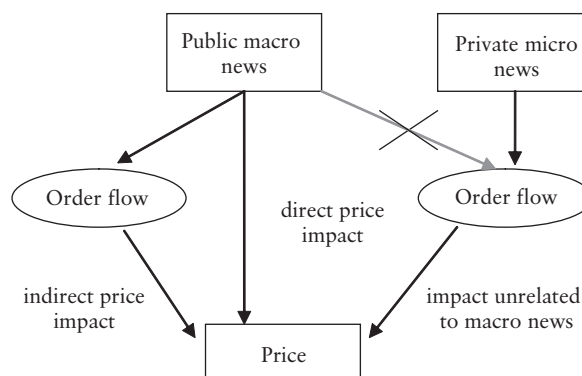
Prices on the foreign exchange market are based on dealers' quotes. The main difference between the microstructure approach and traditional asset price models is that trading is considered as a substantial part rather than an auxiliary activity to price formation and therefore deserves particular attention. As dealers may revise their quotes based on news as well as on the quotes they receive from other dealers, the microstructure approach distinguishes three different relations between news, order flow and the exchange rate (Evans and Lyons, 2006). The relation between the various sources of the exchange rate variation are illustrated in Figure 1.

- (1) The information content of announcements, which is publicly available and evaluated in a similar manner by at least most of the traders (the '*common-knowledge*' part of macro news), directly and immediately affects prices, with no role for the trading process in the price formation.
- (2) There may be news which is not unambiguous and difficult to interpret or not publicly available. Accordingly, there can be a non-public information component of news – the so-called '*non-common knowledge*' part – in which case private information is dispersed and transmitted to prices via the trading process, more precisely via the order flow. This is called the indirect effect of the news, conveyed by the FX market transactions triggered by the news.
- (3) There are some FX market transactions which are unrelated to macroeconomic announcements, but reflect information related to other exogenous factors (changing hedging or liquidity demands, or changing risk tolerances). This type of order flow is independent of the macroeconomic news, but may have an impact on the exchange rate.

Earlier work by the Magyar Nemzeti Bank (MNB, the central bank of Hungary), has shown the relevance of determinants of exchange rate movements from the field of

Figure 1

Determinants of exchange rate movements



traditional macroeconomics, as well as from the field of microstructure (see, e.g., Kiss M., 2004; Pintér and Wenhardt, 2004; Gereben, Gyomai and Kiss M., 2006). This analysis can be regarded as a proceeding of this research, as it combines these fields of research to some extent and attempts to reveal the joint dynamics of news, order flows and price movements.

DATA USED IN THE ANALYSIS³

FX market making banks can trade with each other in two ways: directly (on a bilateral basis), and indirectly (through brokers). Our database contains the trading data of the transactions for two years – 2003 and 2004 – conducted in an electronic brokerage system. The data originate from the Reuters D2000-2 system. We had access to all limit price and market price orders posted in the system, as well as all the actually executed trades, with the related information on quantities and prices.

Taking into account that this is the most important platform of inter-dealer trading, our database can be considered as representative of the entire market. As the time-stamp variables are accurate to the second decimal of the second, it is possible to conduct high-frequency analyses; in our study we have chosen to analyse exchange rate changes observed every 1 and 10 minutes.

One of the most important variables is the so-called order flow, which plays a key role in the microstructure literature. As we knew the size of the concluded deals, we could calculate the order flow, indicating the buying (order flow with a positive sign) or selling (order flow with a negative sign) pressure on a particular currency as the balance of the net *value* of the FX market transactions initiated by the

³ The detailed description of the used data is contained in the study on which the article is based (Frömmel, Kiss M. and Pintér, 2007). Gereben, Gyomai and Kiss M. (2006) also describe in more detail the channels of FX market trading and the used exchange rate database.

buyers and the sellers.⁴ During the calculation of the order flow, it is of key importance to identify the initiating and passive parties. Our database contains an entry type for each transaction too, which can be regarded as a buy/sell indicator and allows for identification of the initiating party without having to rely on assumptions about it.

