Mikael Bask – Jarko Fidrmuc

Fundamentals and technical trading: behaviour of exchange rates in the CEECs

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Bank of Finland
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Finland
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Mikael Bask* – Jarko Fidrmuc**

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* Postal address: Monetary Policy and Research Department, Bank of Finland, P.O. Box 160, FIN-00101 Helsinki, Finland. E-mail address: mikael.bask@bof.fi

** Department of Economics, University of Munich, CESifo and Comenius University in Bratislava. E-mail: jarko.fidrmuc@lrz.uni-muenchen.de

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Mikael Bask –Jarko Fidrmuc
Monetary Policy and Research Department

Abstract

We present a model of exchange rates, which incorporates the monetary approach and technical trading, and we present the reduced form based on the minimal state variable solution, where both fundamentals and backward-looking term determine the spot exchange rates. Finally, we estimate the impact of the monetary fundamentals for a panel of Central and Eastern European countries (Czech Republic, Poland, Romania and Slovakia) in the second half of the 1990s as well as the complete model of exchange rate determination for daily data over the more recent free-floating period.

Key words: foreign exchange market, fundamental analysis, panel cointegration, technical analysis

JEL classification numbers: C23, F31, F36

Talouden perustekijät ja tekninen kaupankäynti: valuuttakurssidynamiikka Keski- ja Itä-Euroopan maissa

Suomen Pankin tutkimus
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Mikael Bask – Jarko Fidrmuc
Rahapolitiikka- ja tutkimusosasto

Tiivistelmä

Tässä työssä tarkastellaan teknisellä kaupankäynnillä täydennettyä monetaarista valuuttakurssimallia ja sen suppeimman tilamuuttujan ratkaisua, jonka mukaan valuutan käteismarkkinakurssi riippuu sen viipeiden lisäksi reaali- ja rahatalouden perustekijöistä. Rahataloudellisten perustekijöiden välitön valuuttakurssivaikutus estimoidaan kolmen Keski- ja Itä-Euroopan maan 1990-luvun jälkipuoliskon paneeliaineistossa. Lisäksi koko valuuttakurssin määräytymistä kuvaava malli estimoidaan lähivuosien joustavat valuuttakurssijärjestelmät kattavalla päivä-aineistolla.

Avainsanat: valuuttakurssimarkkinat, taloudellinen analyysi, paneeliyhteis-integroituvuus, tekninen analyysi

JEL-luokittelu: C23, F31, F36

Contents

1 Introduction

Ever since the seminal paper by Meese and Rogoff (1983), it has been a difficult task to predict the short-run movements of nominal exchange rates. They found that at horizons up to one year, none of the foreign exchange models could outperform the predictions of a random walk model. Remarkably, this was true even when the predictions of the models were based on realized, and not predicted, values of the explanatory variables, meaning that the out-of-sample fits of the models were surprisingly poor. According to Cheung et al (2005), there is still no single foreign exchange model that has outperformed the predictions of other models, including the random walk. It is, however, possible to find a specific model that do well for a certain exchange rate series, but not for other time series.

The aim of this paper is to augment a monetary exchange rate model with technical trading in foreign exchange to examine whether the resulting equation is suitable to explain nominal exchange rate movements. Indeed, a number of questionnaire surveys made at foreign exchange markets around the world reveal that currency trade behaviour is a complex phenomenon. That technical trading is used extensively in currency trade is confirmed in several surveys. Examples include Cheung and Chinn (2001), who conducted a survey at the U.S. market; Lui and Mole (1998), who conducted a survey at the Hong Kong market; Menkhoff (1997), who conducted a survey at the German market; Oberlechner (2001), who conducted a survey at the markets in Frankfurt, London, Vienna and Zurich; and Taylor and Allen (1992), who conducted a survey at the London market.

Technical trading, or chartism, utilizes past exchange rates to detect patterns that are extrapolated into the future. Focusing on past exchange rates is not considered as a shortcoming for agents using any of these technical trading techniques since a primary assumption is that all relevant information about future exchange rate movements is contained in past movements. Thus, chartism is purely behaviouristic in nature and does not examine the underlying reasons of currency traders. An extensive exploration of the psychology in currency trade behaviour is found in Oberlechner (2004), which is based on surveys conducted at the European and the North American markets.

