Are exchange rates in CEE countries driven by monetary fundamentals? Evidence from a panel approach

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Abstract. The paper investigates whether nominal exchange rates in Central and Eastern European countries are driven by monetary fundamentals. The conventional monetary model is modified to include the difference in the relative price of non-tradables since this is a potentially important factor for exchange rate determination in emerging market economies. Using quarterly data spanning from 2001q1 until 2012q4 we detect cross-sectional dependence in our panel. Thus, in order to avoid erroneous inferences about cointegration and causality, we apply the methodology for non-stationary panels, which allows for cross-sectional dependence.

We find evidence of cointegration implied by the extended monetary model. Though estimated coefficients deviate slightly from those implied by the theory, their signs are correct. Granger causality tests reveal that: (i) in the long-term the exchange rates revert to the equilibrium relation identified; (ii) in the short-term exchange rate Granger-causes the differential in relative price of non-tradables and is Granger-caused by the relative money supply. The results are driven neither by episodes of high inflation nor by the global financial crisis.

Keywords: monetary exchange rate model, Central and Eastern European countries, cross-sectional dependence, panel cointegration, Granger causality.

JEL Classification: C33, E44; F41, F36
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1 Introduction

The exchange rate determination has become one of the major puzzles in international macroeconomics since Meese and Rogoff [12] demonstrated that a random walk model predicts exchange rates as well as any structural model in the short-run and Mussa [13] observed that the exchange rate volatility differed across exchange rate regimes even though volatility of macroeconomic fundamentals did not. Exchange rates were seen as instable and their fluctuations as disconnected from macroeconomic fundamentals.

Advancement in econometrics, however, has opened new avenues for research and equipped researchers with new econometric techniques. It was found that the null hypothesis of no cointegration between the nominal exchange rate and fundamentals was difficult to reject empirically because the available spans of data were relatively short and the standard tests had low power (see [21]). Thus, the natural way to overcome this problem was to use panel data[4]. The line of research based on panel cointegration methods turned out to be relatively successful in 're-connecting' an exchange rate with fundamentals both for advanced economies (see, e.g., [11], [5]) and emerging market economies (see, e.g., [6], [22], [23]).

Though studies on exchange rates in CEE countries that adopt this approach provide the evidence of cointegration between exchange rate and monetary fundamentals (e.g., [6], [22], [23]), their findings are rather tentative rather than conclusive. There are three problems that cast some doubt on the results. First, in these studies the first generation unit root tests (e.g. IPS or LLC) and the first generation panel cointegration tests (see [15]) are used. A common feature of such tests is the assumption of cross-sectional independence of panel units. If it is invalid the null hypotheses of non-stationarity and a lack of cointegration are rejected too often (see [2]). Second, the datasets used in the previous studies covered periods of high inflation. Since the monetary approach to the exchange rate 'performs fairly well when inflation is high' (see [10]), the previous results for CEE countries could be driven mainly by inflation differentials (see e.g. [22]). Third, though the monetary model is supposed to

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[4] An alternative was to use long spans of data (see [19]). This is not discussed due to data availability constraint for CEE countries.

explain exchange rate fluctuations in countries under relatively flexible exchange rate arrangements, panels used in the previous studies included countries with fixed exchange rate arrangements (e.g. Baltic states with currency boards were included in [22]).

In this paper we examine whether the exchange rates of CEE currencies (against the euro) are related to macroeconomic fundamentals as implied by the monetary model. Our contribution to the literature is threefold. First, we find evidence of long-run relationship between nominal exchange rate and fundamentals in CEE countries that is consistent with the monetary model and more reliable than the results of extant studies. Unit root and cointegration tests employed in this paper allow on cross-sectional dependence, the sample period is not contaminated with the episodes of high inflation and the panel consists of countries with relatively flexible exchange rate regimes. Second, the Granger-causality analysis reveals that the nominal exchange rate is related to fundamentals both in the long-run (it readjusts to the equilibrium relation after a shock), and in the short-run. Third, even though the global financial crisis (GFC) has had a relatively strong impact on CEE countries (in comparison with Asian and Latin American emerging market economies), our results are not driven by the recent crisis.