Apart from the order flow, exchange rate changes are explained by certain macroeconomic news and monetary policy decisions. In addition to the interest rate decisions of the central bank, our database also contains announcements on the consumer price index, GDP growth, the budget balance and the current account deficit. We assume that market participants are rational, and therefore their expectations about the pre-scheduled announcements are reflected in the prices before the actual announcement is made. Consequently, in respect of macroeconomic news and interest rate decisions, only their deviation from preliminary expectations, their surprise component affects the exchange rate following publication.

However, for the various types of announcements the actual figures can differ from the expectations to various extents, therefore we rescaled ('standardised') the surprise components to be measured in comparable terms, i.e. in the case of each announcement type we compared the surprise at a given time to the "usual", average surprise in the given variable.⁵ It is a common characteristic of these announcements and news that the exact time of their publication is known in advance and they reach all participants simultaneously. Therefore, in their case, the time of the announcement indicates the time precisely when the direct effect of the news can be first reflected in the exchange rate. Consequently, we were able to perform our analysis on 1-minute data in the case of this category.

The other group of the news we analysed consists of central bank communication related to the macro economy, inflation outlook and monetary conditions. An important characteristic of such news is that it is not announced at a pre-specified time and does not reach market participants directly, but is transmitted via news agencies (Reuters, Bloomberg). On the one hand, the individual pieces of news

are not necessarily published everywhere at the same time, and there can be some minor time delay in the disclosure of the reports, on the other hand, the news is regularly updated and new details are added in a few minutes' time. Therefore, it is very difficult to clearly identify the time when their impact should be reflected in the exchange rate, therefore we used 10-minute data in our analysis focusing on the effect of communication.

Our database contained statements of Monetary Council members related to the economic outlook, the future path of the central bank interest rate and the exchange rate, as reported by Reuters, and any news items which were published several times were only used for the analysis once, when it was released first. There are no expectations about central bank communication; therefore, in this case, we registered the statement as news, but were unable to measure its surprise content.

We also distinguished 'positive' and 'negative' news in terms of both communication and macro news depending on whether we expect the news to imply appreciation or depreciation of the exchange rate based on the contents of the statement or the direction of its departure from expectations. In this way, we can analyse whether the phenomenon often described in literature, namely that market participants react to 'positive' and 'negative' news in an asymmetric way, can also be observed on the EUR/HUF market.

We must stress that the classification of news as "positive" or "negative" refers to the expected direction of the exchange rate change instead of the 'quality' of the news. The same piece of news could be favourable and unfavourable under different economic conditions, and the various theoretical models also vary according to the direction of the exchange rate movement they consider justified based on surprises in different directions. Where the assignment was not clear, we used an event-study analysis for the classification. Based on our experiences, strengthening of the exchange rate can be assumed when inflation is lower, growth is higher, the deficit is lower than expected, or the monetary policy decision is stricter than expected.⁶

⁴ Consequently, the order flow is a variable with a prefix, and is not identical with the traded volume or the FX market demand. Gereben, Gyomai and Kiss M. (2006) describe in detail the role of the order flow in the microstructure models and its relationship with other indicators of market trading.

⁵ Apart from the fact that a standardised surprise is based on the difference between the expectations and actual data in percentage, it also takes into account the average surprise related to a particular type of data. Its importance can be intuitively explained as for data where market participants generally can guess the actual data very accurately, a given percentual difference means a bigger surprise than in the case of those data where they usually make big forecast errors.

⁶ The typical response to an inflation surprise (favourable inflation rate – stronger exchange rate, unfavourable figure – weaker exchange rate) is not absolutely intuitive in an inflation targeting regime. The result stems from the fact that most probably there was not a close relationship between the actual inflation figure and the next expected interest rate decision because of the special features of the inflation processes of the analysed period (several peaks and valleys), the central bank communication at that time and the monetary policy decision mechanism for the most part of the period (until the middle of 2004, interest rate decisions were made not only monthly, but even every two weeks, even before the release of the inflation figures). This and the other results, however, are consistent with the portfolio balance theory suggesting that the demand for HUF denominated assets increases as a result of any favourable news about the economy, such as, e.g., low inflation.