While technical trading is a general phenomenon at foreign exchange markets around the world, we concentrate our paper on the developments in selected Central and Eastern European countries (CEEC's) during the accession to the European Union (EU). To be more specific, the focus is on the Czech Republic, Poland, Romania and Slovakia, and we selected these countries by the criteria of relatively flexible exchange rates between January 1996 and October 2004, and high trade volumes as indicated by, for example, capital inflows to these countries.

Although technical trading is important in general, we argue that CEEC's are more likely to be subject to self-fulfilling beliefs than other markets for a variety of reasons. Firstly, the specific conditions in these economies, especially the catching-up process reflected in fast productivity growth and the appreciation of their currencies (ie, the Balassa-Samuelson effect), cause standard concepts of the equilibrium exchange rate (eg, purchasing power parity) not to be directly applicable. Secondly, these countries received several times news related to the EU accession process influencing strongly the investors' attitudes. Finally, the prospect of the euro adoption creates potential for the so-called convergence game.

Surprisingly, there is little literature going behind the Balassa-Samuelson effect in the new member states (see MacDonald and Wójcik (2004) for a survey on this topic). An example, however, is Égert and Halpern (2006), who document large deviations of market exchange rates from various concepts of equilibrium exchange rates. Moreover, Crespo-Cuaresma and Hlouskova (2005) discuss the exchange rate disconnect puzzle for several countries of the region. Our paper aims to fill this gap in the literature and looks directly at the short-run dynamics of exchange rates in the new member states of the EU.

The rest of the paper is organized as follows: The monetary exchange rate model that is augmented with technical trading in foreign exchange is developed in Sections 2 and 3, whereas Section 4 contains our empirical work, and Section 5 concludes the paper.

2 Expectations formations in currency trade

Herein, we will describe the expectations formations used in the monetary approach to exchange rates that is outlined in the next section. To be more specific, the market expectations and the expectations formed by chartism and fundamental analysis about the next time period's exchange rate are formulated and discussed.

2.1 Market expectations

According to questionnaire surveys (see references in the previous section), the relative importance of technical versus fundamental analysis in the currency market depends on the time horizon in currency trade. For shorter time horizons, more weight is placed on technical analysis, or chartism, while more weight is placed on fundamental analysis for longer horizons. This observation is formulated as

$$s_{t+1}^{e} = \omega(\tau)\, s_{f,t+1}^{e} + (1-\omega(\tau))\, s_{c,t+1}^{e}, \tag{2.1}$$

where s^e, s_f^e and s_c^e are the market expectations and the expectations formed by fundamental analysis and chartism about the next time period's exchange rate, respectively, and the superscript e denotes expectations. Moreover, $\omega(\tau)$ is a weight function that depends on the 'artificial' time horizon, τ, in currency trade

$$\omega(\tau) = 1 - \exp(-\tau), \tag{2.2}$$

which is exogenously given in the model.

2.2 Chartism

The most commonly used technical trading technique is moving averages (see Lui and Mole (1998) and Taylor and Allen (1992)). According to this trading technique, buying and selling signals are generated by two moving averages; a short-period moving average and a long-period moving average. Specifically, a buy (sell) signal is generated when the short-period moving average rises above (falls below) the long-period moving average. In its simplest form, the short-period moving average is the current exchange rate and the long-period moving average is an exponentially weighted moving average of current and past exchange rates.

Thus, it is expected that the nominal exchange rate, s, will increase (decrease) when the current exchange rate is higher (lower) than an exponentially weighted moving average of current and past exchange rates

$$s^e_{c,t+1} - s_t = \gamma \left(s_t - MA_t \right), \tag{2.3}$$

where the exchange rate is defined as the domestic price of the foreign currency. Moreover, the long-period moving average, MA, is formulated as

$$MA_t = \left(1 - \exp\left(-v\right)\right) \sum_{j=0}^{\infty} \exp\left(-jv\right) s_{t-j}, \tag{2.4}$$

where the weights given to current and past exchange rates sum up to 1

$$\left(1 - \exp\left(-v\right)\right) \sum_{j=0}^{\infty} \exp\left(-jv\right) = 1. \tag{2.5}$$

Note that when $v \to 0$ or $v \to \infty$, the long-period moving average in (2.4) does not depend at all on past exchange rates. Specifically, for small v, all weights in the long-period moving average get small, including the weight given to the current exchange rate, while for large v, only the weights for past exchange rates get small, but the weight given to the current exchange rate approaches 1. However, even if past rates do not affect the expected rate, as in these special cases, the market expectations and the expectations formed by fundamental analysis do not coincide. Still, the time horizon in currency trade is not necessarily infinitely long, meaning that technical trading affects the exchange rate.

