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Monetary policy, exchange rate and stability[1]

In inflation targeting, it is difficult to manage the relation between monetary policy and the exchange rate. If the central bank pays attention to this connection, it may be under criticism that they are targeting the exchange rate and not inflation. Our paper discusses an element of the relation between monetary policy and the exchange rate which has been overlooked to date. The difference between domestic and Euro interest rates are in close correlation with exchange rate volatility. What it also means is that interest rate policy has a significant impact on market stability.

According to one school of new theories, it is hardly possible to grasp monetary policy by the impact it has on specific macroeconomic variables or on their average. Instead, more information is conveyed in other statistical indicators, e.g. dispersion. The difference between forint and euro interest rates is an important attribute of monetary policy yet opinions vary on what and how it affects. According to the traditional theory of uncovered interest rate parity, Hungary needs to keep up a higher interest rate than the euro region in order to offset expectations for the devaluation of the forint against the euro. Real life, however, seems to prove just the opposite of this thinking. What goes with the positive interest margin is the revaluation of the domestic currency and not devaluation expectations. What we discuss in this paper is that a close correlation exists between the interest margin, an important attribute of monetary policy and the *volatility* of the exchange rate.

Among the many functions of monetary policy, the role to serve the stability of financial markets is becoming increasingly important today. This role used to be dominant in the beginning when the embryos of today's central banks emerged in the first half of the last century. While price stability is undoubtedly an important element of this stability, it is not necessarily so important that it should overshadow everything else. Over time, monetary policy will serve efficiently the stability of financial markets in a different manner. This change will depend on the way the key elements of monetary policy, i.e. interest rate policy and central bank communications are transformed on the financial markets (monetary transmission). While these issues will not be resolved in this paper, we underline their significance and point out an overlooked congruence. We will take the exchange rate fluctuation of the forint as an example to demonstrate that although there is no direct, easily describable correlation between monetary policy and exchange rate changes, the impact on exchange rate volatility is apparent.

We will present the correlation between interest margin and exchange rate volatility in graphic form. The significance of this correlation can be interpreted in two ways. One interpretation suggests that it is not the average value of macroeconomic variables used in various models that monetary policy affects but their volatility or dispersion. This conclusion may supply guidance to or set requirement for model building and analysis. The other interpretation says that since monetary policy primarily impacts the volatility of macroeconomic variables, it is of special importance to take into consideration the stabilisation goals of monetary policy and stability of financial markets in general.

ABOUT UNCOVERED INTEREST RATE PARITY

In this section, we review the theoretical and empirical attributes of the categories and correlations used herein based on data from Hungary. Readers who have an in-depth knowledge of this subject are free to skip this section as it presents the traditional, textbook approach in a nutshell.

Uncovered interest rate parity is a frequently mentioned term and here we provide a very simple explanation to it. On an invested Y amount, we expect to get back at least $Y(1+r_t)$ forints after one year, where r_t refers to the interest rate in period t.

If we happened to invest in Euro bonds, the formula is extended with the forint/euro exchange rate, represented by z_t at a t point of time. This is the price of the euro expressed in forints, i.e. the increase of the figure refers to forint devaluation. Converting Y forints to euro we get $Y\frac{1}{z}$ euros. The returns on that are calculated at the r_t^* euro interest rate. At the end of the period, we reconvert our euro investment into forint and get to this formula: $Y\frac{1+r_t^*}{z_t}E(z_{t+1})$. As we make the investment decision in period t, the exchange rate of period $t+1$ is unknown at that point, thus we can only calculate with the $E(z_{t+1})$ exchange rate. Assuming that both investment options are available without limits, the returns are expected to converge: $Y(1+r_t) = Y\frac{1+r_t^*}{z_t}E(z_{t+1})$ = , i.e. the correlation between interest rates and exchange rates, the *interest rate parity* can be expressed as follows:

$$1+r_t = \frac{1+r_t^*}{z_t}E(z_{t+1})$$

As we did not use any hedging to secure the exchange rate during the financial transaction described in a somewhat complicated manner above, the accurate name of the formula is *uncovered interest rate parity.*

Thus interest rate parity means that if investors anticipate the devaluation of the forint against the euro, domestic interest rates must be higher than euro interest rates. This difference must be large enough so that the domestic interest margin matches the surplus gain which a forint investor would obtain in forints thanks to the euro returns and the devaluation of the forint in the meantime, or to compensate the loss of a euro investor which he would realise upon changing his devaluated forint returns into euros.

One proven approach in analysing this type of nonlinear correlations is to transform the equation into log-linear format which is then easier to analyse with mathematical and econometrical methods. The first step is to take the logarithm of the equation presented above:

$$(1)\ \log(1+r_t) = \log(1+r_t^*) - \log(z_t) + \log E(z_{t+1})$$

By rearranging equation (1) and introducing $i=\log(1+r)$, we get to the following expression[2] of *interest rate parity:*

$$(2)\ i_t - i_t^* = \log E(z_{t+1}) - \log(z_t)$$

Even after the transformations described above, equation (2) is still saying the same: If investors expect the devaluation of the forint against the euro, domestic interest rates must be higher than euro interest rates and the difference must be sufficiently big to allow the domestic interest margin to compensate the losses suffered on converting the devaluated forint returns into euro. This correlation is an important element of macroeconomics textbooks. The only trouble is that empirical studies are in contradiction with it. (The main findings of relevant studies are summarised in *Annex 1*)

The impossibility of grasping the notion of interest rate parity derives from the fact that it includes an unobservable category, namely the $E(z_{t+1})$ exchange rate for day $t+1$ as expected at a certain t point of time. There is a long list of bridging solutions, e.g. the replacement of the relevant figures in the equation with the actual exchange rate, as if the investor's prediction was perfect. If we do this, the equation (2) will be as follows:

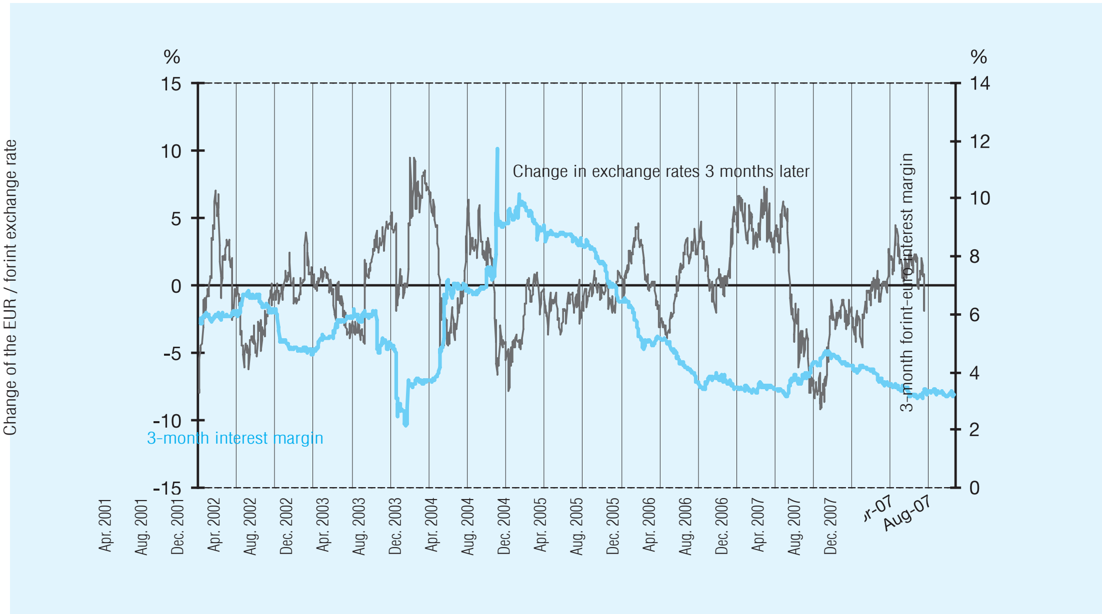
(2a) $$i_t - i_t^* = \log(z_{t+1}) - \log(z_t)$$

Neglecting the original assumption behind the formula temporarily, i.e. by looking back and not forward in time, equation (2a) can be examined empirically. Taking the interest margin as a difference between three-month interbank interest rates (BUBOR) and EURIBOR, the corresponding indicator of the euro region, we get the trend shown in Chart 1 for Hungary. The interest margin calculated on the basis of three-month interbank rates is usually compared to the change of exchange rate projected for the same period, i.e. the change calculated with a view to the exchange rate three months later. This is what we do in the first step.

This comparison is shown in *chart 1* where the two time series reflect a distinctive negative correlation (–0.37 for the entire period). This negative correlation is just the opposite of the congruity assumed in (2a), as the equality of the left and right side of equation (2a) would suggest a significant positive correlation

Chart 1

INTEREST MARGIN AND EXCHANGE RATE FLUCTUATIONS



Source: Bloomberg, authors' calculations between the two sides. Based on the uncovered interest rate parity, the forint should weaken against the euro when the interest margin is high. The chart, however, shows the opposite of that: Typically the forint becomes stronger when the interest margin is high and weakens when the interest margin is low. (This finding is in line with the results referenced in Annex 1)

What comes from this immediately is that the gracious assumption of a perfect prediction applied upon moving from (2) to (2a) did not prove to be a fruitful approach in the world of exchange rates. Maybe we should be more careful already upon interpreting equation (2) as it is suggested by the failures or rather the consistently negative outcome of the countless empirical takes at uncovered interest rate parity, i.e. equation (2). However, *Fernando Alvarez, Andrew Atkeson* and *Patrick J. Kehoe* (2007) came up with a remarkable idea. In their opinion, the starting point (2) is more or less correct. The problem lies in the conclusions derived from it, or in the overall theory and modelling of monetary policy impact mechanisms. The reason is that it does make a difference whether we monitor the average of a variable or its dispersion.

AVERAGE AND DISPERSION, EXCHANGE RATE AND VOLATILITY

To illustrate the key point of the proposal of Fernando Alvarez, Andrew Atkeson and Patrick J. Kehoe (2007), let us transform equation (2) further relying on the fact that *E(z)* expected value of random variable *z* with a *log-normal* distribution assumed for the static attributes of economic time series is expressed with the $\log E(z) = E\log z + \frac{1}{2}\mathrm{var}(\log z)$ formula.

$$(3)\quad i_t - i_t^* = E\log(z_{t+1}) - \log(z_t) + \frac{1}{2}\mathrm{var}(\log(z_{t+1}))$$

Here we note that if we were to apply the same assumption on equation (3) which took us to the (2a) formula, we would have at least one hopeful candidate for explaining the deviation in chart 1 – namely, the last member in equation (3). For the sake of a simpler reference, now we introduce the expression $\delta_t = \frac{1}{2}\mathrm{var}(\log z_{t+1})$ for that member along with *x=log(z)* which takes us to the following equation:

$$(3a)\quad i_t - i_t^* = Ex_{t+1} - x_t + \delta_t$$

There are disputes concerning the interpretation of equation (3a) and the δ_t factor in it. One objection says that when interpreted as a semi-variance of the exchange rate, δ_t leads to a way too low figure, since a 10 per cent change in the exchange rate would result in a semi-variance of 0.5 per cent. This argument is mentioned by *Engel* (1995) as well (op.cit. p. 133). In this context we must note that formula (3) is only a simplified expression, e.g. here we only consider the expected exchange rate as a likelihood variable. The referenced distortions may originate in simplifications of this sort. The representation reviewed in *Annex 2,* which follows the article of Fernando Alvarez, Andrew Atkeson and Patrick J. Kehoe (2007), considers interest rate as a factor in pricing *(pricing kernel).* Thus the stochastic link between interest rate and exchange rate already appears in this presentation and it is represented by the covariance member in formula (F.2.7) in the Annex. This way, in this broader stochastic approach, factor δ_t contains more than only the semi-variance of the exchange rate. According to formula (F.2.7) in Annex 2, this risk factor will be the sum of the semi-variance of the logarithm of exchange rate change and the covariance of the stochastic discount factor and the logarithm of exchange rate fluctuation.

