Doctoral (PhD) thesis summary

THE ANALYSIS OF THE LONG RUN BEHAVIOUR OF NOMINAL EXCHANGE RATES

An empirical testing of monetary exchange rate models

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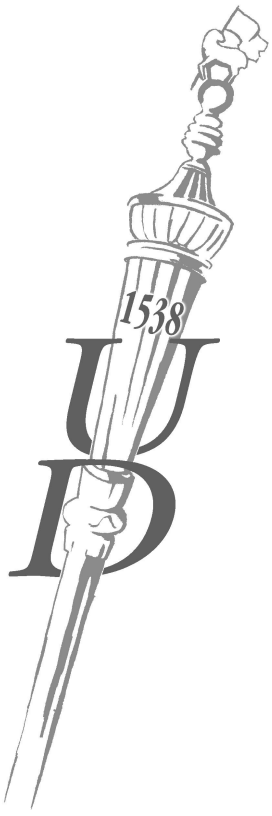

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1 THE OBJECTIVES OF THE DOCTORAL THESIS

Motivation

The relative price of two currencies can show extreme volatility especially in case of floating exchange rates, but the exchange rate volatility can observable also in the long run. The economists are interested in the explanation of both the short and long run behaviour of the exchange rate for a long time. The simplest exchange rate model already emerged in the 1920s then Rogoff [1996] pointed out one of the exchange rate puzzles: 1) how can model the long run behaviour of the exchange rates wherein persistent discrepancies can be perceived form its long run equilibrium level, 2) and how can explain the extreme short run volatility of the exchange rates. In the literature this problem is referred as PPP puzzle. In this study we are looking for an explanation only for one dimension of the PPP puzzle, for the long run behaviour of nominal exchange rates.

In addition the purchasing power parity the most decisive long run equilibrium exchange rate model for the nominal exchange rates is the monetary exchange rate model. The exchange rate models are appraised from two perspectives by the literature: 1) the models are estimated for the sample period then the estimated coefficients will be compared to the theoretical coefficients, 2) the other method is the investigation of the forecasting ability of exchange rate models. The monetary exchange rate models are crucial elements of both the international economics and the exchange rate modelling even so their empirical validity is controversial. But despite their empirical failure it is not certain that these theoretical models must be rejected. On the one hand it is feasible that the problem must be looked for in the technique of testing, because using inappropriate techniques will cause estimation biases, or rather lead to spurious regressions. On the other hand the criteria that out-of-sample prediction power is better than a random walk may be too strong and the models should be evaluated from other perspectives (*Engel et al.* [2007]). Since Meese and Rogoff [1983] seminal paper – in which they established that consider the forecasting ability the monetary exchange rate models do not outperform the random walk – several papers have tested the forecasting ability of the monetary exchange rate models. But based on the forecasting ability of a model hardly can conclude its explanatory ability. In this study we investigate only the explanatory ability of the monetary exchange rate models, and in second part its central assumption, the purchasing power parity – which is also a long run equilibrium model – that is we only estimate these models. We suppose that these models can properly explain the long

run behaviour of the nominal exchange rate models, but to justify this it is need to apply adequate methodological process.

Objectives, key research questions

The monetary exchange rate models – and also the PPP – were handled as a short run model for a long time. But when it is accepted that these approaches are long run equilibrium models such methodological processes become required which can capture these long run effects. Engle – Granger [1987][1] seminal paper brought breakthrough with the elaboration of the concept of cointegration. Thus relationships between nonstationary variables became investigable if the variables are cointegrated, that is if long run equilibrium relationship exists between them. But in many cases neither with cointegration methods succeeded in justifying the assumptions of the monetary exchange rate models. The time series techniques did not bring smashing success in several cases. In the literature a number of persons attributed the failure of empirical testing of monetary exchange rate models to the short sample length. In such circumstances the power of unit root and cointegration tests are too low to reject the null hypothesis of no cointegration between the variables. But the accuracy of the tests and the estimations can be increased with the rise of the number of the observations. This can be reached by two ways: 1) examining longer time series than usual, 2) arranging the data in a panel data set. Accordingly in the study we conduct both time series and panel analyses.

The monetary exchange rate models (and the PPP) can be tested also in weak and strong concept. In weak testing concept we consider the models empirically justified if the cointegration can be revealed between the nominal exchange rate and the examined variables. Thus our first research question by the time series analyses is:

Research question 1: *Can be empirically justified the assumptions of the monetary exchange rate models in weak testing concept in the case of the examined exchange rates, that is can be revealed the long run equilibrium relationship with the applied time series cointegration tests between the four nominal exchange rates and the examined monetary macro-fundamentals (nominal money supply, real income)? If yes, is it realized rather by the unrestricted or the restricted specifications?*

[1] The definition of the integration and the coinetgration has already defined by Granger [1981].