The paper is organised as follows. In the next section we sketch the monetary model of exchange rate determination. Section 3 briefly presents methodology applied in the analysis of cross-sectional dependence, cointegration and causality. Empirical results are discussed in Section 4. Conclusions are offered in the last section.

2 The monetary model of the exchange rate

The monetary model of the exchange rate determination has become something of a workhorse in the exchange rate literature (see [6]). It is used to explain movements in exchange rates both in advanced economies (see e.g. [12], [8]) and in emerging market economies (see e.g. [6], [22], [7]).

Its three building blocks include: money market equilibrium conditions (in the domestic and foreign economies), the absolute purchasing power parity and the uncovered interest rate parity (see [20]). Under expectations that are rational and not explosive ('no bubbles' condition), the solution for the log of nominal exchange rate $s_{i,t}$, defined as a price of domestic currency in terms of foreign currency, is

$$s_{i,t} = (1-b)\sum_{j=0}^{\infty} b^j \mathrm{E}_t v_{i,t+j} \tag{1}$$

where $i = 1,\ldots,N$ corresponds to cross-sectional units, $t = 1,\ldots,T$ denotes the time period, E_t is the expectation formed on the basis of an information set available in the time t, b is a function of an interest rate semi-elasticity of money demand, and $v_{i,t}$ stands for the monetary fundamentals:

$$v_{i,t} \equiv -\left(m_{i,t} - m_t^*\right) + \kappa\left(y_{i,t} - y_t^*\right) + \left(p_{i,t} - p_{i,t}^T\right) - \left(p_t^* - p_t^{T*}\right) \tag{2}$$

Thus, the exchange rate is determined by current and expected future levels of fundamentals: relative stock of money, $m_{i,t} - m_t^*$, relative output, $y_{i,t} - y_t^*$, and a difference in the relative price of non-tradables[5], $(p_{i,t} - p_t^*) - (p_{i,t}^T - p_t^{T*})$. All variables are in log form and the asterisk denotes a foreign variable.

Subtracting $v_{i,t}$ from both sides of (1), it is possible to demonstrate that (see e.g. [20]):

$$s_{i,t} - v_{i,t} = \sum_{j=1}^{\infty} b^j \mathrm{E}_t \Delta v_{i,t+j} \tag{3}$$

From (1) we know that if fundamentals are non-stationary $I(1)$ processes, the nominal exchange rate is non-stationary as well. Transformation given by (3) reveals that exchange rate and its fundamentals are cointegrated with cointegrating vector $(1,-1)'$. Thus, the implied long-run equilibrium relationship to be examined in the empirical section is:

$$s_{i,t} = \beta_1\left(m_{i,t} - m_t^*\right) + \beta_2\left(y_{i,t} - y_t^*\right) + \beta_3\left[\left(p_{i,t} - p_{i,t}^T\right) - \left(p_t^* - p_t^{T*}\right)\right] + \varepsilon_{i,t} \tag{4}$$

[5] Here we make use of the definition of the general price level as a weighted average of prices of tradables and non-tradables that implies: $p_t - p_t^T \equiv \alpha(p_t^N - p_t^T)$. The parameter κ is an income elasticity of money demand.

with $\beta_1 = -1, \beta_2 = \kappa > 0, \beta_3 = 1$ and the error term, ε_t.

3 Methodology and data

In this study we use a panel cointegration technique to test the long-term and short-term relationships between the nominal exchange rate and macroeconomic fundamentals. According to [1], the default assumption of independence between cross-sections seems to be inadequate both in the cointegration analysis and causality analysis. Incorrect cross-sectional independence assumptions may lead to erroneous causal inferences. Therefore, to test for the presence of such cross-sectional dependence in our data, we apply two different statistics, Lagrange multiplier (*LM*) (see [4]) and *CD* (see [17]), with the null hypothesis claiming no cross-sectional dependence.