EMPIRICAL RESULTS

Our empirical analysis can be divided into two parts based on the applied methodology, the frequency of the time series used and the variables involved in the analysis. On the one hand, we have analysed the impact on the EUR/HUF market of five relevant Hungarian macroeconomic announcements at 1-minute intervals using an event-study methodology, focusing on an event window containing the announcement. In the second part of the analysis, we have included the central bank communication variables as well and analysed the effect of news on the exchange rate at 10-minute intervals using standard regression analysis.

Immediate effect of macroeconomic news and the order flow

In the first step, we analysed the impact on the exchange rate and the order flow of the surprise content of the five macroeconomic announcement types involved in the analysis, i.e. inflation, GDP growth rate, the current account deficit, the budget deficit, the interest rate decision of the central bank (Annex, equations 1 and 2). We could generally conclude from the results that most of the news has a statistically measurable (significant) immediate impact on exchange rate changes as well as the dominant direction of trading, which is reflected in the order flow.

In the majority of cases, the surprise can clearly be felt during the minutes that follow the announcement and the news drives the exchange rate and the dominant direction of the transactions according to its 'positive' or 'negative' nature. The only exception was GDP announcements, in which case the news did not have any impact on the exchange rate or the order flow that could be detected over a short time. On the other hand, the impact of an inflationary surprise is highly significant and concentrated. An inflation rate, which is 1 per cent higher than expected, generates – on average – almost half a per cent depreciation and net HUF sales-EUR purchases equivalent to EUR 17.2 million within a few minutes. It is interesting to note that even the 2 and 3-minute delays are significant, yet they work in the contrary direction indicating that there is an overreaction in the first minute, followed by some partial correction in the next few minutes.

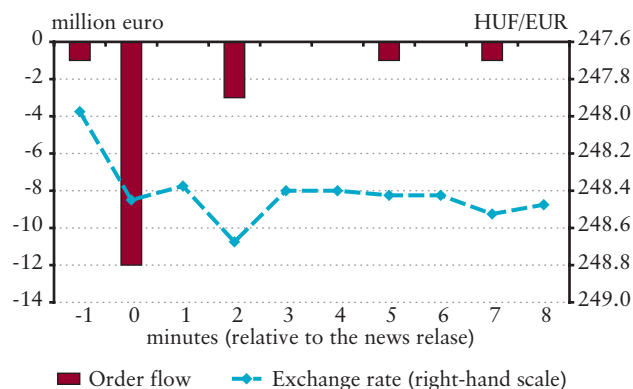
The results are also favourable for the budget deficit: any data which are more favourable than the expectations results in immediate appreciation and net HUF purchases. The correlation is not so strong, but it can still be detected within a few minutes after the announcement, without any statistically significant correlations before or after.

Regarding the current account figures, the results indicate slower transmission of any new information. No correlation can be detected one minute after the announcement, but then the information has a continuous impact on the exchange rate and order flow for several minutes. The delayed reaction may be caused by the relatively early announcement of the figure at 8.30 a.m., because at that time the trading activity is significantly lower than during the day.

Our results prove that any interest decisions of the central bank which differ from the expectations have a statistically significant impact on the exchange rate and the dominant direction of the transactions following the decision. A stricter-than-expected decision, i.e. a higher rate increase or smaller rate cut, typically results in immediate appreciation of the HUF, and generates net HUF purchases. This impact prevails not only immediately after the decision, but also during the subsequent minutes, i.e. the decisions of the Monetary Council have both a concurrent and delayed impact on the order flow. Figure 2 illustrates the results with one specific example. On 16 August 2004, the interest rate was cut by 50 basis points, and the size of the interest rate cut exceeded the expectations of market participants. This negative surprise was accompanied by HUF depreciation and net HUF sales.