2.3 Fundamental analysis

When fundamental analysis is used in currency trade, it is assumed that the agents have rational expectations regarding the next time period's exchange rate

$$s^e_{f,t+1} = E\left[s_{t+1}\right], \tag{2.6}$$

where $E\left[s_{t+1}\right]$ is equal to the mathematical expectation of s_{t+1}, based on the information set available at time t, which includes the knowledge of the full model as well as the realized values of all variables in the model up to and including time t. Thus, because currency trade based on chartism is affecting the exchange rate, currency trade based on fundamental analysis will take this into account when forming exchange rate expectations.

In the next section, where we outline the baseline model for the monetary approach to exchange rate determination, we will also augment this model with the trading behaviour described in this section. Thus, we will derive the foreign exchange model that is taken to data in Section 4.

3 The monetary approach to exchange rates

The baseline model is in focus in the first subsection, whereas this model is augmented with technical trading in the second subsection.

3.1 The baseline model

The baseline model used in this paper is the monetary approach to exchange rate determination, which consists of two parity conditions, uncovered interest rate parity (UIP) and purchasing power parity (PPP), as well as equilibrium conditions at the domestic and foreign money markets.

The first parity condition is UIP, which states that the expected change of the exchange rate is equal to the difference between the domestic and foreign interest rates

$$s_{t+1}^{e} - s_t = i_t - i_t^{*}, \tag{3.1}$$

where i and i^* are the domestic and foreign nominal interest rates, respectively. The parity condition in (3.1) is based on the assumption that domestic and foreign assets are perfect substitutes, which only holds if there is perfect capital mobility. Since the latter also is assumed, only the slightest difference in expected yields would draw the entire capital into the asset that offers the highest expected yield. Thus, the parity condition in (3.1) is an equilibrium condition at the international asset market.

The second parity condition is PPP, which states that the exchange rate is equal to the difference between the domestic and foreign price levels

$$s_t = p_t - p_t^{*}, \tag{3.2}$$

where p and p^* are the domestic and foreign nominal price levels, respectively. The parity condition in (3.2) means that the domestic and foreign price levels, expressed in a common currency, are equal to each other. Thus, according to PPP, a relative increase (decrease) in the domestic price level not only means that the domestic price of the foreign currency increases (decreases), it also means that the increase (decrease) in the exchange rate is of such a magnitude that the price levels, expressed in a common currency, are still equal to each other.

Equilibrium at the domestic and foreign money markets hold when real money supply is equal to real money demand

$$m_t - p_t = \alpha y_t - \beta i_t, \tag{3.3}$$

and

$$m_t^* - p_t^* = \alpha y_t^* - \beta i_t^*, \tag{3.4}$$

where m and m^* are the domestic and foreign nominal money supplies, and y and y^* are the domestic and foreign real incomes, respectively. Thus, real money demand increases (decreases) when real income increases (decreases) or the interest rate decreases (increases). Note that we assume that the real income elasticities, α, in (3.3)–(3.4) are equal to each other. The same assumption is made for the interest rate semi-elasticities, β, in the same equations.

Now, if we substitute the conditions for money market equilibrium in (3.3)–(3.4) into the condition for PPP in (3.2), we have an equation describing the monetary approach to exchange rate determination

$$s_t = m_t - m_t^* - \alpha\left(y_t - y_t^*\right) + \beta\left(i_t - i_t^*\right). \tag{3.5}$$

According to (3.5), the exchange rate depreciates (appreciates) if the relative money supply increases (decreases). To be more specific, an increase (decrease) in the domestic money supply, relative to the foreign money supply, causes a one-to-one depreciation (appreciation) of the exchange rate. Moreover, the exchange rate depreciates (appreciates) when the relative income decreases (increases) as well as when the relative interest rate increases (decreases). The magnitudes of the two latter effects depend on the real income elasticity and the interest rate semi-elasticity, respectively.