The use of index *t* in the expression δ_t herein emphasises that at a certain *t* point of time, we assume concerning the exchange rate expected at the next point of time that the stochastic attributes of the exchange rate or at least its dispersion will not change. Therefore we assume that this rate is known based on information available at time *t*.

Regarding the naming of factor δ_t, we follow the paper of Engel, *Mark and West* (2008). Not surprisingly, these authors call this factor the *deviation from uncovered interest rate parity*. Engel, Mark and West (2008) note that while it is well known about this deviation that empirical results disproof the $\delta_t=0$ hypothesis (this is agreed by professionals), we do not know much regarding δ_t. This way, there is no common agreement on how we could model this factor or what it expresses in reality. As pointed out by *Gyula Barabás* (1996) the deviation (represented by δ_t here) is a kind of a risk premium, it may express a short-term deviation from rational expectations may reflect the consequence of another market attribute or barrier.[3] The interpretation of δ_t as a risk premium (3a) can be derived from the following rearranged version of the formula:

$$(3b) \qquad \delta_t = i_t - (i_t^* + Ex_{t+1} - x_t)$$

The first member on the right side of equation (3b) represents the domestic interest rate, the three-member expression next to it is the forint value of the expected yield of Eurobonds bought for forints and calculated at the expected exchange rate. Thus the difference between the two can be interpreted as risk premium.

Obstfeld and *Rogoff* (2003) do not exclude the possibility that the changes of δ_t may convey important information concerning the explanation of exchange rate trends or at least the related expectations. In other words, the theory of exchange rates has been challenged quite a bit. In this paper, we do not wish to dive into the depths of these theories. We rather return to the concept of Fernando Alvarez, Andrew Atkeson and Patrick J. Kehoe (2007) which does not focus on exchange rate theory but on modelling the impact mechanism of monetary policy, or more specifically, on criticism that shakes the very foundations of monetary policy.

THE IMPACT OF MONETARY POLICY

Theoretical explanations will follow, so we interpret monetary policy in a rather narrow sense and identify it with interest rate changes. As a further simplification, we limit our focus to the short term money market interest rate (interbank rate, BUBOR) as opposed to the central bank's base rate. *Chart 2* presents the day-to-day trends of these variables during the past six years.

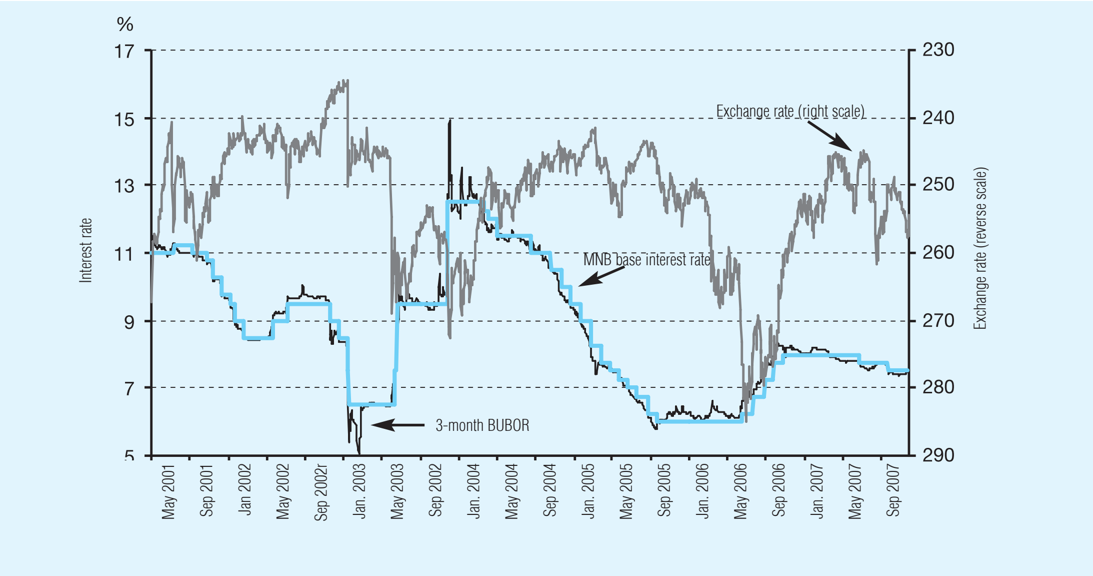
The fluctuations of interbank rates are not only affected by the central bank's base rate but by a number of other factors. And the base rate has an even further-stretching significance. Still, the interbank rate can be considered one of the key elements of the interest transmission mechanism. The channels of this mechanism are summarised in detail in a study by *Vonnák* (2006). Vonnák notes that the 3-month interbank rate is a preferred and frequently used variable for analysing the monetary policy. The reason is that while this interest rate moves in very close correlation with the central bank's base rate, its day-to-day fluctuation is a good indication of market expectations concerning the future changes of the base rate.

One popular and widely used method of monetary policy evaluation is the analysis of the central bank's *response function.* A potential objective of an analysis carried out on this basis is to present the correlations between interest rates and other macroeconomic variables. A paper by *János Hidi* (2006) provides a very interesting overview of the response function assessment of Hungary's monetary policy.

Just for a brief experiment, we can interpret

Chart 2

MNB'S BASE INTEREST RATE, THE INTERBANK RATE (3-MONTH BUBOR) AND THE EXCHANGE RATE (HUF/EURO)



Source: Bloomberg

equation (3a) as a cut back response function. Going from right to left the equation illustrates how monetary decision makers are affected by the trends of exchange rate expectations $E(x_{t+1})$ and the risk premium (δ_t) that reflects market stability attributes and how this effect shows up in interest rate trends.

The response function can also be read from left to right. Looking at it from this direction, it provides an interpretation of the changes of interest rate fluctuations as opposed to explaining why the central bank changed the interest rate. In the dream world of equation (3a), it calls for the analysis of what and how is impacted by the growth of domestic interest rates which exceeds the growth of foreign interest rates.

Naturally, playing this game back and forth does not add anything to the picture at this extreme level of simplification. It does not make the model more realistic and it does not take us to a deeper level of understanding. This way, we can even alternate freely between the "directions" applied for arguing.