If the examined exchange rates in weak testing concept confirmed the assumptions of the monetary exchange rate models it is not sure that this is also the case in strong testing concept. We would like to know if we receive the expected theoretical signs by each variable and if the size of the coefficient approximates the expected theoretical size. Thus our second research question is:

Research question 2: *Can be empirically justified the assumptions of the monetary exchange rate models in strong testing concept in the case of the examined exchange rates that is do the monetary macro-fundamentals (nominal money supply, real income) affect the long run behaviour of the four examined exchange rates in accordance with the assumptions of the monetary exchange rate models? If yes, primarily in case of which specification can be justified this?*

The other solution to increase the number of the observations is arranging the data in a panel data set. During the panel estimations we examined the U.S. dollar exchange rate of 14 OECD countries and the eurozone with five cointegrated panel estimation methods. By these examinations we are also looking for the answer if the estimations of the available samples empirically justify the assumptions of the monetary exchange rate models, and its central condition, the purchasing power parity. Thus the third and the fourth research questions are:

Research question 3: *Can be revealed the cointegration between the examined U.S. dollar exchange rates of the OECD countries and the monetary macro-fundamentals (nominal money supply, real income, price level) with panel coinetgartion tests that is can be empirically justified the assumptions of the monetary exchange rate models and the purchasing power parity in a weak testing concept? If yes, in case of which specifications?*

Research question 4: *Do the monetary macro-fundamentals (nominal money supply, real income, price level) affect the long run behaviour of the U.S. dollar exchange rates of the OECD countries in accordance with the assumptions of the monetary exchange rate models and the purchasing power parity, that is can be empirically justified the assumptions of the two long run equilibrium exchange rate models in a strong testing concept? If yes, which specifications and estimation methods provided preferential (which are in accordance with the theory) results?*

Since the panel investigations probably provide more accurate results because of the greater number of observations thus in these cases the fulfilment of the proportionality and the symmetry hypothesis by the monetary exchange rate models and the PPP were examined. However we did not consider the fulfilment of these hypotheses as a condition by the confirmation of the models. Thus our following research question is:

Research question 5: *Are the proportionality and the symmetry hypotheses realized during the estimation of the examined U.S. dollar exchange rates of the OECD countries? Which long run equilibrium exchange rate model typifies the fulfilment of the two hypotheses in case of the examined samples?*

Since the empirical justification of the monetary exchange rate models and the PPP is a controversial question in the literature thus our last research question is in connection with the received results and the applied methodology. Based on the empirical results in the literature we assume that with appropriate methodological process, and by longer time series than the foregoing or by panel data the crucial role of the monetary macro-fundamentals in determining the long run behaviour of the nominal exchange rate can be confirmed. The question is if the results of the investigations on the available samples support this assumption or not. Thus this sixth question is connected to the first four research questions.

Research question 6: *Can be empirically justified by the examined samples – by longer time series than the foregoing and panel data – with cointegration methods that the monetary macro-fundamentals (nominal money supply, real income, price level) affect the behaviour of the nominal exchange rate in accordance with the assumptions of the monetary exchange rate models and the purchasing power parity in the long run?*

Answering the research questions we would like to contribute the debate in connection with the empirical justification of the monetary exchange rate models and the purchasing power parity.

2 THE APPLIED METHODOLOGY

Methodology of the time series analyses

As the long run equilibrium relationship between the nominal exchange rate and monetary macro-fundamentals is examined by means of monetary exchange rate models, our prior hypothesis is these variables are cointegrated[2] that is exists a linear combination of them which is stationary. The cointegration can exist only between nonstationary variables therefore we examined the order of integration of the variables with Augmented Dickey Fuller (ADF) and Ng − Perron unit root test, and Kwiatkowski − Phillips − Shmidt − Shin (KPSS) stationary test. The null hypothesis of the ADF and Ng − Perron test is that the examined time series is a unit root process, as long as the null hypothesis of the KPSS test is that the examined process is stationary. Since the tests are sensitive to the models of the time series in case of the ADF test all the three model possibilities (the time series includes a) an intercept, b) an intercept and a trend, c) none of them), in case of the Ng − Perron and KPSS test both model possibilities (the time series includes a) an intercept, b) an intercept and a trend) were examined. By the ADF and Ng − Perron test the lag length in the auxiliary regression was determined by automatic method, with the Schwarz information criteria. (*Dickey − Fuller* [1979], *Ng − Perron* [2001], *Kwiatkowski et al.* [1992])