3.2 Incorporating chartism

Substitute the condition for UIP in (3.1) into the monetary approach to exchange rate determination in (3.5), and solve for the current exchange rate

$$s_t = \frac{m_t - m_t^* - \alpha\left(y_t - y_t^*\right)}{1+\beta} + \frac{\beta s_{t+1}^e}{1+\beta}. \tag{3.6}$$

The main difference between the monetary approach in (3.5), and the same approach in (3.6), is that the market expectations about the next time period's exchange rate has replaced the relative interest rate. According to (3.6), the exchange rate depreciates (appreciates) in the current time period when the exchange rate is expected to depreciate (appreciate) in the next time period. Thus, (3.6) is characterized by a kind of self-fulfilling expectations, meaning that if the market believe that the currency will be weaker (stronger) in the next time period, it will be weaker (stronger) already in the current time period.

Technical trading is introduced into the baseline model in (3.6) via the expected exchange rate. This is accomplished in two steps. Firstly, the expectations formed by chartism and fundamental analysis in (2.3) and (2.6), respectively, are substituted into the market expectations in (2.1), where also the weight function in (2.2) and the long-period moving average in (2.4) are used in the derivation. Thus, an equation describing how the expected exchange rate is determined by technical trading and fundamental analysis is derived. Secondly, this equation is substituted into (3.6), the resulting equation is solved for the current exchange rate, and we have, finally, derived the monetary approach to exchange rate determination that has been augmented with technical trading in foreign exchange. See Lemma 3.1 and the proof of it for details.

Lemma 3.1 *The expectational difference equation for the full model is*

$$\begin{aligned} s_t &= x_1 \left(m_t - m_t^* - \alpha\left(y_t - y_t^*\right)\right) - \\ & \quad x_2 \sum_{j=1}^{\infty} \exp\left(-jv\right) s_{t-j} + x_3 E\left[s_{t+1}\right], \end{aligned} \tag{3.7}$$

where

$$\begin{cases} x_1 \equiv \frac{1}{1+\beta(1-\exp(-\tau)-\gamma\exp(-\tau-v))} \\ x_2 \equiv \frac{\beta\gamma\exp(-\tau)(1-\exp(-v))}{1+\beta(1-\exp(-\tau)-\gamma\exp(-\tau-v))} \\ x_3 \equiv \frac{\beta(1-\exp(-\tau))}{1+\beta(1-\exp(-\tau)-\gamma\exp(-\tau-v))} \end{cases}. \tag{3.8}$$

Obviously, since both chartism and fundamental analysis are used in currency trade, the current exchange rate is affected by past exchange rates (see the second term at the right-hand side of (3.7)) as well as expectational matters (see the third term at the right-hand side of (3.7)). It is also clear that $x_2 = 0$ when the time horizon in currency trade is infinitely long (see (3.8)), meaning that the term including past exchange rates in (3.7) vanish.

The linear difference equation in (3.7) has several rational expectations solutions. One way to circumvent this problem is by simplicity. Therefore, the minimal state variable (MSV) solution, suggested by McCallum (1983), is of interest, which is the solution to a linear difference equation that depends linearly on a set of variables such that there does not exist a solution that depends linearly on a smaller set of variables. See Proposition 3.2 and the proof of it for the MSV solution of (3.7) when the long-period moving average in (2.4) is a moving average of a finite ($j_{\max}$) number of past exchange rates. An obvious justification for the latter is the lack of an infinite amount of data.

Proposition 3.2 *The MSV solution to the expectational difference equation in (3.7) is*

$$s_t = \beta_0 \left(m_t - m_t^* - \alpha\left(y_t - y_t^*\right)\right) + \sum_{j=1}^{j_{\max}} \beta_j s_{t-j}, \tag{3.9}$$

where the parameters $\{\beta_j\}_{j=0}^{j_{\max}}$ *solve the following equation system:*

$$\begin{cases} \beta_0 = \frac{x_1+\beta_0 x_3}{1-\beta_1 x_3} \\ \beta_j = \frac{\beta_{j+1}x_3 - x_2\exp(-jv)}{1-\beta_1 x_3} \\ \beta_{j_{\max}} = -\frac{x_2\exp(-j_{\max}v)}{1-\beta_1 x_3} \end{cases}, \tag{3.10}$$

where $j \in \{1, ..., j_{\max}-1\}$.