Let us take the latter direction and read equation (3a) from left to right. So if the domestic interest rate goes up, what will happen on the right side of the equation? While this is a simple question, it is not easy to answer it and the question itself needs further specification.

One potential interpretation of the question may be to seek the *immediate* response of the exchange rate to momentary interest rate changes. This immediate connection is analysed in a study by *András Rezessy* (2005) who examined the one-day and two-day response of the forint's exchange rate, domestic interest rates of various terms and the stock market to the fluctuations of the central bank's base rate. He concluded that the forint responded with a 0.27–0.30 per cent revaluation when the base rate was raised by surprise with 50 basis points. For the first sight, this result does not differ from the negative correlation between the interest margin and the change of the exchange rate presented in chart 1.

Still, due to the complex technical details and the different time horizons (one day to three months), we have to be careful with wording.[4]

When embedded in monetary transmission, the long-term consequence of the central bank's interest rate change may be more important than its momentary impact. *Another* interpretation of our question might be as follows: On a time horizon *identical to the term* of interest rates discussed herein, i.e. 3 months, what will be the impact of the interest margin calculated at interbank rates (3-month BUBOR) changed due to the central bank's interest rate change on exchange rate fluctuations? While this assumption extends the time horizon to 3 months, it does not answer the question whether we want to know the impact on *exchange rate expectations* for three months into the future or the difference between the exchange rate today and three months later.

If we take the latter of these choices as a basis and focus on the actual change of the exchange rate, we have an easy road ahead. We already discussed it in conjunction with Chart 1 and found that on a 3-month horizon, the growth of forint interest rates triggered the strengthening of the forint, i.e. typically there is a negative correlation between interest rate parity and the change of the exchange rate. This conclusion contradicts the uncovered interest rate parity concept. Thus from a monetary policy standpoint, we cannot draw conclusions on exchange rate trends from within the closed system of interest rate parity.

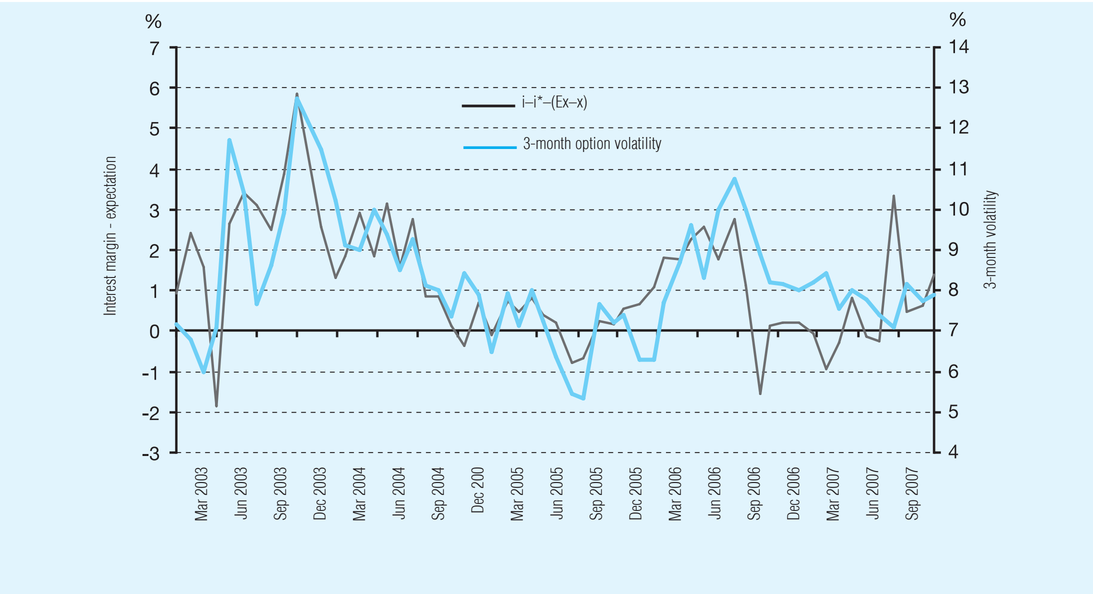
If we want to know the impact on exchange rate changes we have quite another story. If we take a closer look at equation (3a), we see that it includes *exchange rate expectations* on the one hand and, at the end of the formula, the δ_t factor on the other hand. Building on these subtleties, Fernando Alvarez, Andrew Atkeson and Patrick J. Kehoe (2007) lands a huge strike on the traditional theory. For what they say[5] is that if exchange rates are like *random walks*, monetary policy does not directly impact the actual *average* value of the exchange rate or other variables (including inflation). When analysing interest transmission, nobody is looking for any immediate impact so it is natural that the preferred focus is on the future trends of macroeconomic variables (fundamentals). Concerning the attributes of these future variables, we tend to forget that our predictions are usually imperfect and therefore we can only have an idea of the statistical attributes of the variables in the present. E.g. *dispersion characteristics* convey important information. Overlooking them is a false practice. If for no other reason, this approach should be objected because it places too big an emphasis on the *expected future value* of variables about which very little can be known (both for sceptics and optimists) while overlooking statistical attributes which are significant for assessing future variables trends and on which more information is available. E.g. one attribute of this sort is the *conditional dispersion* of variables (calculated on the basis of past observations) taken into consideration upon decision-making. This problem has an important practical consequence.

On the short run, monetary policy affects market risks, meaning that the increase of the left side of formula (3a) after the raise of the domestic interest rate *does not affect* the exchange rate variables (expected values) on the right side and the impact of monetary policy step is manifested in the changes of the δ_t risk premium.