After the examination of integration of the variables we tested the cointegration between them. On one hand this is a weak test of the monetary exchange rate models. If we succeeded in revealing cointegration between the examined variables then the conjectures of monetary exchange rate models can be accepted in a weak sense. On the other hand the cointegration between the examined variables is the assumption of the specification of a cointegrated VAR model. In addition we need to know the number of the cointegrating vectors, and the model which fit the best on the cointegrating vector(s) (and on the error correction equations), hence we used Johansen cointegration test. (*Johansen* [1991, 1995]) In case of the restricted, two-variable specification we applied the Engle − Granger two-step procedure to investigate the cointegration. We estimated a linear model by OLS on the level of the variables (on the reduced form of the monetary models), then tested the residuals with the three test mentioned above (ADF, Ng − Perron, KPSS) if it is stationary or not. (*Engle − Granger* [1987]) However the residual based test can reveal only one cointegrated vector, but the equilibrium

[2] We can read about the cointegration in Hungarian among others in Kovács [1989], Kőrösi et al. [1990] and Darvas [2004].

could be maintained by more equilibrium mechanism. The cointegration test advocated by Johansen [1991, 1995], based on maximum likelihood estimation, is able to exhibit more cointegrating vectors. All the specifications were investigated by the Johansen test. From the five model possibilities of the Johansen test we selected the best fitting model among others by information criteria, but we also consider the autocorrelations of the residuals.

By the estimation and identification (if there are more cointegrating vectors) of the cointegrated VAR models we can identify the long run equilibrium mechanism, the cointegrating vectors. Since in this case the signs and the size of the coefficients in the cointegrating vectors can be investigated and also the adjustment process[3] through the error correction coefficient, therefore it is a strong test of the monetary exchange rate models. Since we would like to examine if the monetary macro-fundamentals influence the nominal exchange rate in the long run hence we normalized the cointegrating vectors primarily for the exchange rate (*Boswijk* [1996]), except for if it showed weak exogeneity (*Burke – Hunter* [2005]). If the exchange rate is weakly exogenous, then we cannot detect the conjectures of the monetary exchange rate models, because the exchange rate does not adjust to the long run equilibrium while we would like to identify a process like this. In the case of more cointegrating vectors we identified them with restrictions. We considered the following viewpoints by imposing the restrictions: 1) we took into account the ideas of the theory, 2) it was imposed zero restrictions on the non-significant variables, 3) the LR statistics was also considered, 4) then the autocorrelations of the residuals of the given specification, 5) and the information criteria to investigate the fitting of the model. In the case of one cointegrating vector we did not impose any restrictions; we ran an unrestricted cointegrated VAR model.

The order of the cointegrated VAR models, that is the lag length of the differenced variables, was determined also by information criteria (AIC, BIC, Hannan – Quinn). First we specified an initial VAR model and from the different lag length models it was selected the best fitting one. The order of the vector error correction model is less by one by definition (*Lütkepohl* [2005]). The unbiasedness of the estimation is based on the assumption that the residuals are uncorrelated, homoskedastic and normal distributed thus we ran the following diagnostic tests on the residuals of the cointegrated VAR models: the autocorrelation LM test, the White heteroskedasticity test and the Jarque-Bera residual normality test. In addition we tested the stationarity of the residuals with IPS (Im – Pesaran – Schin), Fisher – ADF and

[3] If the exchange rate does not adjust, then long run equilibrium relationship does not exist, while we would like to identify long run equilibrium exchange rate models. For this reason we report the error correction coefficients of the exchange rates, although it reflects primarily short run dynamics.

Fisher – PP unit root test based on the idea of the Engle – Granger two-step procedure. If the residuals of the cointegrated VAR models are stationarity it can imply cointegration between the variables. These tests were selected because they assume heterogeneous autoregressive structure for the examined time series. Their null hypothesis is the assumption that the examined time series contain a unit root. (*Im et al.* [2003], *Maddala – Wu* [1999]) Presumably, we would reach more accurate results if we applied time series unit root tests but these results serve only as complement information.

The long run behaviour of the nominal exchange rate is determined by the monetary exchange rate models only if its conjectures be realized. If we conduct only a weak test it is enough to investigate only the existence of the cointegration between the variables. In this concept if the Engle – Granger test or the Johansen test reveal cointegration between the variables it will justify the conjectures of the monetary exchange rate models. If we examine the long run equilibrium mechanism in details and we expect that the signs and the size of the coefficients of the variables in the cointegrating vectors do not depart significantly from the conjectures of the monetary exchange rate models, then we can talk about a strong test of the model. In this concept two hypotheses can be investigated: the proportionality and the symmetry hypothesis. According to the proportionality hypothesis the coefficient of the nominal money supplies does not depart significantly from unity. That is the change in the nominal money supplies entirely reflects the change of the nominal exchange rate. According to the symmetry hypothesis the size of the coefficient of the domestic and the foreign variable does not deviate significantly form each other. This hypothesis can be investigated only in the case of the unrestricted specification. We do not consider the fulfilment of the symmetry hypothesis as a criterion of the justification of the monetary exchange rate models because the dissimilarity of the coefficient of the domestic and foreign variables is an assumption, which is closer to reality. Thus in a strong testing concept we consider the monetary exchange rate models justified if there exist cointegration – that is the adjustment to the long run equilibrium can be detected –, the signs of the coefficients of the variables in the cointegrating vector match to the conjectures of the theory and the size of the coefficients converge to the expected size. If the cointegration exists, but the sings of the coefficients are wrong, that is the exchange rate adjusts such a cointegrating vector which does not reflect the conjectures of the monetary exchange rate models, then we cannot find empirical support for the monetary exchange rate models. If we succeeded in identifying an appropriate cointegrating vector but the exchange rate does not adjust to this, then we empirically cannot confirm the monetary exchange rate models, again. In addition the proportionality hypothesis was also examined,