The estimation of the panel cointegration requires testing whether the variables contain unit roots. We use second-generation panel CIPS unit root test proposed in [18]). To test for cointegration we used the second generation tests proposed in [24]. The equation for Westerlund cointegration tests can be formulated as follows:

$$s_{i,t} = \beta_0 + \beta_1 m^r_{i,t} + \beta_2 y^r_{i,t} + \beta_3 x^r_{i,t} + \varepsilon_{i,t} \tag{5}$$

where $i = 1,\ldots,N$ denotes the number of countries in the panel, and $t = 1,\ldots,T$ denotes the time period. The variables $s_{i,t}$, $m^r_{i,t} \equiv m_{i,t} - m^*_t$, $y^r_{i,t} \equiv y_{i,t} - y^*_t$, $x^r_{i,t} \equiv (p_{i,t} - p^*_t) - (p^T_{i,t} - p^{T*}_t)$, denote the natural logarithm of nominal exchange rate, the natural logarithm of money supply, the natural logarithm of real income, and the natural logarithm of the relative price of non-tradables for each country *i*, respectively. A superscript *r* means that the variable is a difference between the relevant home and foreign level. The monetary model of exchange rate determination implies that we should expect $\beta_1 < 0$, $\beta_2 > 0$ and $\beta_3 > 0$.

Given the presence of cointegration, we estimate the long-term parameters in the cointegrating vector. For this study, we use fully modified ordinary least squares FMOLS estimator (see [16]). The last step is to estimate a panel vector error correction model. This final representation is used to determine Granger causal relations between the variables. The two-step procedure of Engle-Granger (see [9]) is performed first by estimating the long-term model specified in Eq. (5) to obtain the estimated residuals, and then by defining the lagged residuals from Eq. (5) as the error correction term. The panel VECM can be written as follows:

$$\Delta s_{i,t} = \omega_{1i} + \sum_{j=1}^{p} \gamma_{11ij} \Delta s_{i,t-j} + \sum_{j=1}^{p} \gamma_{12ij} \Delta m^r_{i,t-j} + \sum_{j=1}^{p} \gamma_{13ij} \Delta y^r_{i,t-j} + \sum_{j=1}^{p} \gamma_{14ij} \Delta x^r_{i,t-j} + \theta_{1i} ECT_{i,t-1} + u_{1i,t}, \tag{6a}$$

$$\Delta m^r_{i,t} = \omega_{2i} + \sum_{j=1}^{p} \gamma_{21ij} \Delta s_{i,t-j} + \sum_{j=1}^{p} \gamma_{22ij} \Delta m^r_{i,t-j} + \sum_{j=1}^{p} \gamma_{23ij} \Delta y^r_{i,t-j} + \sum_{j=1}^{p} \gamma_{24ij} \Delta x^r_{i,t-j} + \theta_{2i} ECT_{i,t-1} + u_{2i,t}, \tag{6b}$$

$$\Delta y^r_{i,t} = \omega_{3i} + \sum_{j=1}^{p} \gamma_{31ij} \Delta s_{i,t-j} + \sum_{j=1}^{p} \gamma_{32ij} \Delta m^r_{i,t-j} + \sum_{j=1}^{p} \gamma_{33ij} \Delta y^r_{i,t-j} + \sum_{j=1}^{p} \gamma_{34ij} \Delta x^r_{i,t-j} + \theta_{3i} ECT_{i,t-1} + u_{3i,t}, \tag{6c}$$

$$\Delta x^r_{i,t} = \omega_{4i} + \sum_{j=1}^{p} \gamma_{41ij} \Delta s_{i,t-j} + \sum_{j=1}^{p} \gamma_{42ij} \Delta m^r_{i,t-j} + \sum_{j=1}^{p} \gamma_{43ij} \Delta y^r_{i,t-j} + \sum_{j=1}^{p} \gamma_{44ij} \Delta x^r_{i,t-j} + \theta_{4i} ECT_{i,t-1} + u_{4i,t}, \tag{6d}$$

where *p* is the optimal lag length(s) determined by the BIC, $ECT_{i,t}$ is the error correction term, that is the lagged residuals from the panel FMOLS estimation of the Eq. (5), and the error term $u_{i,t}$ is assumed to be i.i.d. with a zero mean and constant variance. The VECM is estimated using SUR techniques that allow for cross-sectional specific coefficient vectors and cross-sectional correlation in the residuals.