In formula (3b), we rearranged the variables and expressed δ_t as the difference between the interest margin and the expected exchange rate trends. This difference can be considered the counterpart of the difference between the exchange rate change expected by analysts and presented in *Chart 3* and the change of exchange rate implied by the interest rate pari-

Chart 3

THE DEVIATION OF 3-MONTH EXCHANGE RATE EXPECTATIONS FROM INTEREST RATE PARITY AND THE IMPLIED EXCHANGE RATE VOLATILITY



Source: Reuters, authors' calculation

ty. According to the model, δ_t is in close correlation with the dispersion of the exchange rate. Now we also examine that congruence empirically, using Chart 3. To do this, we need the forward-looking exchange rate volatility figure. We can obtain relevant data, specifically 3-month implied volatility figures from the euro-forint option market. By definition, implied volatility is the volatility parameter which we can put in the Black-Scholes option formula as a substitution to calculate the market price of the option. (We will explain implied volatility in more detail in Annex 2) In the case of foreign exchange options, this substitution step is not even necessary, as the price of foreign exchange options is usually presented in volatility, thus the data are available from Reuters or from another official source.[6]

Chart 3 compares the 3-month δ_t value from (3b) calculated as a residue based on exchange rate expectations[7] to the implied volatility of options with a 3 month expiry. The simultaneous motion is clearly visible and the correlation between the two variables was 0.61 between 2003 and 2007.

Based on Chart 3, we can risk the statement that risk premium δ_t defined as the deviation from the uncovered interest rate parity is in close correlation with exchange rate volatility. We do not think that this close relation is actually an identity.[8] In reality, the deviation from the uncovered interest rate parity is not likely to be equal to the exchange rate semi-variance as the simplifying assumptions of our equation (3) would suggest. Beyond volatility in a statistical sense, other things also fit in this deviation, e.g. considerations and explanations that relate to the volatility of risk appetite and other mysterious things. What would be hard to fit in this picture is the neglecting of the role of volatility and the impact of monetary policy on exchange rate volatility. In the previous section of this paper we saw that the impact of interest rate changes on the exchange rate is ungraspable, i.e. most of the interest rate change is absorbed in the change of the risk premium.

This factor, however, is very easy to relate to exchange rate volatility based on Chart 3. So the impact of the interest rate changes mostly manifests in the fluctuations of exchange rate volatility. It is likely that monetary policy primarily affects exchange rate volatility, market stability in general while its impact on the exchange rate (value or average) is weaker.

To refine the analysis, we break up the right side of formula (3b) and express separately the market expectations concerning exchange rate changes and the interest margin. Exchange rate expectations are represented by the $-(Ex_{t+1}-x_t)$ member and this is what we show together with volatility in *Chart 4.* Member $-(Ex_{t+1}-x_t)$ represents the expectations concerning the changes of the forint exchange rate against the euro. What we see is that in high volatility periods the market expects a more significant strengthening of the forint which can also be put as follows: market players expect a higher risk premium from a forint that conveys a higher risk. As a further explanation, we can add that the volatility of the forint jumps upwards in stressful times, typically in periods when the forint weakens. Compared to momentary exchange rate shifts, however, exchange rate expectations for a longer (in our case 3 months) outlook change only to a lesser extent. This way the momentary weakening of the forint may open the way for future exchange rate growth, as expectations predict that the exchange rate will return to the forecasted level on the long run. The correlation between the two variables was 0.45 in the examined period.

Chart 5 matches volatility to the interest margin, i.e. to monetary policy. As it is visible in the chart, the interest margin and the exchange rate risk showed a perceivable correlation in the past five years.

Based on these experiences, we can draw the conclusion that the risk premium determined by the (3b) formula is in close correlation with exchange rate volatility in an empirical sense as well. Either member of formula (3b), i.e. exchange rate expectations or interest margin can be correlated to exchange rate volatility on

Chart 4

3-MONTH EXCHANGE RATE FLUCTUATIONS AND IMPLIED EXCHANGE RATE VOLATILITY

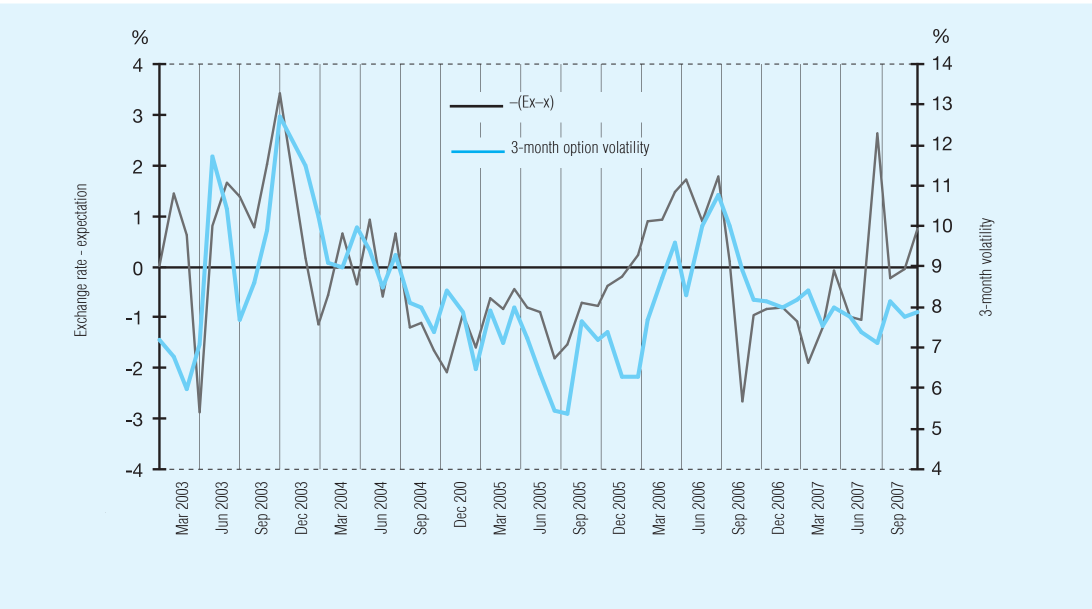
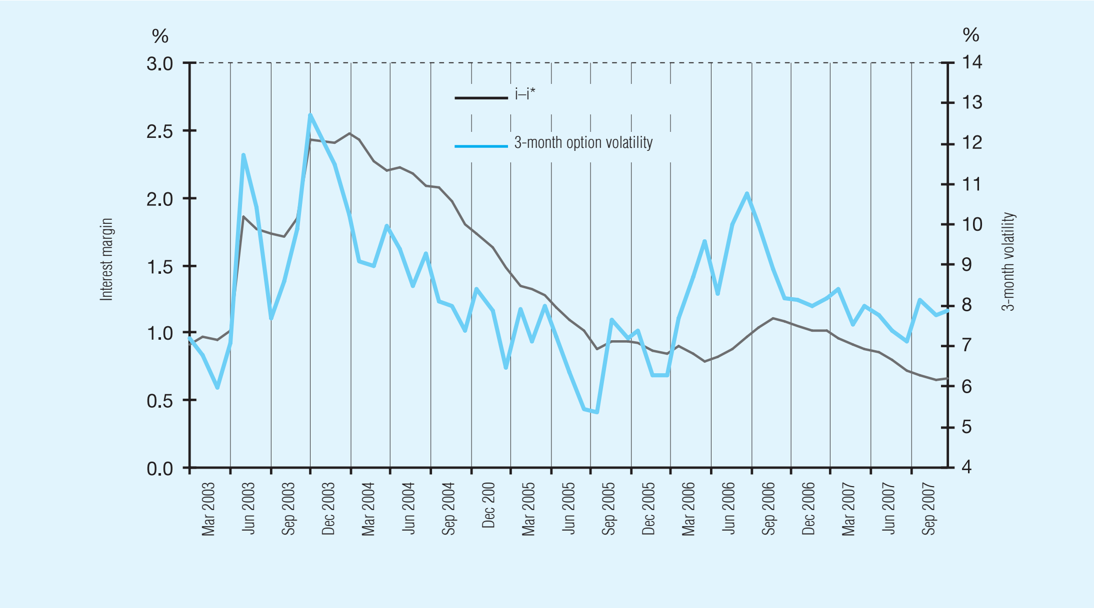