but we do not consider as a necessary criterion – similar to the symmetry hypothesis – in justifying the monetary models. (Applying the panel method usually better results can be reached, thus it is worth examining them in this concept.)

Methodology of the panel analyses

As we could see by the time series analyses the cointegration can only be interpreted among non-stationary processes; therefore we must investigate the order of the integration of our variables before testing the cointegration also by the panel analyses. Since the unit root tests are, in general, very sensitive, we applied more tests to check the robustness of our results: Im, Pesaran, Shin (IPS), Fisher-ADF, Fisher-PP and Hadri tests (*Im et al.* [2003], *Maddala – Wu* [1999], *Hadri* [2000]). The Hadri test is the only one which has the null hypothesis of stationarity (the alternative hypothesis is that a few cross sectional units contain a unit root, but not all do so); the other three tests are panel unit root tests. The IPS *t*-statistics are the average of the individual ADF tests; the null hypothesis is that all the time series contain a unit root, and the alternative hypothesis is that a few cross sectional units contain a unit root (*Im et al.* [2003]). The Fisher type tests combine the *p*-value of the individual unit root tests across the cross sections. Their null hypothesis is also the conjecture of the unit root in the time series (*Maddala – Wu* [1999], *Baltagi* [2008]). In case of the IPS and Fisher-ADF test the lag length in the auxiliary regression was determined by Schwarz information criterion, as long as by the Fisher-PP and the Hadri test Bartlett kernel was applied to correct the feasible autocorrelation. In the interest of the robustness of the results, all model possibilities were tested, i.e. the time series a) includes an intercept, b) includes a constant and a trend, and c) includes none of the formers. The selection of the tests was influenced by their assumptions. There are tests which presume there is an identical autoregressive structure at each cross sectional unit, but this assumption is far from realness. The selected tests have no such an assumptions, they permit the different autoregressive structure of the pooled time series, with the exception of the Hadri test (but this is the only panel stationarity test which is supported by software packages).

If only the cointegration between the variables is investigated it is a weak test of monetary exchange rate models. If the cointegration between the examined variables can be revealed then in a weak concept we can consider the monetary exchange rate models as confirmed empirically, in the opposite case we cannot find empirical evidence for the monetary exchange rate models. Furthermore if we would like to apply cointegrated panel estimation methods it is an assumption that the variables in the cross sectional units are cointegrated. The

panel cointegration tests have greater power than the time series tests thus rarely accept incorrectly the null hypothesis of no cointegration. During the analysis three panel cointegration tests were applied: the Pedroni, the Kao and the Westerlund panel cointegration test (*Pedroni* [2001, 2004], *Kao* [1999], *Westerlund* [2007]). The Pedroni and the Kao test use the idea of the Engle and Granger [1987] time series cointegration test in the sense that they are residual-based tests; both tests include the null hypothesis of no cointegration among the examined variables. Pedroni [2000, 2004] proposes several tests to examine the cointegration in panels. The tests can be divided into two groups: 1) there are tests which average the test statistics of the individual time series across the cross sectional units, 2) other tests are based on averaging not the test statistics as a whole, but make separate averages for the numerator and for the denominator terms. (*Baltagi* [2008]) The tests also differ in terms of the assumption of the time series autoregressive structure, i.e. some tests assume an identical autoregressive structure of the examined time series and other tests allow different autoregressive structures. Since the assumption of identical autoregressive structures is far from realistic, we use only tests which allow enough heterogeneity. Because these tests are also sensitive to the modelling of the time series, all the model possibilities – i.e. the time series a) includes an intercept, b) includes a constant and a trend, and c) includes none of the former – were investigated to check the robustness of the results. (*Pedroni* [2001, 2004], *Baltagi* [2008]) The Kao test also has DF and ADF tests, but we only use the ADF test statistics. There is only one modelling possibility: the time series including an intercept. (*Kao* [1999]) In both cases the residuals are obtained from the panel fixed effects estimation and the lag order in the auxiliary regression was determined with automatic method, the Schwarz information criterion. (*Baltagi* [2008])

