THE PROCESS OF CONVERGENCE TOWARDS THE EURO FOR THE VISEGRAD-4 COUNTRIES

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Discussion Paper No. 25, 2008
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ABSTRACT

The aim of the paper is to analyze the foreign transmission mechanism between each of the Visegrad-4 countries and the eurozone, through an empirical analysis of the basic international parity conditions linking Czech, Hungarian, Polish and Slovakian inflations and interest rates with the ones of the current euro area members. The focus of the analysis is to show the differences among these catching-up economies, with particular attention to their process of convergence towards the eurozone economy. For reasons due to the availability of data, the sample covers the last decade. We use the cointegrated VAR model to define long-run stationary relations as well as common stochastic trends. The methodology adopted is properly apt to uncover the dynamic structure underlying the stochastic behaviour of prices, interest rates and exchange rate. Of particular interest is the empirical finding that the parities do not hold on their own, as expected, but that weaker form of the same parities, or linear combinations of them, hold in our data set, with some differences for each country. Also the process of convergence is different: the Czech Republic seems to have reached a relative convergence, while for the other countries we have that the process show a tendency towards convergence.

Keywords: Visegrad_4 countries, PPP, UIP, RIP, Cointegrated VAR, Convergence

JEL Classifications: E31, E43, F31

Paper accepted for presentation at the  

*7th International Conference*  
Economic integrations, competition and cooperation

University of Rijeka  
University of Ljubljana  
CEDIMES Paris

Opatija – Croatia  
April 1-4 2009
1. Introduction

The attention of the paper focuses on the Visegrad-4 countries, the Czech Republic, Hungary, Poland and Slovakia. Since their accession to the European Union they have committed themselves to take economic policy decisions which affect the level and stability of prices, long-term interest rates, the fiscal position and the nominal exchange rate. In order to analyze how the foreign transmission mechanism\(^1\) between each of the four country and the Euro area influences the relevant variables for the adoption of Euro, we perform an empirical analysis of the basic international parity conditions, such as purchasing power parity (PPP), uncovered interest parity (UIP), and real interest parity (RIP), showing also the differences for each country in the process of convergence with the current euro area members\(^2\).

As the empirical literature in international finance has shown, these parities have been hardly found to be satisfied on their own, in their strong form. Therefore, we do not expect to find much evidence of them between each of the formally centrally planned transition economies and the eurozone economy. But the joint empirical analysis of the parity conditions, based on the cointegrated VAR model, is particularly apt to bring more information on these parity relations and on the linkages between inflations, interest rates and real exchange rate, defined as the deviation from long-run PPP condition.

According to Juselius, MacDonald (2000a), when applying cointegration analysis to a system of variables made up by home and foreign inflations, home and foreign long-run interest rates and real exchange rate, we should find two stationary relations combining the parities, and three non stationary relations, the common stochastic trends, representing the forces driving the system: the first corresponding to a trend in inflation rates, the second a trend measuring the relative impact of different monetary policies between the eurozone and each country, and the third a trend reflecting the role of the euro as a reserve currency.

The question of primary interest we would like to address also, on the basis of empirical analysis, is whether there is any evidence that a certain degree of sustainable economic convergence towards the eurozone economy, has been achieved by the Visegrad-4 countries. There are three potentially interesting cases that can emerge: the case of absolute convergence, the case of relative convergence and the case of convergence in act, corresponding to a situation where there are clear signals towards convergence. The idea we have is that the case of relative convergence corresponds to a significant constant present in the cointegrating relations, implying an equilibrium mean different from zero, while convergence in act corresponds to the case where a significant trend is present in the cointegration space, implying a linear trend in the levels of the variables, which does not cancel in the equilibrium relations, that is, the model contains trend-stationary cointegrating relations.

The structure of the paper is the following. In the second section we discuss briefly the parity conditions. In the third, we outline the econometric model with particular attention to the deterministic components, constant and trend, which play a particular role in the process of convergence. In the fourth, we report the cointegration and weak exogeneity properties of the system variables for each country, together with the identified significant long-run relations, interpreted in terms of the parities. In the fifth, we define the common stochastic trends and show the long-run impact of shocks to the system variables. In the final section we summarize and draw the conclusions.

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1 Égert, MacDonald (2006) surveys recent advances in the monetary transmission mechanism with special attention to exploring possible interrelations between different channels, especially they relate to countries in Central and Eastern Europe.