Figure 2

Impact of interest rate decisions on the exchange rate and order flow – example: 16 August 2004



Rescaling the surprise content of the various news types expressed in different measurements to comparable units (standardising the news variables), we can compare the relative impact of the various news on the FX market (Figure 3). As it could be expected, the interest rate decisions and inflation data had the strongest impact on the FX market, i.e. their surprise value caused the biggest change in the exchange rate and triggered the largest number of transactions in the same direction. In terms of its impact on

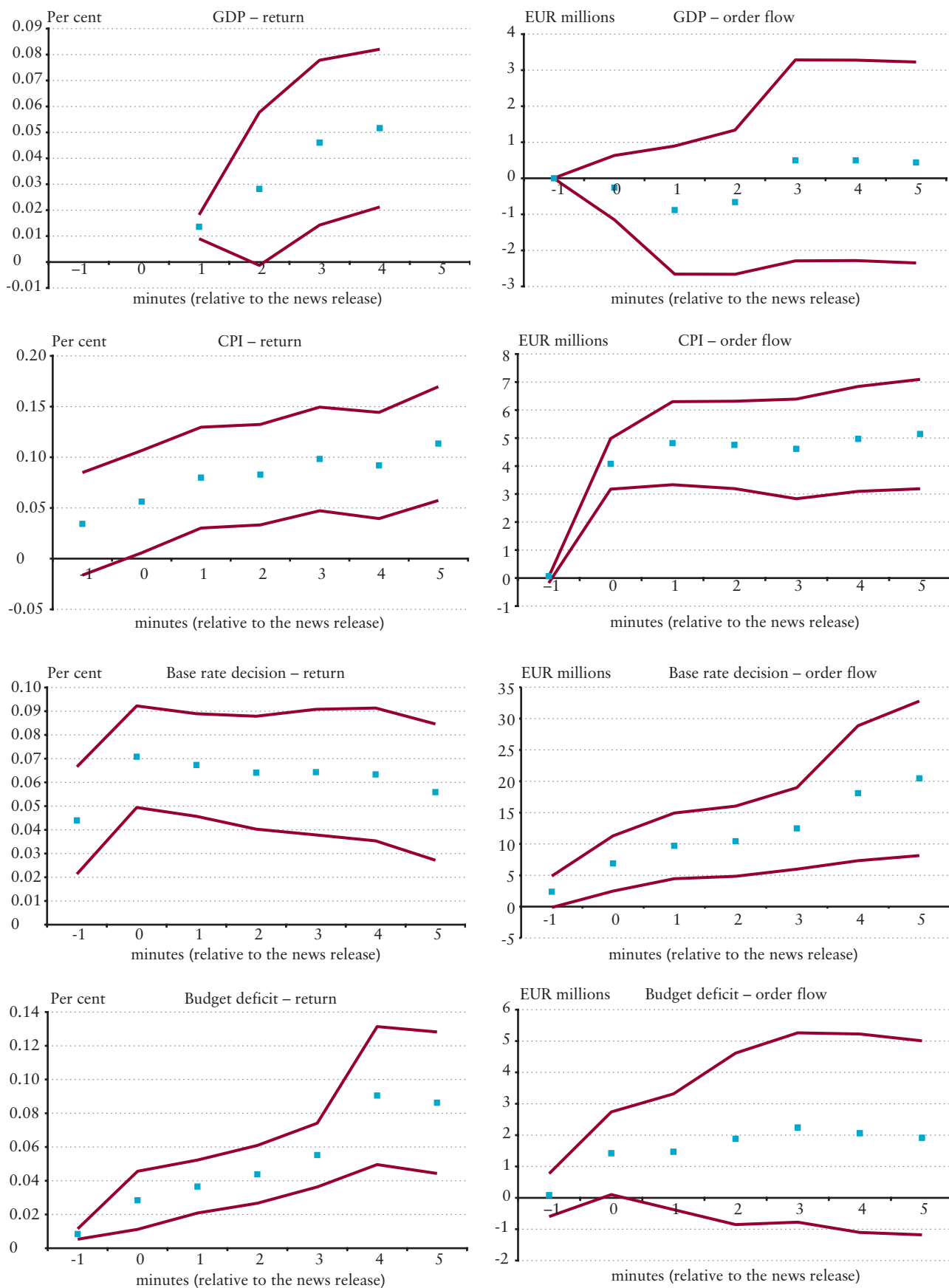
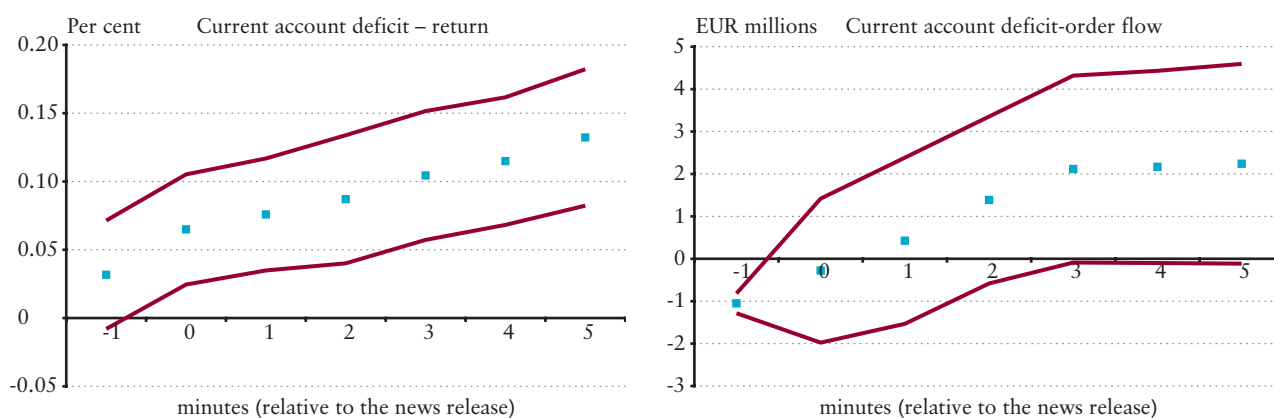
Figure 3**Impact of the announcements on the exchange rate and order flow***(standardised figures)*