Chart 5

3-MONTH INTEREST MARGIN AND IMPLIED EXCHANGE RATE VOLATILITY



its own. In the case of expectations, it is the market players themselves who express the "need" for a higher exchange rate gain in a higher risk period (typically following a devaluation of the forint). From a monetary policy viewpoint, we see that the impact of the interest rate change mostly manifests in the change of exchange rate volatility. It is likely that monetary policy primarily impacts exchange rate volatility, it affects market stability in general while its impact on (the value or average of) the exchange rate is weaker.

SUMMARY AND CONCLUSION

Exchange rate fluctuations and monetary policy are interrelated. We might think that it is difficult to take this congruence into consideration in inflation targeting because anyone doing so would be exposed to criticism that he or she is targeting the exchange rate instead of inflation. It is like the story about "The miller, his son and the donkey".[9] You can never please everyone. Common public opinion, however, is wrong. In respect of the exchange rate, monetary policy does not directly impact its expected value. What is more, not only the role of monetary policy in shaping the exchange rate is questionable but the impact of many other fundamental factors is equally ungraspable. Perhaps this is why the exchange rate fluctuations described with the "random walk" theory often approximate actual exchange rates just as well as any other theory.

A freely evolving exchange rate is characterised by fluctuations, i.e. volatility. Exchange rate fluctuations cause uncertainty which makes investors calculate with higher returns (risk premium). Out of these three factors (interest margin, expected exchange rate and risk premium), monetary policy can only influence one: the interest margin. It does not have an exclusive and obvious effect on exchange rate expectations. At the same time, it is very likely that monetary policy does impact the risk premium and the volatility of the exchange rate through stabilising money markets. The separate identification and measurement of these effects, however, is not simple. It can also happen that out of these three factors, the expected exchange rate and the risk premium fluctuate at each other's expense, perhaps even independently of monetary policy. Still, from a stability standpoint, this triangle must not be neglected.

The interest margin calculated on the basis of the interbank interest rate (3 month BUBOR) and the optional volatility of the forint-EUR exchange rate shows close correlation while the theory of interest rate parity does not supply an empirical basis for this relationship. Thus it is not necessarily the expected exchange rate value but its dispersion (higher statistical momentums) that monetary policy affects. From a theoretical standpoint, this impact can be explained simply and has been proved empirically.

Monetary policy can only fulfil its stabilising role on the money market effectively if it does not limit its focus to inflation but takes other money market factors into consideration as well. Stabilisation aspects also have a key role in inflation targeting systems and for a reason. Yet in inflation targeting we are inclined to refer this role to central bank communication. What we presented in this paper was that this aspect must also be handled in an interest rate policy context. Just because interest rate policy does not have a clearly describable impact on the *expected* exchange rate values, it does not mean that the exchange rate could be neglected. The reason is that interest rate policy affects the *volatility* of the exchange rate instead of just the rate itself. In the case of the forint, this impact is well graspable empirically as well.

Over time we may be able to understand stabilisation congruencies. The horizon of monetary policy will broaden accordingly and the role of stabilisation considerations will be more significant in inflation targeting.

NOTES

1 The thoughts presented in this article do not necessarily reflect the opinions of the International Monetary Fund and the World Bank.

2 Regression functions which include an exchange rate element are usually written in logarithmic form in order to avoid the problem known as the Siegel paradox (see Siegel, 1972), as $1/E(z_t) \neq E(1/z_t)$, but $E(-x_t)=-E(x_t)$, where $x_t=\log(z_t)$. Otherwise the choice of exchange rate by the euro/forint or forint/euro convention would distort calculations.

3 The deviation marked as δ_t was examined by Cumby, R. E. – Obstfeld, M. (1981) who found that the statistical attribute of the factor (high autocorrelation indicator) did not refer to a waiting error but to the presence of a factor with an independent impact mechanism which the authors interpreted as risk premium.

4 An opposite interpretation of this result also exists as pointed out by András Rezessy. E.g. let us take the potential scenario that the domestic interest rate in equation (3a) is raised by surprise. Concerning the factors on the right side of the equation, this does not necessarily shake up the exchange rate expected for three months into the future [$E(x_{t+1})$ does not change] and we can also take the δ_t risk premium unchanged for a time horizon of one day. In this case, the momentary growth of the exchange rate (i.e. the decrease of x_t) can still harmonise with the interest rate parity described with equation (3a) which suggests a positive correlation between the two aforementioned variables.