Note that when the time horizon in currency trade is infinitely long, $\beta_{j_{\max}} = 0$ since $x_2 = 0$ in this case. According to (3.10), this also implies that all other parameters for past exchange rates in (3.9) vanish. Moreover, since $x_1 = \frac{1}{1+\beta}$ and $x_3 = \frac{\beta}{1+\beta}$ when the time horizon in currency trade is infinitely long (see (3.8)), $\beta_0 = 1$ and the solution in (3.9) reduces to

$$\overline{s_t} \equiv s_t|_{\tau\to\infty} = m_t - m_t^* - \alpha\left(y_t - y_t^*\right). \tag{3.11}$$

Thus, $\overline{s_t}$ is the exchange rate when there is no technical trading in the currency market. Consequently, this exchange rate is named the *fundamental exchange rate*. Then, if we utilize (3.11) in (3.9), we may write the MSV solution for the current exchange rate as

$$s_t = \beta_0\overline{s_t} + \sum_{j=1}^{j_{\max}} \beta_j s_{t-j}. \tag{3.12}$$

Be aware that the exchange rate s_t in (3.12) is the equilibrium exchange rate since it is assumed that the domestic and foreign money markets as well as the international asset market are continuously in equilibrium.

It is the foreign exchange model in (3.12) that forms the theoretical basis for our empirical work in the next section.

4 Data and empirical analysis

Our empirical work tries to reflect the behaviour of currency traders, who consider various sources and frequencies of financial data in their decisions. On the one hand, the majority of macroeconomic variables is available only in monthly or quarterly frequencies. These data are used to form expectations about the long-run trends at the foreign exchange market, ie, $\overline{s_t}$ in (3.11). Alternatively, we look also at the behaviour of moving averages, which are used to proxy the aforementioned trends. On the other hand, the actual trading decisions reflect the expectations of the short-run developments, which may deviate from the long-run trends. Therefore, we estimate separately the fundamental exchange rate with monthly data (or as a moving average over a relatively long period of time), and subsequently, the full model with chartism using daily data.

Following Crespo-Cuaresma et al (2005a)–(2005b), we estimate an extended version of the monetary exchange rate model for the Czech Republic, Poland, Romania and Slovakia. Our approach relaxes the PPP condition, which is assumed to hold only for tradable products (see Clements and Frenkel (1980)). This implies that the Balassa-Samuelson effect may play a role in the analyzed countries as noted, for example, by Égert and Lommatzsch (2004). Furthermore, we estimate the monetary model jointly for a panel of all four involved countries since the individual time series are relatively short (from July 1994 to September 2004).

Our model based on (3.11) can be stated as

$$\overline{s_{it}} = \delta_i + \eta_t + \gamma_1 \left(m_{it} - m_{it}^*\right) + \gamma_2 \left(y_{it} - y_t^*\right) + \gamma_3 \left(p_{it} - p_t^*\right), \tag{4.1}$$

where m and y denote, as in the previous section, money (M2) and real income (industrial production). In addition, p stands for the relative prices (ie, the ratio of consumer and producer prices), which are assumed to proxy the Balassa-Samuelson effect. Variables of the euro area are indicated by an asterisk. Finally, δ and η denote fixed and time effects, while γ are the model parameters (elasticities).

Given the inflation and growth differentials between the CEEC's and the EU, all variables can be expected to be non-stationary. Table 1 summarizes the results of the Im, Pesaran and Shin (2003) test (IPS test), which is a panel version of the standard augmented Dickey-Fuller test, for the variables in levels and first differences.[1] The null hypothesis of a heterogenous panel unit root cannot be rejected for any variable in levels, while it is clearly rejected for the first differences.

	Exchange Rate	Money (M2)	Industrial Production	Price Ratio
IPS test, levels	1.110	0.011	2.146	2.205
IPS test, first differences	-16.616***	-16.199***	-29.694***	-23.140***

Note: *** denotes significance at the 1 per cent level.

Table 1: Panel Unit Root Tests, 1994:4–2004:9

Because all involved variables are non-stationary, Kao (1999) and Kao and Chiang (2000) recommend ordinary least squares (OLS), dynamic OLS (DOLS) and DOLS with time effects (DOLST), which can be found in Table 2. Although there are not many differences between the specifications, we use DOLS for further analysis.

[1] The IPS test in levels includes an intercept and a trend while the test in first differences includes only an intercept.

Parameter	OLS	DOLS	DOLS-T	DOLS-SUR
γ_1	0.800***	0.831***	0.833***	0.831***
	(123.712)	(85.462)	(52.196)	(112.542)
γ_2	-0.724***	-0.791***	-0.974***	-0.730***
	(-19.628)	(-21.095)	(-16.161)	(-20.091)
γ_3	-1.230***	-1.145***	-0.873***	-1.110***
	(-18.111)	(-16.089)	(-6.589)	(-19.292)
No. of obs.	504	504	504	504
Panel ADF test	-17.914***	-17.397***	-35.353***	-18.162***

Note: t-statistics are in parenthesis. *** denotes significance at the 1 per cent level. The intercept, fixed and time effects are not reported.