Figure 3**Impact of the announcements on the exchange rate and order flow***(standardised figures)*

the exchange rate, the inflationary surprise stands out from the other variables: the impact of one 'unit' of inflation-surprise is almost three times as big on the exchange rate as the impact of one 'unit' of the surprise of an interest rate decision, which variable has the second strongest impact. Comparing the surprises caused by the budget deficit and the current account balance, they have similar impacts on the exchange rate, but their impact is only 50 per cent of the impact of the interest rate decisions.

In the next step, we analysed the sensitivity of the relationship between the exchange rate and the order flow to news announcements. To be more precise, we wished to see whether this relationship changes around data disclosures, whether the impact of the order flow on the exchange rate is stronger or weaker whenever any new public information hits the market. In theory, both outcomes are possible.

As soon as market participants learn about new data, they may adjust their expectations and exchange rate quotations according to this more reliable information, instead of looking at the noisy information conveyed by the trades. This behaviour may even temporarily break the correlation between the exchange rate and the order flow. On the other hand, assuming that well-informed market participants trade more actively when new information is released, the market makers may attach more importance to information in trading if initiatives in a particular direction dominate the trade. Under such conditions, the order flow may have a more pronounced impact on the exchange rate than at times when no macroeconomic announcements are made.

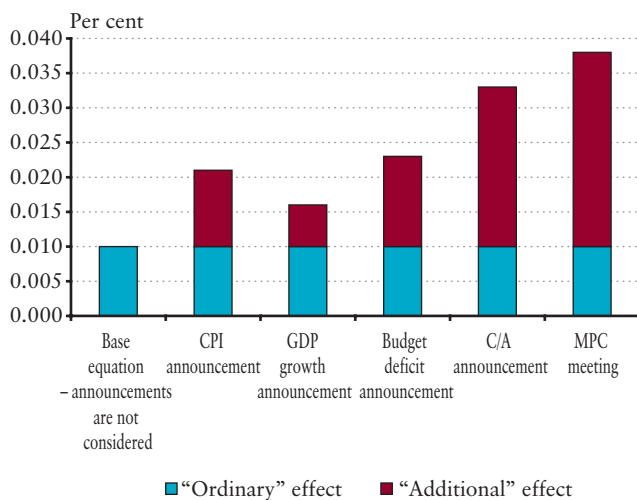
We estimated two regression equations for analysing the relationship between the exchange rate and order flow under various market conditions: in the basic regression equation,