We use the balanced panel of quarterly data spanning from 2001:4 till 2012:4 for eight CEE countries: the Czech Republic, Hungary, Moldova, Poland, Romania, Serbia, Turkey and Ukraine. Nominal exchange rates are end-of-quarter observations from the IMF/CEIC database. They are expressed in euros per national currency, so an increase means an appreciation of national currency. Our measure of money stock is an aggregate M2 from the IMF/CEIC database. Real GDP is used to measure economic activity. The data come from the national sources for Moldova and Serbia, from the IMF/CEIC for Turkey and Ukraine, and from the Eurostat for other countries. The general price levels are measured with GDP deflators and are collected from the same sources as

GDPs. Producer price indices from the IMF/CEIC database are used as a proxy for the price of tradables. All variables are expressed as indices (2005 = 100) and specified in natural logarithms. The seasonal adjustment has been done by means of the Eviews default version of the Census X12 algorithm.

4 Empirical results

The analysis of panel data begins with testing for cross-sectional dependence. The results of two different cross-sectional dependence test statistics, LM (see [4]), and CD (see [17]), reject the null hypothesis of no cross-sectional dependence with p values lower than 1 percent for all variables included in our framework. Since we find evidence of cross-sectional dependence among the variables, we use the second-generation panel unit root tests (see [18]) and we apply the cointegration test developed in [24]. CIPS unit root test results for both 'constant' and 'constant and trend' specifications do not reject the null of unit roots for the panel at level for most variables, on the contrary, the differenced series are stationary. After establishing the nonstationarity of the time series, we test for the existence of the long-term relationship between the nominal exchange rate and macroeconomic fundamentals using the Westerlund cointegration test. G_a and G_t group test statistics show that the null hypothesis of no cointegration for at least one of the cross-sectional units is rejected in favour of cointegration at the 5 percent level. Similarly, P_a and P_t panel test statistics using the pooled information over all cross-sectional units indicate that the null hypothesis of no cointegration for the whole panel is rejected at the 10 percent level[6]. Overall, the results of cointegration tests reveal the existence of the long-term relationship between the nominal exchange rates and fundamentals in CEE countries even if the cross-sectional dependence is allowed for.

Since evidence confirms the long-term relationship, we next estimate long-term coefficients using the panel FMOLS. The FMOLS estimates of equation (5) are as follows:

$$s_{i,t} = 4.586 - \underset{(-4.717)^{***}}{0.300}\, m^r_{i,t} + \underset{(2.649)^{***}}{0.502}\, y^r_{i,t} + \underset{(6.776)^{***}}{1.349}\, x^r_{i,t} \tag{7}$$

where the numbers in parentheses are t-statistics and variables.

Since variables are in natural logarithms, the estimated coefficients can be interpreted as long-run elasticities. All of them are highly significant and correctly signed. One per cent increase in the money supply triggers depreciation against the euro by 0.3 per cent in the long-run. Though it is smaller than the one per cent depreciation implied by the model, it is in line with estimates found in the literature. Beckmann et al. [3] estimate that for 18 OECD countries it is even lower (0.20), whereas the estimates for CEE countries provided in [6] range from 0.300 to 0.975 depending on the method applied.

One per cent rise in the relative output brings about an appreciation by 0.5 per cent. The finding that the income elasticity is greater than the money supply elasticity is in accordance with the results available for advanced economies in [3] or [11], but not with those for CEE countries obtained in [6] and [23]. The difference can be an outcome of inflation differentials dominance over the dataset, i.e. the flaw discussed in Section 1. Since we avoid this flaw, the estimate of β_2 is closer to the one for advanced economies, although still well below it (0.502 vs. 1.6 obtained in [3]).

One per cent increase of a differential in relative price of non-tradables results in a nominal appreciation against the euro of 1.3 per cent. This can be interpreted as a manifestation of the BS effect: a certain fraction of real currency appreciation takes a form of a nominal appreciation.