But the residual based panel cointegration tests were criticised among others Westerlund [2007]. This kind of tests has a great disadvantage; they assume that the long- and short-run coefficients are equal, which can reduce the power of the tests considerably (*Westerlund* [2007]). Thus we also applied the test statistics of Westerlund [2007]. These tests have also the null hypothesis of no cointegration among the examined variables. The adjustment parameter of a conditional panel error-correction model is analyzed to see whether it is zero or not. If the adjustment parameter is zero, there is no cointegration among the examined variables; if it is less than zero, the variables are cointegrated. The test not only allows the heterogeneity of the short-run parameters but can also manage cross section dependence. Westerlund [2007] constructed four tests, which can be divided into two groups on the

grounds of their alternative hypotheses. Two tests (P_τ, P_α) investigate whether the panel cointegrated as a whole, the alternative hypothesis of the other two tests (G_α, G_τ) is that at least one unit in the panel is cointegrated.

Previously, in the case of the panel analysis, it was typical to assume the cross section independence of the residuals but this does not apply in several cases. This is mainly true with large cross sectional units (i.e. with more than 10 cross sectional units) (*Pesaran* [2004]). In our case, it is not only the somewhat restricted number of the cross sectional units, but the application of the US dollar as the anchor currency which can be the origin of the cross section dependence. Our examined exchange rates are all dollar exchange rates, thus all the cross sectional units contain the US variables. This can be cause cross section dependence between the residuals. Also two common factors can be appeared in the exchange rates, either is the variation in the value of the dollar, the other is the variation in the US price indices, which appear also in the monetary exchange rate models through the purchasing power parity. These two common components can be defined as two common shocks, which influence every exchange rate in the panel. In addition other common shocks (for example a cyclical change in a given region) can also cause cross section dependence (*O'Connell* [1998]). Therefore we also analyzed the extent of the possible cross section dependence between the residuals and the variables. We used the Pesaran [2004] CD test based on the average of pair-wise correlation coefficients. We obtained the residuals from the pooled mean-group (PMG)[4] estimation of the panel, which is a typical cointegrated panel estimation method; it results asymptotically unbiased and normal distributed parameter estimation (*Pesaran et al.* [1999]). In the presence of cross section dependence the distribution of the Westerlund test statistics is changed hence running the tests again we report bootstrapped *p*-values. Then we assess the results of the panel cointegration tests by the bootstrapped *p*-values.

Then we estimated the six panels applying five cointegrated panel estimation methods (FM-OLS, DOLS, DFE, MG, PMG) on three specifications of the reduced form of the monetary exchange rate models and on a central assumption of the monetary models, on the purchasing power parity. Thus we can check the robustness of the results. This is a strong test of the monetary exchange rate models. We do not consider the fulfilment of the proportionality and in the case of the unrestricted specification the symmetry hypothesis as a criterion of the justification of the monetary exchange rate models, though we investigated

[4] Since according to the theory the examined panels are cointegrated, and the previous tests also exhibit the cointegration, we chose such a panel estimation method which is typically applied for estimating cointegrated panels.

them. If the signs in the estimated cointegrated vectors accord to the theory and the size of the coefficients approximate[5] the expected size then we can consider the monetary exchange rate models and the purchasing power parity empirically justified in a strong concept. The dynamic fixed-effects (DFE), the mean-group (MG) (*Pesaran et al.* [1995]) and the pooled mean group (PMG) estimation (*Pesaran et al.* [1999]) estimate a panel error correction model, thus these methods estimate also the error correction coefficients. In these cases we apply similar decision rules as by the time series analyses. Thus in a strong testing concept we consider the monetary exchange rate models and the purchasing power parity justified if there exist cointegration – that is the adjustment to the long run equilibrium can be detected –, the signs of the coefficients of the variables in the cointegrating vector match to the conjectures of the theory and the size of the coefficients converge to the expected size. If cointegration exists, but the sings of the coefficients are wrong, that is the exchange rate adjusts such a cointegrating vector which does not reflect the conjectures of the monetary exchange rate models, then we cannot find empirical support for the monetary exchange rate models and the purchasing power parity. If we succeeded in identifying an appropriate cointegrating vector but the exchange rate does not adjust to this, then we empirically cannot confirm the monetary exchange rate models and the purchasing power parity, again.