Table 2: Panel Estimation of the Monetary Model, 1994:4–2004:9

The panel cointegration tests (panel ADF tests) confirms that all specifications provide a true cointegrating relationship. Therefore, we continue our empirical analysis with the estimation of the full model in (3.12), including an error correction term

$$\Delta s_t = c + \rho \Delta s_{t-1} + \theta \left(\overline{s_t} - s_{t-1} \right). \tag{4.2}$$

That is, the full model includes technical trading that is proxied by an autoregressive process. A positive autoregressive coefficient, ρ, means that technical analysis may introduce herding behaviour of investors in the foreign exchange market. In turn, the fundamental analysis is reacting to the deviation from the fundamental exchange rate as observed in the previous period with coefficient θ that should be positive for a mean reverting process. We estimate this model for the Czech Republic, Poland, Romania and Slovakia, which had relatively broad fluctuation bands or free floating between January 1996 and October 2004. This period is chosen according to the availability of daily data[2] as well as macroeconomic data for the estimation of the fundamental exchange rate.

The fundamental exchange rate, $\overline{s_t}$, is given from the previous panel estimation that, however, only is available at monthly frequencies. Our robustness analysis with smoothed data did not change any results. Alternatively, the fundamental exchange rate may be proxied by the moving average of the last and coming month (ie, ± 20 trading days), respectively. We also use alternative lengths of the moving average in our sensitivity analysis, which are available upon request. As far as daily data provide a sufficient number of observations, and the individual behaviour of investors is more likely to differ between countries than the determination of the fundamental exchange rates, we estimate (3.12) separately for the individual countries.

The results are summarized in Table 3. In general, the market exchange rates deviate considerably from the estimated fundamental exchange rates, which is also reported in the literature (see Égert and Lommatzsch (2004)). Therefore, we excluded the starting period for the Czech Republic, and

[2] For Romania, we have daily exchange rate data starting only in January 1998.

included a dummy for selected periods in the Czech Republic and Poland, which are characterized by a strong persistent appreciation of the exchange rates. Also, after these modifications, the correction behaviour of exchange rates is weaker for the specifications using the panel estimations of the fundamental exchange rates than for those using a moving average of ±20 trading days. However, it should be noted that the difference is less important if we use longer moving averages (eg, ±120 trading days).

A. The fundamental exchange rate is estimated by the DOLS specification				
	Czech R.[a]	Poland[b]	Romania	Slovakia
ρ	0.035*	-0.050**	0.057**	0.048**
	(1.677)	(2.395)	(2.332)	(2.315)
θ	0.004**	0.003**	0.005**	0.003**
	(2.183)	(2.294)	(2.205)	(2.575)
Period	1996:1-2004:9	1996:1-2004:9	1998:1-2004:9	1996:1-2004:9
No. of obs.	2283	2283	1673	2283
R^2	0.004	0.008	0.006	0.005
DW	1.989	2.001	2.000	1.997
B. The fundamental exchange rate is proxied by the moving average				
	Czech R.	Poland	Romania	Slovakia
ρ	0.116***	0.056***	0.166***	0.139***
	(5.591)	(2.672)	(7.025)	(6.751)
θ	0.169***	0.217***	0.193***	0.190***
	(14.777)	(16.299)	(14.655)	(15.915)
Period	1996:1-2004:9	1996:1-2004:9	1998:1-2004:9	1996:1-2004:9
No. of obs.	2283	2283	1673	2283
R^2	0.088	0.106	0.114	0.102
DW	1.977	1.999	1.960	2.015

Note: The intercept term is not reported. t-statistics are in parenthesis. a A dummy variable for 1997:1 to 1997:12 is not reported. b Dummy variable for 1999:11 to 2001:5 is not reported. *, **, and *** denote significance at the 10, 5, and 1 per cent level, respectively.

Table 3: Estimation of Portfolio Behaviour

In both specifications, the stabilization parameter θ is significant at least at the 10 per cent level. The estimated autoregressive coefficient is found to be small but positive in all specifications, except for Poland with panel estimates of the fundamental exchange rate. This implies that the corresponding autoregressive coefficient for the exchange rate in levels is larger than one. Thus, technical trading contains explosive features, which are counteracted by the error correction behaviour at the market in the long-run.