2 Stazka (2008) has performed a similar analysis, but only for Poland and covering the period 1994-2005. Her results are quite different from ours.
2. **A brief presentation of international parity conditions**

In this section we discuss briefly the international parity conditions we are going to analyse in the following of the paper\(^3\). The first one we consider is purchasing power parity, which relates the prices of one country to the prices of another country measured in the same currency. Formally the strong form condition states the following:

\[
(1) \quad p_t^* - p_t = e_t,
\]

where \(p_t^*\) denotes the price level in the home country, \(p_t\) the price level in the foreign country, \(e_t\) the spot exchange rate (home currency price of a unit of foreign currency), and lower case letters denote natural logarithm. An alternative way of expressing the form (9) of the PPP is to say that the term:

\[
(2) \quad ppp_t = p_t^* - p_t - e_t
\]

should be a stationary steady state relation.

The second condition is the uncovered interest parity, which expresses the expected change in the exchange rate in terms of the long-term interest rate spread between the two countries, as follows:

\[
(3) \quad E_t^{e}(\Delta_t e_{t+1}) / \ell - (R_t^{le} - R_t^{lf}) = 0,
\]

or, with a risk premium term added:

\[
(4) \quad E_t^{e}(\Delta_t e_{t+1}) / \ell - (R_t^{le} - R_t^{lf}) = v_t.
\]

If the difference between \(E_t^{e}(\Delta_t e_{t+1})\) and \(\Delta_t e_{t+1}\) is stationary and the differenced process \((e_{t+1} - e_t) / \ell\) is stationary, it follows that \(\Delta e_t\) is stationary, which implies that \((R_t^{le} - R_t^{lf})\) is stationary, unless the term \(v_t\), that is the risk premium, is non stationary.

The third condition we consider, derived using the Fisher decomposition, is the real interest parity, defined as:

\[
(5) \quad (R_t^{l} - E_t^{e}(\Delta_t p_{t+1}) / \ell) = (R_t^{le} - E_t^{e}(\Delta_t p_{t+1}^*) / \ell) + v_t,
\]

or

\[
(6) \quad (R_t^{l} - R_t^{le}) = (E_t^{e}(\Delta_t p_{t+1}) / \ell - E_t^{e}(\Delta_t p_{t+1}^*) / \ell) + v_t,
\]

where \(v_t\) is a stationary error term if the condition empirically holds.

A testable relation between PPP, which arises from conditions in goods markets, and uncovered interest rate parity (UIP), which arises from conditions in capital markets, can be derived if we make the plausible assumption (Juselius, 2006, p. 394) that the expected change in future exchange rate, that is the expected depreciation rate, is a linear function of the

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\(^3\) A detailed presentation of the international parity conditions can be found in Juselius, MacDonald (2000b, 2004a, 2004b) and in Juselius (2006). We draw largely from them.
observed inflation rate differential and the deviation from the long-run PPP level, as measured by the \( ppp \) term. The relation is the following:

\[
E_t^p(\Delta e_{t+1}) = \omega_1 \Delta(p_t - p_t^*) + \omega_2 ppp_t + v_t.
\]

that leads to the empirically testable relation:

\[
(R_t^I - R_t^{I*}) = \omega_1 \Delta(p_t - p_t^*) + \omega_2 ppp_t + v_t.
\]

Relation (8) contains all the parity conditions as special cases.

3. The econometric model

In the empirical analysis\(^4\) we have assumed for the \( p \) observed variables an unrestricted cointegrated vector autoregressive (VAR) model, as in Johansen (1996) and Juselius (2006). The model has been augmented to include constants, a trend and intervention dummies. It is given by:

\[
\Delta y_t = \sum_{i=1}^{n-1} \Gamma_i \Delta y_{t-i} + \Pi y_{t-1} + \mu_0 + \mu_1 t + \Phi D_t + \varepsilon_t, \quad \varepsilon_t \sim IN_p(0, \Omega)
\]

The hypothesis on the empirical relevance of some stationary parity conditions implies the existence of \( r < p \) cointegrating relations and therefore a singular matrix \( \Pi \), of reduced rank \( r \), which can be rewritten as \( \Pi = \alpha \beta' \), where \( \alpha \) and \( \beta \) are matrices of full rank \( r \). The stationary linear combinations \( \beta' y_{t-1} \) correspond to the \( r \) cointegrating relations, which represent the long-run relations that can be detected among the variables \( y_t \), whereas the elements in the columns of \( \alpha \) are the short-run adjustment coefficients of the variables to the equilibrium error from the previous period, \( \beta' y_{t-1} \).