In the final step we estimate a panel vector error correction model in order to uncover the Granger causal relations between the variables. The Granger causality test is based on the model with a dynamic error correction term. Table 1 presents F-statistics and t-statistics which are useful in the short- and long-run Granger causality analyses respectively. Table 1 shows that the exchange rate is Granger caused by the relative money in the short run. On the one hand, it is a bit surprising since as pointed by Engel et al. [8] 'the models have little power to forecast exchange rate changes'. On the other hand, evidence of such a causality is also found in [8] for OECD countries. We conjecture that the exchange rate may possibly be considered an implicit target of monetary policy.

It is interesting to observe the causality running from exchange rate to the difference in relative price of non-tradables. As explained in [8] it is the causality of that type that is implied by the monetary model: an exchange rate is a reflection of expected future levels of fundamentals. Thus, it may be useful in predicting the fundamentals (assuming that the unobservable fundamentals are not a primary driver of an exchange rate).

[6] Detailed test results on cross-sectional dependence, unit roots and cointegration are available upon request.

Dependent variable	Source of causation (independent variables)				
	Short term - F-statistics				Long term - t-statistics
	Δs	Δm^r	Δy^r	Δx^r	ECT_{t-1}
Δs	-	9.675***	0.028	0.003	-5.113***
Δm^r	0.475	-	1.664	0.760	3.296***
Δy^r	1.741	6.122**	-	1.512	1.343
Δx^r	8.731***	0.005	0.529	-	3.552***

Notes: The null hypothesis is that there is no causal relationship between variables. Δ is the first difference operator. ECT_{t-1} represents the error correction term lagged one period. ***, **, * indicate statistical significance at 1, 5 and 10 percent level of significance, respectively.

Table 1 Panel Granger causality test results

The coefficient for the ECT in the exchange rate equation is significant, so the nominal exchange rate is related with fundamentals in the long-run as well. It indeed adjusts to the equilibrium relation implied by the model. Interestingly, the relative output seems to be weakly exogenous in the long-run (the coefficient on ECT is insignificant) and thus the return to the equilibrium relation after a shock involves changes in variables other than the relative output.

CEE countries as a group were severely hit by the crisis especially in comparison with Asian and Latin American emerging market economies. Thus, we introduce a crisis dummy in order to check whether the results of causality analysis are not an offshoot of the crisis. Results from Table 2 can be summarized as follows: even with the crisis dummy both short- and long-run relations remain unchanged. The exchange rate adjusts to the long-run equilibrium relation and in the short-run it is a Granger cause of the differential in relative price of non-tradables.

Dependent variable	Source of causation (independent variables)				
	Short term - F-statistics				Long term - t-statistics
	Δs	Δm^r	Δy^r	Δx^r	ECT_{t-1}
Δs	-	7.466***	0.192	0.163	-5.233***
Δm^r	0.381	-	1.493	0.632	3.329***
Δy^r	1.586	5.541**	-	0.640	1.006
Δx^r	7.254***	0.159	0.120	-	3.288***

Notes: Crisis dummy is equal to 1 for 2008:3-2009:4 and 0 otherwise. The null hypothesis is that there is no causal relationship between variables. Δ is the first difference operator. ECT_{t-1} represents the error correction term lagged one period. ***, **, * indicate statistical significance at 1, 5 and 10 percent level of significance, respectively.

Table 2 Panel Granger causality test results for a specification with a crisis dummy.

5 Conclusion

Using the second generation panel unit root and cointegration tests we have found that exchange rates and fundamentals in CEE countries are cointegrated as implied by the monetary model of exchange rate determination. This finding holds even though evidence of cross-sectional dependence among CEE countries is strong, the sample does not include periods of high inflation and the panel consists of countries with relatively flexible exchange rate regimes. Estimated elasticities deviate slightly from those implied by the theory but they are significant and correctly signed.

Granger causality tests reveal that in the long-term the exchange rates revert to the equilibrium relation identified. In the short-term the exchange rate is Granger-caused by the relative money supply and Granger-causes the differential in relative price of non-tradables. The results are not driven either by high inflation episodes or by the global financial crisis.

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