Our sensitivity analysis confirmed this pattern for different lengths of the moving average used for the computation of the fundamental exchange rates in the Czech Republic and Slovakia. Only in Poland, we find $\rho < 0$ at least for some specifications, which implies stationary properties of the non-differenced time series. Nevertheless, it is interesting to note that the error correction term is explaining a relatively large part of the variance of short-run exchange rate movements. This variable is also very robust, especially for the moving average specifications and significant in specifications without autoregressive terms, while ρ is often not significant.

5 Concluding discussion

There are not too many papers that incorporate technical analysis in a foreign exchange model, and we believe there are two reasons for this. The first is that most researchers do not believe that currency traders using chartism can survive in the market, and the second reason is that even if some researchers are aware of the use of chartism in currency trade, most of them argue that it is of uttermost importance to explain *why* these traders survive in the market. We are sympathetic to this standpoint, but we also believe that this may be a hindrance to a better understanding of the *effects* of chartism in currency trade since it is not easy to develop a theoretical framework to explain human behaviour at the currency market or any financial asset market.

We incorporated technical trading into the monetary exchange rate model. Furthermore, we estimated the model for a group of four CEEC's, which have introduced the policy of free floating in the late 1990s. We argue that the technical trading approach is likely to be used in these countries because of the lack of data on fundamental variables and the importance of news regarding, for example, the EU accession and the macroeconomic performance.

Actually, we find that the backward-looking parameters contribute significantly to the determination of spot exchange rates. Furthermore, the analysis of the backward-looking parameters shows that technical trading is likely to increase the volatility in the market. In turn, we also find feed-back behaviour driving the exchange rate to its fundamental value, although the parameter is relatively small. Overall, this means that the foreign exchange market have already developed a complex structure of different trader types, which is documented for developed countries in earlier literature.

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Proofs

Proof of Lemma 3.1

Firstly, the expectations formed by chartism and fundamental analysis in (2.3) and (2.6), respectively, are substituted into the market expectations in (2.1)

$$s^e_{t+1} = \omega(\tau) E[s_{t+1}] + (1 - \omega(\tau))(s_t + \gamma(s_t - MA_t)). \tag{5.1}$$

Thereafter, substitute the weight function in (2.2) and the long-period moving average in (2.4) into (5.1)

$$\begin{aligned} s^e_{t+1} &= (1 - \exp(-\tau)) E[s_{t+1}] + \exp(-\tau) \cdot \\ & \left(s_t + \gamma \left(s_t - (1 - \exp(-v)) \sum_{j=0}^{\infty} \exp(-jv) s_{t-j} \right) \right). \end{aligned} \tag{5.2}$$

Secondly, substitute (5.2) into the baseline model in (3.6), solve for the current exchange rate, and the proof is completed.

Proof of Proposition 3.2

Assume that the solution in (3.9) is correct, determine the rationally formed forecast of the next time period's exchange rate, substitute this forecast into the difference equation in (3.7), and solve the resulting equation for the current exchange rate

$$\begin{aligned} s_t &= \frac{x_1 + \beta_0 x_3}{1 - \beta_1 x_3} \cdot (m_t - m^*_t - \alpha(y_t - y^*_t)) + \\ & \frac{1}{1 - \beta_1 x_3} \cdot \sum_{j=1}^{j_{\max}-1} \left(\beta_{j+1} x_3 - x_2 \exp(-jv) \right) s_{t-j} - \\ & \frac{x_2 \exp(-j_{\max} v)}{1 - \beta_1 x_3} \cdot s_{t-j_{\max}}, \end{aligned} \tag{5.3}$$

where

$$m_t - m^*_t - \alpha(y_t - y^*_t) = m_{t-1} - m^*_{t-1} - \alpha\left(y_{t-1} - y^*_{t-1}\right), \tag{5.4}$$

has been utilized in the derivation, ie, it is assumed that the so-called fundamentals are constant over time. Then, the equation system for the parameters $\{\beta_j\}_{j=0}^{j_{\max}}$ in (3.10) is derived by comparing the parameters in (3.9) with those in (5.3), and the proof is completed.

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Suomen Pankki
Bank of Finland
P.O.Box 160
FI-00101 HELSINKI
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