5 Actually they do not exactly say this and do not say it this way. The authors use more careful wording and their assumptions, explanations are elaborated in more detail. Here we only illustrate their approach. The theory of Fernando Alvarez, Andrew Atkeson and Patrick J. Kehoe (2007) is explained more precisely in the Annex hereto.

6 A study by Csaba Csávás and Áron Gereben (2005) provides a good overview of the Hungarian foreign exchange options market.

[7] We calculated the expectations concerning the forint exchange rate based on the analyst assessment published monthly by Reuters. The 3-month expected exchange rate was calculated by interpolating the medians of exchange rates expected for the end of the following month after the assessment and for the end of the actual year or the following year.

[8] If we had sufficiently large self confidence to scan all significant elements of the world into equation (3), then we could think about an identity here.

[9] The miller, his son and the donkey
A man, his son and their donkey were strolling down the dusty streets of Keshan in the dog days of summer.
The donkey was led by the boy while his father travelled on the donkey's back. "Poor child" thought a passer-by. "With his short legs, he can hardly keep up with the walk of the donkey. How can someone be so lazy to ride the donkey and let his child work his soul out?" The man listened to the criticism: he got off the donkey at the next corner and put his son on the donkey's back.
After a short while, another passer-by frowned: "What an arrogant behaviour! This little urchin is sitting up there like a king on a throne and lets his poor old father try to keep pace with the donkey." This time the son was saddened, so he asked his father to sit on the donkey behind him.
"What an unprecedented scene?!" – nagged an old woman from behind her veil. "What a torture for the donkey! These two bad hats are sitting on the poor creature as if he was a couch!" Having been berated again, father and son looked at each other and got off the donkey.
They walked with the donkey and just after a few steps, another passer-by began to laugh at them: "You morons, how can you be so stupid? Are you walking your donkey? Why do you keep him if he is so worthless? He is not working and not even carrying you."
The father gave a handful of straw to the donkey, put his hand on the son's shoulder and said: "No matter what we do, there is always someone who will not like it. I think the best we can do is to go our own way."
From: The scholar and the camel drover – Oriental stories to heel Western souls by Nossrat Pesaschkian. Helikon Kiadó (Helikon Publishing House), 1991. page 200

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ANNEX 1:
ABOUT THE EMPIRICAL ANALYSES OF INTEREST RATE PARITY

Interest rate parity is an important building block of exchange rate theories. *Moosa – Bhatti* (1997) provided a great overview of the extensive literature on the subject. As we could see, the *uncovered interest rate parity* equation is as follows:

$$\text{(F1.1)} \quad 1+r_t = \frac{1+r_t^*}{z_t} E(z_{t+1})$$

We get an apparently similar but actually different equation if we replace the $E(x_{t+1})$ expected exchange rate with the h_t future exchange rate, i.e. the price for which we can buy 1 EUR for $t+1$ time at a certain t point of time:

$$\text{(F1.2)} \quad 1+r_t = \frac{1+r_t^*}{z_t} h_t$$

This equation describes a hedge deal where we actually use a future exchange rate transaction to eliminate the exchange rate risk. As we covered the exchange rate risk with the transaction, the formula is the *covered interest rate parity* equation.

When examining interest rate parity empirically, the first difficulty comes from the fact that the $E(x_{t+1})$ expected exchange rate is not observable. That is the reason that usually the x_{t+1} observed value is applied as a substitute for it (as if exchange rate expectations were characterised by perfect prediction). Taking the logarithm of the aforementioned equations for a statistical analysis, we get to a linear formula. Using expressions $i_t=\log(1+r_t)$, $x_t=\log(z_t)$, $f_t=\log(h_t)$ and taking the two formulae above:

$$\text{(F1.1)-ből:} \quad i_t - i_t^* = x_{t+1} - x_t = \Delta x_{t+1}$$

$$\text{(F1.2)-ből:} \quad i_t - i_t^* = f_t - x_t$$

Comparing these two formulae we get to the following equation that is used upon statistical examinations:

$$\text{(F1.3)} \quad \Delta x_{t+1} = \alpha + \beta(f_t - x_t) + \varepsilon_{t+1}$$

By estimating the value, we can decide questions like how can one develop predictions for the expected exchange rate using the futures premium, i.e. if the futures premium indicates the trend of a weakening exchange rate or not.

If a positive correlation exists between the devaluation and the futures premium, the coefficient of the futures premium in equation (F1.3) must be positive ($\beta > 0$). A similar formula was examined by Fama (1984) who found that the coefficient is usually negative, i.e. in reality it is revaluation and not devaluation which can be linked to the futures premium. *Fama* called this phenomenon an anomaly *(forward premium anomaly)*.

The negative result of the Fama regression drew extensive interest. Having reviewed the empirical studies in 1990 and based on 75 published estimation results[1], *Froot* and *Thaler* (1990) found that the average of estimates for the β parameter was 0.88. While some of these were positive, none of the estimates of β produced a result reaching or exceeding 1.

It is not easy to explain the approximately minus 1 figure of the β coefficient in equation (F1.3). Assuming a flexible market where arbitrage options are eliminated and perfect predictions (which in our case would mean that $E(x_{t+1})=x_{t+1}$ is true), this parameter should equal plus 1. Understandably, this question was in the focus of researchers' interest and the overview written by *Sarno* (2005) mentioned several old and new reasons and approaches to explain this anomaly. A number of excuses can be cited for why uncovered interest rate parity is not happening in reality. E.g. the risk premium (which increases the return expectations of risk-averse investors, but this factor was not part of the equation that described the uncovered interest rate parity), exchange rate expectations are not perfectly rational, exchange rates are not only impacted by the market and its free development can be diverted by monetary policy interventions (McCallum, 1994, Chinn – Meredith, 2004). In Hungarian technical literature, a great overview of the subject is rendered in a paper by Gyula Barabás (1996) and *Zoltán Schepp* (2003). Both of them highlighted considerations that relate to forint exchange rate trends and, applying a new approach, Zoltán Schepp even provided a more general explanation to the phenomenon.

In the long run, however, macroeconomic fundamentals have a decisive impact on the exchange rate and many analyses prove that the paradox with the interest rate parity disappears as well.