used as the basis of comparison, the order flow had the same impact on the exchange rate at every time, while in the other equation we divided the impact of the order flow into an 'ordinary' component and an 'additional' component, which only prevailed around the time of the release of data (Annex, equations 3 and 4). In this way we allowed the impact of the order flow on the exchange rate to be different around the time of release of new information than under 'ordinary' market conditions.

Our analysis performed on high-frequency data clearly proved and confirmed our earlier results based on daily data, namely that the order flow has a statistically significant and in economic terms important impact on the exchange rates on the Hungarian market. In addition, it also became obvious that the impact of the order flow on the exchange rate changes when macroeconomic data are disclosed. At the minute of the disclosure, the influence of the order flow on the exchange rate is stronger than usual, because it conveys additional information about the fundamentals. This additional impact depending on the type of the news doubles and quadruples the ordinary impact, with the interest rate decisions having the strongest additional impact (Figure 4). Comparing the models we see that the 'base' equation has moderate explanatory power ($R^2=12\%$), but the inclusion of the additional variables into the model significantly improves the explanatory power of the specification ($R^2=25-32\%$).

Long-term relationship between news, order flows and exchange rates

First we looked at the relationship between the factors affecting exchange rate volatility and the absolute volume of the order flow (Annex, system of equations [5]).

Figure 4**Impact of the order flow on the exchange rate**

The meetings of the Monetary Council, especially when an effective change in the base rate happens have a clearly significant impact both on exchange rate volatility and the absolute volume of the order flow. In general, we can conclude that both volatility and one-way trading increase before the meeting, one possible interpretation of which is that the position-taking (sales or purchases on the FX market) based on the expectations of the market participants boost market activity before the decision. In case of interest rate changes, both increases and cuts, the buying or selling pressure on the HUF grows as the decision is announced, which is probably the result of positions taken or closed in response to the changed interest rate conditions. Interestingly, volatility seems to be falling after interest rate changes.

Macroeconomic news announcements do not cause aggressive one-way trading, but this result can also be attributed to the lower frequency of the time series used in this part of the analysis. As we saw earlier, the impact of data disclosures on the order flow emerges very quickly, therefore within 10 minutes the impact is most probably partly offset, and hence it can be detected less strongly. On the other hand, the announcement of the news has a very strong impact on volatility, especially if the surprise is 'negative'. Volatility is lower before the release of the data, and then increases significantly after the surprise hits the market. There are weaker reactions to 'positive' surprises, as volatility does not increase immediately, only 10 minutes after the announcement.

We can not draw general conclusions regarding the effect of central bank communication, as the impact varies widely according to the type of communication and the analysed time horizon. The intensity of trading, measured with the

number of deals conducted, is positively related to both volatility and the absolute order flow volume. A strong intra-day pattern can be observed in the volatility. The explanatory power of the order flow equation is very impressive ($R^2=65\%$), and our model explains volatility quite well too ($R^2=16\%$).

Our other system of equations based on 10-minute data intervals looks at the factors affecting the exchange rate changes and the order flow (Annex, equation system [6]).

The interest rate decisions of the Monetary Council have a lasting effect on the exchange rate changes and the dominant direction of trading. Interest rate cuts typically involve HUF depreciation, but their impact on the order flow is not consistent over time: both selling and buying pressures can be observed at different lags. On the other hand, the impact of interest rate increases on the order flow is clear: the increases result in aggressive HUF purchases, and this effect lasts long in time. Consequently, in such cases the HUF typically appreciates. In summary, the market reactions to interest rate changes are in line with our intuition and indicate a close relationship between the surprise value of the announcement and the exchange rate change and order flow.