The fully modified ordinary least square (FM-OLS) and the dynamic ordinary least square (DOLS) do not estimate the error correction coefficient only the cointegrating vector. In addition the methods do not report the variable for which the cointegrating vector was normalized. Both estimation are based on the triangular representation of a regression specification, as in Hansen [1992], and assume one common cointegrating vector for all cross sectional unit. But they allow individual fixed effects (if we specify them) and the heterogeneity of the short run effects at the cross sectional units. It is assumed that between the independent and the dependent variables the existence of the cointegration can be revealed, but the cross sectional units are not cointegrated. Originally none of the methods were panel estimation method. The FM-OLS was elaborated by Phillips − Hansen [1990], which was revised by Phillips − Moon [1999], Pedroni [2001a] and Kao – Chiang [2001] to panel estimation method. The DOLS was primarily developed by Stock − Watson [1993] and

[5] Since in the case of the time series analyses we may face two-digit parameters during the estimation, thus we evaluated positive result that in the course of the panel estimation in every case one-digit parameters were estimated. In absolute value the least coefficient at till considered the model justified was 0.106 and the greatest was 3.698. But we received in several cases such parameters, which are fairly close to one, thus even if the estimated results would be assessed based on stricter criterion, it can be also found empirical support for the monetary exchange rate models and the purchasing power parity, just a bit in fewer cases. However if we require the fulfilment of both the proportionality and the symmetry hypothesis by the assessment of the results then we could consider the models empirically justified only in a few cases.

Saikkonen [1992] for analyzing cointegrated time series, which was adapted by Kao – Chiang [2001], Mark − Sul [2003] and Pedroni [2001b] for cointegrated panel estimation. The FM-OLS is appropriate for the estimation of the cointegrating vectors of heterogeneous panels till the DOLS was originally developed for homogeneous panels. Although according to Kao – Chiang [2001] simulation results in the case of heterogeneous panels the bias of the FM-OLS estimation increases compared to the estimation of homogeneous panels and they also establish that the DOLS provide less biased results in most cases. The FM-OLS corrects the endogeneity and the autocorrelation in the traditional OLS since it leads strongly biased results in case of cointegrated time series. The DOLS contains not only the level of the explanatory variables but the lags and leads of the differenced variables (Δx_{it}) (also for the treatment of the endogeneity and the autocorrelation). (*Kao – Chiang* [2001], *Pedroni* [2001a])

Both estimations were conducted in three variations: we applied a pooled, a pooled weighted and a grouped mean versions of the estimations. The pooled estimation run the standard FM-OLS and DOLS on the pooled sample after removing deterministic parts from both the dependent and the independent variables. The grouped mean estimation calculates the mean of the FM-OLS and DOLS cross section estimations. The pooled weighted estimation tries to capture the heterogeneity, but the weights are different at the two estimations because of technical differences. The pooled weighted FM-OLS applies the individual estimation of the long run covariances to reweight the data before calculates the pooled estimation. The DOLS applies the cross section estimation of the conditional long run residual variances to reweight the moments of the cross sectional units when computes the pooled DOLS estimation. (*Kao – Chiang* [2001], *Pedroni* [2001a]) The cointegrated vectors and the equations of the explanatory variables also include a constant in case of both estimations. From 1980Q1 and shorter panels in case of the two- and three-variable specifications of the monetary exchange rate models the equations of the explanatory variables also involve a trend beside the constant by both estimations, because the fitting of the model proved better. By the DOLS the cross section-specific lag length and leads order were determined by automatic method, the Schwarz information criterion. Since the estimation (the size of the coefficients and the *t*-statistics) is sensitive for the lags and leads order (and presumably for the additional settings), we estimated the models with the settings of Kao – Chiang [2001], that is 2 lags and 1 leads were also applied.

The DFE, the MG and the PMG estimations are primarily used for estimating such nonstationary heterogeneous panels in which the number of cross section observations and also the number of time series observations are large. The DFE is a traditional fixed-effects estimation, till the mean-group and the pooled mean group relatively new estimation methods which was developed by Pesaran et al. [2005, 1999]. The three estimation methods differ in how much the estimated parameters can vary across the cross sectional units. The DFE allows only the intercepts heterogeneity (e.g. $\Delta e_{it} = \beta_{i0} + \gamma(e_{it-1} - \alpha_1 f_{it-1}) + \beta_1 \Delta f_{it} + u_{it}$). The MG estimates N time series regressions and averages the coefficients (e.g. $\Delta e_{it} = \beta_0 + \gamma(e_{it-1} - \alpha_1 f_{it-1}) + \beta_1 \Delta f_{it} + u_{it}$) thus in this case the intercepts, the slope coefficients and the residual variances are allowed to differ across the cross sectional units. The PMG assume a common cointegrating vector for every cross sectional unit, but the adjustment parameters and the short run effects (the intercepts, the short run parameters and the residual variances) can differ across individuals (e.g. $\Delta e_{it} = \beta_{i0} + \gamma_i(e_{it-1} - \alpha_1 f_{it-1}) + \beta_{i1} \Delta f_{it} + u_{it}$). The PMG applies maximum likelihood estimation. (*Pesaran et al.* [1995], [1999]) But the DFE and the PMG do not provide consistent estimate in every case. The DFE forces the homogeneity of the slope coefficients on the model, but if they are heterogeneous in truth then the DFE estimates will be inconsistent and misleading. In addition the DFE models are subject to simultaneous equation bias because of the endogeneity between the residual and the lagged dependent variable. But the extent of the endogeneity can be measured with the Hausman test. The PMG constrains the long run homogeneity on the data. If this restriction is true then the results will be efficient and consistent. However if the long run effects are heterogeneous along the cross sectional units then the PMG estimations will be inconsistent. The MG provides consistent estimations even if the originally parameters are homogeneous or heterogeneous, that is in both cases. Thus we can examine with the Hausman test that from the three estimations which fits the best to data. (*Blackburne III – Frank* [2007])