[1] Many of these estimates were also discussed by Hodrick (1987), Lewis (1995) and Engel (1996).

Annex 2:
Interest rate parity, exchange rate and variance

In this paper we often refer to the article of Alvarez, F., Atkeson, A. and Kehoe, P. (2007), yet the explanations provided herein are different from theirs. It is worth therefore to outline their approach briefly which starts out from the overall theory of asset pricing. The terms and congruencies of the theory behind the explanation, consumption-based asset pricing are discussed in an excellent book by *Cochrane* (2001).

Starting out from the well-known asset pricing equation $P_t = E_t(m_{t+s} \cdot x_{t+s})$ where x represents future cash flow and m stands for the stochastic discount factor, we get the following formula by definition:

$$\text{(F.2.1)} \quad \exp(-i_t) = E_t(m_{t+1})$$

From this and using the $\log E(x) = E \log x + \frac{1}{2} \mathrm{var}(\log x)$ equation which expresses the expected value of random variables with lognormal distribution we get:

(F.2.2) $i_t = -E_t(\log m_{t+1}) - \frac{1}{2}\mathrm{var}_t(\log m_{t+1})$

After the introduction of a foreign exchange, Fernando Alvarez, Andrew Atkeson and Patrick J. Kehoe (2007) arrived at the following expression for the interest rate differential:

(F.2.3a) $i_t - i_t^* = E_t(\log m_{t+1}^*) - \log m_{t+1} - p_t$,

where

(F.2.3b) $p_t = \frac{1}{2}(\mathrm{var}_t(\log m_{t+1}^*) - \mathrm{var}_t(\log m_{t+1}))$

For complete arbitrage-free markets and, with some qualifications (see Alvarez, 2007, page 342) also for incomplete markets, the following equation between exchange rates and stochastic discount factors apply:

(F.2.4) $m_{t+1}^* = m_{t+1}\frac{z_{t+1}}{z_t}$.

Using (F.2.4) and adding it to formula (F.2.3a) as a substitution, we get

(F.2.5) $i_t - i_t^* = E_t(\log z_{t+1}) - \log z_t - p_t$

By rearranging the formula, we can express the expected extra returns on and risk premium of the investment into a foreign currency:

(F.2.6) $p_t = i_t^* + E_t(\log z_{t+1}) - \log z_t - i_t$

We can get a picture of the contents of the p_t risk premium by comparing[1] (F.2.3b) and (F.2.4):

(F.2.7)

$$p_t = \frac{1}{2}\mathrm{var}\left(\log\frac{z_{t+1}}{z_t}\right) + \mathrm{cov}\left(\log m_{t+1}, \log\frac{z_{t+1}}{z_t}\right)$$

Consequently, the risk premium is in close correlation with the variance of exchange rate changes and with the covariance of the exchange rate change and the stochastic domestic discount factor.

[1] $\mathrm{var}(\log m_{t+1}^*) = \mathrm{var}(\log m_{t+1}) + \mathrm{var}\left(\log\frac{z_{t+1}}{z_t}\right) + 2\cdot\mathrm{cov}\left(\log m_{t+1}, \log\frac{z_{t+1}}{z_t}\right)$

ANNEX 3: VOLATILITY OF OPTIONS

Based on the Black-Scholes model, the value of foreign exchange options can be calculated with the following formula for call (c) and put (p) options:

$$c = S\,exp(-r_f T)N(d_1) - X\,exp(-r_d T)N(d_2)$$

$$p = X\exp(-r_d T)N(-d_2) - S\exp(-r_f T)N(-d_1)$$

where

$$d_1 = \frac{\ln(S/X) + (r_d - r_f + \sigma^2/2)T}{\sigma\sqrt{T}}$$ and

$$d_2 = d_1 - \sigma\sqrt{T}.$$

Using the well-known notation, S stands for the prompt price (identical to *zt* in the study), X refers to the exercise price, σ is the dispersion of exchange rate fluctuations, r_d and r_f are the "domestic" and "foreign" risk-free interest rate in T years that matches the expiry of the option. In this study, i_t^* stands for r_f i.e. the euro interest rate while i_t represents the r_d forint interest rate.

One decisive parameter of the option's value is the volatility of the underlying. Like with many other instruments, the price of foreign exchange options is presented in volatility as opposed to a specific money amount, i.e. the option trader must put actual volatility as a replacement in the formula based on the current price of the underlying in order to calculate the fee receivable or payable on the option. The benefit of this solution is that the trader does not need to subscribe a new option price moment by moment if the price of the underlying changes.

The volatility applied in option pricing is forward-looking volatility, i.e. it reflects the expectations of market players regarding the volatility of the underlying until the expiry of the option. In case the option fee is presented in an amount of money, we usually talk about implied or discount volatility. In this scenario, put and call option fees are known for various exercise prices and with these we can numerically determine the σ parameter which we can use in the Black–Scholes formula to get a value that is identical to the market price of the option. This calculated value is the discount volatility or volatility implied by the market price of the option.

While this is forward-looking volatility, its trend is a good reflection of the actual market mood. Typically, in turbulent times discount volatilities go up along with risk premiums and realised volatilities. If the analyst chooses to calculate volatility not only for the exercise prices of *at-the-money* positions but also for prices that are further away from the prompt price (e.g. if X<S, we talk about an *in-the-money* position regarding call options and about an *out-of-the-money* position regarding put options), we get to the a volatility smile. The term comes from the typical graph shape of the discount volatilities / exercise prices function: In-the-money and out-of-the money volatilities are typically higher than the values calculated for the at-the-money exercise price. The reason is that while the Black–Scholes formula assumes normal distribution for the rate changes of the underlying, market players usually assign higher likelihood to extreme events which deviate from that distribution. In the case of exercise prices that are further away from the prompt price, market players "push up" the volatility value in order to compensate for the difference between normal distribution and observed (or expected) "fat tail" distributions. Thus we can draw conclusions from the volatility smile on market expectations regarding the distribution of the underlying.

A study by *Gray, Merton and Bodie* (2007) discusses in a clearly structured theoretical framework the assessment of the volatility of variables and the vulnerability of the economy.