The majority of the results related to the announcement of macroeconomic news also correspond to the theoretical assumptions. The strongest reaction follows favourable news about the economy. Although there is a 10-minute delay, 'positive' news cause strong buying pressure, triggering HUF appreciation. Together with the results obtained when analyzing the effects of news at a 1-minute interval this indicates that news do not only have short-term influence which lasts for a few minutes after the disclosure, but may also induce a long-term effect on the FX market. Although the 'negative' news have statistically significant impacts as well, these are less strong. The order flow parameter shows significant net HUF sales following the announcement of 'negative' news, but the exchange rate change is moderate. Consequently, our results indicate strong asymmetric behaviour of market participants when reacting to favourable or unfavourable news.

The direction and strength of the impact of the central bank communication variables are different, and it is rather difficult to show clear tendencies in their impacts. This result may stem from the fact that very often it is more difficult to interpret these types of news and that their timing is typically not known in advance. Consequently, we cannot draw general conclusions about the impact of the communication, but it seems that 'positive' communication is more likely to induce exchange rate appreciation and HUF purchases, 'neutral' communication leads to selling pressure and

depreciation, while ‘negative’ communication triggers HUF sales. The explanatory power of the order flow equation is relatively low, but the fit of the exchange rate equation may be considered rather good ($R^2=22\%$).

CONCLUSIONS

During recent years the analysis of order flow has become an important issue, which has been extensively debated in academia as well as by policy makers. Our study adds to this discussion by complementing earlier papers typically analysing the world’s major FX markets. In addition to analyzing the exchange rate of a small open economy (Hungary), characterized by a less liquid market and comparatively high capital flows, we extend the analysis to include the relationship between the news, exchange rate and the order flow.

According to our results, the surprise content of macroeconomic announcements triggers very strong immediate reactions both in the exchange rates and the order flow. There is a strong positive relationship between the order flow and the exchange rates, i.e. strong one-way purchasing (selling) interest appreciates (depreciates) the exchange rate. The impact of the order flow on the exchange rate is stronger than usual around the macroeconomic announcements, and at these times the FX market transactions convey additional information and cause larger movements. The impact of the new information affecting the FX market is not only temporary or short-lived, and it does not only apply to macroeconomic announcements, but also remains valid if the analysis is extended to a longer time horizon and central bank communication is included as well. Our results indicate that the role of order flow seems to be independent from the size of the market: The EUR/HUF market behaves, in terms of the mean as well as the volatility of the exchange rate, more or less in a similar way as e.g. the EUR/USD market.

Our models, which include news on economic fundamentals, central bank communication and order flow as explanatory variables, have relatively high explanatory power in case of the exchange rate, volatility and order flow. This may lead to the conclusion that by combining traditional macro models and the microstructure approach, a considerable part of exchange rate movements and the characteristics of the trading processes on the FX market can be explained.

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ANNEX

Impact of macroeconomic news on the exchange rate and order flow

Using the event study approach, we estimated the impact of the surprise content of the various macroeconomic news on the exchange rate and order flow based on the following equations:

$$\Delta p_{t,n} = \alpha^p + \sum_{i=k}^l \beta_{i,m}^p N_{t-i,n,m} + \varepsilon_{t,n} \quad (1)$$

$$OF_{t,n} = \alpha^{of} + \sum_{i=k}^l \beta_{i,m}^{of} N_{t-i,n,m} + \eta_{t,n} \quad (2)$$

where $\Delta p_{t,n}$ is the logarithmic change in the exchange rate on n day between $t-1$ and t times, multiplied by one hundred, $OF_{t,n}$ is the order flow in EUR million on n day between $t-1$ and t times, and $N_{t,n,m}$ is the surprise content of the news on n day for intervals ending at t time, for m news, while $\varepsilon_{t,n}$ and $\eta_{t,n}$ are the error components.

The equations were estimated separately for each individual macroeconomic variable used (CPI, GDP growth, current account, budget deficit, interest rate decision) at a 70-minute interval ($k=60$ and $l=-10$ minutes), i.e. the impact of the news can prevail for a period of 10 minutes before the

announcement for 60 minutes after the disclosure of the news.