3 RESULTS AND THESES

The foreign exchange rate is one of the monetary macro-fundamentals which have crucial importance in the economic performance (e.g. important channel of monetary transmission through which the output can be influenced in the short run and it has a significant role in preserving the price stability). The explanation of the short run volatility and the long run

behaviour of the nominal exchange rate are also in the centre of inquiry of the economists. This paper tries to explain the long behaviour of nominal exchange rates.

During the time series analyses the Danish krone, the Canadian dollar and the yen U.S. dollar exchange rates were analyzed by quarterly data in the floating period in two specifications (five- and two-variable model) for two intervals: until 1997 and 2012. Besides we reported the results of the Hungarian forint-euro exchange rate also for two specifications. In a weak concept the exchange rates were analyzed with Engle – Granger two-step procedure and Johansen coinetgration test. Based on the results rather by the five-variable, unrestricted specifications can be justified the existence of a long run equilibrium relationship between the nominal exchange rate and the monetary macro-fundamentals. Thus the following thesis was conceived:

Thesis 1: *In weak testing concept the Hungarian forint-euro, the Danish krone, the Canadian dollar and the yen U.S. dollar exchange rates in certain specifications can empirically justify the existence of a long run equilibrium relationship between the examined monetary macro-fundamentals (nominal money supply, real income) and the nominal exchange rate. By the analyzed samples this can be revealed primarily in the case of the unrestricted, five-variable specifications, exception the Hungarian forint euro exchange rate, by which this long run equilibrium relationship can also unanimously exhibit in the case of the restricted specifications.*

In strong concept we found preferential results just by the restricted specifications, exception the Danish krone U.S. dollar exchange rate. In addition by the Hungarian forint-euro exchange rate it can be confirmed that its long run behaviour is in accordance with the assumptions of the monetary exchange rate models only if the Balassa – Samuleson effect is also captured by the model. Thus the following thesis can be formulated:

Thesis 2: *In strong testing concept the Hungarian forint-euro, the Canadian dollar and the yen U.S. dollar exchange rates in the case of the restricted (two-variable) specifications empirically justify that the examined monetary macro-fundamentals (nominal money supply, real income) affect the long run behaviour of the nominal exchange rate in accordance with the assumptions of the monetary exchange rate models. We cannot say this about the Danish*

krone, and by the Hungarian forint-euro exchange rate the above assertion can confirm only when the Balassa – Samuelson effect is captured by the model.

The results of the time series analyses are accordance with, among others, Darvas and Schepp [2007b] (in the case of the Hungarian forint-euro exchange rate), Rapach and Wohar [2004] (in the case of the Danish krone U.S. dollar exchange rate), Zhang et al. [2007] (in the case of the Canadian dollar U.S. dollar exchange rate) and Dutt and Gosh [2000] (in the case of the yen U.S. dollar exchange rate) results.

During the panel analyses 14 OECD countries and the eurozone U.S. dollar exchange rates were investigated by quarterly data. Since in case of certain countries the data were available for restrained time interval six panels were constructed which are differ in the length of the examined time period and the number of the cross sectional units: the panels with larger time dimension (e.g. 1973Q1-2011Q4), have fewer cross sectional units, while the shorter panels (e.g. 1996Q1-2011Q4) include more exchange rates. The empirical validity of three specifications of the monetary exchange rate models and the purchasing power parity were investigated both in weak and strong testing concept. The Kao, the Pedroni and the Westerlund panel cointegration tests were applied in the weak concept. We found empirical support for the reduced form of the monetary exchange rate models and the purchasing power parity by all the six panels. Consider the whole investigation (if by the Pedroni test we decide only on the strength of the ADF test statistics) the monetary exchange rate models a bit more than in 76% of the cases, the purchasing power parity approximately in 67% of the cases can be empirically justified. Based on the results the following thesis can be ascertained:

Thesis 3: *In weak testing concept the examined U.S. dollar exchange rates of the OECD countries by all the samples at least in case of one testing process confirm the empirical validity of the monetary exchange rate models and the purchasing power parity that is the existence of a long run equilibrium relationship between the examined monetary macro-fundamentals (nominal money supply, real income, price level) and the nominal exchange rate. All the three specifications of the monetary exchange rate models were justified by all the samples at least by one estimation method, though we received better results in case of the restricted models. Primarily the panels, which are shorter and containing more exchange rates, provided more preferential results.*

In strong testing concept the six panels were estimated with five cointegrated panel estimation methods: with FM-OLS, DOLS, DFE, MG and PMG estimation methods to investigate if the monetary macro-fundamentals affect the long run behaviour of the nominal exchange rate in accordance with the assumptions of the examined models. Consider the whole investigation the reduced form of the monetary exchange rate models a bit more than in 51% of the cases, the purchasing power parity approximately in 72% of the cases can be empirically justified. Based on the estimation results the followings can be established:

Thesis 4: *In strong testing concept the examined U.S. dollar exchange rates of the OECD countries with all the applied cointegrated panel estimation methods nearly by every sample at least in case of one specification empirically justify that the examined monetary macro-fundamentals (nominal money supply, real income, price level) affect the long run behaviour of the nominal exchange rate in accordance with the assumptions of the monetary exchange rate models and the purchasing power parity. In addition the followings can be established: 1) With the FM-OLS and the DOLS method we found justification for the examined models by every sample, 2) with the DFE, the MG and the PMG estimation we could not justify the monetary exchange rate models in case of the 1973Q1-2011Q4 panel and the purchasing power parity in case of the 1976Q4-2011Q4 panel, 3) by the justification of the monetary exchange rate models the DOLS method was the most successful according to our decision criteria, 4) the restricted (primarily the two-variable) specifications performed better from among the specifications of the monetary exchange rate models, 5) we found empirical support for the purchasing power parity greater percentage of the investigations, 6) during the panel estimations also such panels provided more preferential results, which are shorter and containing more exchange rates.*

The results of the panel analyses are confirm, among others, Mark – Sul [2001], Rapach – Wohar [2004], Basher – Westerlund [2009], Cerra – Saxena [2010], Dąbrowski et al. [2014] results in case of the monetary exchange rate models, and Pedroni [2001], Pedroni [2004], Robertson et al. [2014] results in case of the purchasing power parity among others.

However nor by the evaluation of the estimations of the monetary exchange rate models, neither by the purchasing power parity was determined as acceptance criterion that the proportionality and the symmetry hypothesis be realized by the estimated coefficients; we investigated them with Wald test in case of each panel estimation. If we consider the whole examination then in the case of the estimated significant variables of the monetary exchange

rate models a bit more than in 21% of the cases, and in the case of the estimated significant variables of the purchasing power parity a bit more than in 38% of the cases the Wald test did not reject the proportionality hypothesis. The symmetry hypothesis was not rejected by the Wald test in the case of the estimated significant variables of the monetary exchange rate models again a bit more than in 21% of the cases, and in the case of the estimated significant variables of the purchasing power parity in 26% of the cases. On the basis of the results the followings can be conceived:

Thesis 5: *During the estimation of the U.S. dollar exchange rates of the OECD countries by the examined monetary macro-fundamentals (nominal money supply, real income, price level) in certain cases the Wald test do not reject the proportionality and the symmetry hypothesis. In connection with this the followings can be conceived: 1) the two hypotheses can be realized also in such cases when the monetary exchange rate models and the purchasing power parity could not be confirmed empirically, 2) just a few percentage of the investigations could be estimated such models where these two hypothesis are also realized in addition to our acceptance criteria, 3) the Wald test do not reject the proportionality and the symmetry hypothesis in greater percentage of the investigations by the estimations of the purchasing power parity.*

Our results disaffirm Pedroni [2001] and Robertson et al. [2014] results in the sense that we could show the proportionality and the symmetry hypothesis can be realized in certain cases.

In the literature the empirical justifiability of both the monetary exchange rate models and its central condition, the purchasing power parity is a controversial area. With our investigations in this study we would like to contribute to this debate. Based on our results and the first four theses we form the following view:

Thesis 6: *By the examined samples – by longer time series than the foregoing and by panel data – with cointegration methods in certain cases the assumptions of the monetary exchange rate models and the purchasing power parity could be empirically justified. Thus these results also confirm that the monetary macro-fundamentals, considered by the examined models (nominal money supply, real income, price level), affect the behaviour of the nominal exchange rate in accordance with the assumptions of these models primarily in the long run,*

and this long run equilibrium relationship with the appropriate methodological process (with cointegration methods) can be revealed.

This assertion confirm, among others, Mark [1995] viewpoint.

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