Sensitivity of the relationship between the exchange rate and order flow on the announcements

We used a *dummy* variable for analysing the sensitivity of the correlation between the exchange rate and order flow in order to break down the impact of the order flow into an ‘ordinary’ part and an ‘additional’ part, which is related to the time of the announcement. We estimated the (3) equation as a basis of comparison, in which the impact of the order flow was not broken down into components.

$$\Delta p_t = \alpha^b + \beta^b \cdot OF_t + \varepsilon_t \quad (3)$$

In the following (4) specification, we allowed the order flow coefficient to be different from its ordinary level if any new information is released.

$$\Delta p_{t,n} = \alpha + \beta \cdot OF_{t,n} + \sum_{i=-k}^k \gamma_{i,m} \cdot OF_{t,n} \cdot I(i)_{t,m} + \eta_{t,n} \quad (4)$$

where $I(i)_{t,m}$ is a *dummy* variable, which takes the value of 1 if the announcement was made at t time. By using *dummy* variables under equation (4), we practically ‘take out’ certain intervals around the announcement and test whether the coefficient of the order flow changes compared to its ordinary level. For example, the order flow multiplied by $I(0)_{t,m}$ shows whether the order flow has a stronger or weaker impact on the exchange rate than otherwise one minute after the m announcement. The ‘around the announcement’ definition means five minutes before and after the announcement, i.e. the m value was set to five. With this specification we can also test whether the explanatory power of the model can also be improved by any potential change in the order flow parameter around the announcement.

Analysis of the exchange rate volatility and the absolute value of order flow

For the analysis of the impact of news on volatility, we estimated the following set of equations, taking also into account the relationship between the order flow and volatility:

$$\begin{aligned} h_{t,n} &= \omega_1 + \alpha p(t) + \beta_0 |OF_{t,n}| + \sum_{h=1}^2 \beta_h |OF_{t-h,n}| + \sum_{j=1}^2 \gamma_j h_{t-j,n} + \sum_{j=1}^4 \zeta_j dy_j + \sum_{k=1}^K \sum_{l=-m}^m \delta_{k,l} N_{k,t+l,n} + \varepsilon_{t,n} \\ |OF_{t,n}| &= \omega_2 + \sum_{h=1}^2 \beta_h |OF_{t-h,n}| + \sum_{j=1}^2 \gamma_j h_{t-j,n} + \sum_{k=1}^K \sum_{l=-m}^m \delta_{k,l} N_{k,t+l,n} + \eta_{t,n} \end{aligned} \quad (5)$$

where $h_{t,n}$ is the volatility of the EUR/HUF return observed in t interval on n day, $p(t)$ is the seasonality of volatility within the day, and day is the dummy variable grasping seasonality during the week, the $N_{k,t,n}$ variables indicate various types of macroeconomic news and central bank communication in accordance with the previous equations. As volatility is a one-way variable, in this set of equation we used the absolute degree of order flow as a variable.

Analysis of the exchange rate changes and the order flow

Apart from a few minor differences, the set of equations is similar for the return analysis.

$$\begin{aligned} r_{t,n} &= \omega_1 + \beta_0 OF_{t,n} + \sum_{h=1}^2 \beta_h OF_{t-h,n} + \sum_{j=1}^2 \gamma_j r_{t-j,n} + \sum_{k=1}^K \sum_{l=-m}^m \delta_{k,l} N_{k,t+l,n} + \varepsilon_{t,n} \\ OF_{t,n} &= \omega_2 + \sum_{h=1}^2 \beta_h OF_{t-h,n} + \sum_{j=1}^2 \gamma_j OF_{t-j,n} + \sum_{k=1}^K \sum_{l=-m}^m \delta_{k,l} N_{k,t+l,n} + \eta_{t,n} \end{aligned} \quad (6)$$

On the one hand, we use the order flow with a prefix, because the return change may also work in two ways like the order flow. On the other hand, there is no need to include the intraday and weekly seasonal variables into the model, because, contrary to volatility, no seasonal samples can be observed in the case of returns.