The deterministic terms, constants and trend, are important in the analysis in order to achieve an equilibrium error which has a zero mean. They play a double role within a VEC model, depending on how they are restricted between the cointegrating relations \( \beta' y_{t-1} \) and the equations \( \Delta y_t \). As Juselius (2006, pp. 95-100) shows, the vector of constants \( \mu_0 \), as well as the vector of parameters \( \mu_1 \), can be considered as the sum of two vectors, one accounting for the mean value of the relations \( \beta' y_{t-1} \) and the other for the mean value of the equations \( \Delta y_t \), as follows:

\[
\mu_0 = \alpha \beta_0 + \gamma_0, \quad \mu_1 = \alpha \beta_1 + \gamma_1.
\]

As a consequence the mean of the equilibrium error is given by \( E(\beta' y_{t-1} + \beta_0 + \beta_1 t) \) and the mean of the equations is given by \( E(\Delta y_t) = \gamma_0 + \gamma_1 t \)

\(^4\) All the results relative to the empirical analysis were obtained using CATS in RATS, version 2 (Dennis et al., 2005).
In terms of our interest in the international parity conditions, the strong form of the parities corresponds to a non significant constant term $\beta_0$ restricted to the cointegrating space and no linear trends in the variables, consistent with $E(\Delta y_t)=0$.

The weaker form can correspond either to a significant constant term $\beta_0$ restricted to the cointegrating space and no linear trends in the data, to or to a significant $\beta_1$ and no quadratic trends in the variables, which implies a non significant $\gamma_1$, leaving the constant term unrestricted.

4. The CVAR model for inflation rates, bond rates and ppp

The $p$-dimensional ($p = 5$) observed process $y_t$ is given by $[\Delta_{12} p_t^*, \Delta_{12} p_{Eu}^*, R_t^*, R_{Eu}^*, \ ppp_t^*]$, where the variables are observed monthly for $t = 1999/1 - 2008/VIII$ and are defined as:

$p_t^*$ = the logarithm of the "home" HICP price index, where "home" stands, in turn, for Czech Republic, Hungary, Poland and Slovakia;

$p_{Eu}^*$ = the logarithm of the eurozone HICP price index;

$R_t^*$ = the "home" annual long-term bond yield;

$R_{Eu}^*$ = the euro-zone annual long-term bond yield;

$ppp_t^* = p_t^* - p_{Eu}^* - e_t$, where $e_t$ is the logarithm of the spot exchange rate, defined as "home currency"/Euro.

The difference operator $\Delta_{12}$ applied to the log of the price indices gives a measure of the annual inflation rates. The price indices and the spot exchange rates series have been extracted from the European Central Bank data base, while the bond yields series have been extracted from IMF International Financial Statistics.

Prior to any analysis on the cointegration properties of the variables, various misspecification tests have been performed, aiming to choose the proper number $n$ of lags. These include the LM autocorrelation, ARCH effects and Normality tests.

As the samples cover a rather short number of years, the choice of $r$ has been based on different criteria analyzed together, in order to make the choice as robust as possible: the trace test, the roots of the companion matrix for different values of $r$, the graphs representing the cointegration relations and the recursively calculated trace test statistics.

Czech Republic

The specification search for the model relative to this country, after having controlled for extraordinary large observations with proper intervention dummies, has given a number of lags $n$ equal to 2. The determination of the cointegration rank is strictly connected with the choice about the restrictions on the vector of constant terms and of the linear trend parameters. The graphs of the observed series, given in the Appendix, show no clear linear trend in the variables and, when running long run variable exclusion tests in the cointegrating

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5 First emissions of longer-term government bonds in the Visegrad-4 countries started at the end of the Nineties, with a different timing for each county. For this reason we loose some observations differently at the beginning of each sample.

6 We use HICP annual inflation rates because they are used by the European Central Bank in its Convergenge Reports.

7 In order to obtain residuals close to Normality, in the Czech data set we introduced two permanent intervention dummies defined for 2003/VII and 2008/I.
relations, the results were in favour of the exclusion of a linear trend component at the 1% significant level. Therefore we chose a vector of constant terms restricted to the cointegrating space.

The cointegration rank choice for the Czech Republic, as well as for the other three countries, has been dealt with by looking at as much as possible information coming from the data and not just on the basis of the formal trace test. The final choice is \( r = 1 \), which implies the empirical relevance of just one linear combination of the variables, that is just one parity, or a linear combination of the parities, is stationary. Therefore there are \((p - r) = 4\) common stochastic trends driving the system variables, that is the system is characterized by four stochastic trends associated with shocks that need to be identified.

Looking for the empirical relevant stationary relation we have proceeded by testing each possible relevant hypothesis of the form \( H_1: \mathbf{\dot{\beta}} = \mathbf{H}_1 \mathbf{\phi}_i \). The results are in Table 1, where \( H_1 \) and \( H_2 \) test the stationarity of relative inflation and relative interest rates, \( H_3 \) and \( H_4 \) the Fisher parity conditions, \( H_5 \) the real interest parity condition, \( H_6 \) restricts the two inflation rates to have unitary coefficients and the nominal interest rates to have equal and opposite signs, \( H_7 \) the relation between the real long-term interest rates, \( H_8 \) to \( H_{14} \) the stationarity of the same relations jointly with the \( ppp \) term, \( H_{15} \) a homogenous relation between Czech inflation, eurozone inflation and the Czech bond rate, and \( H_{16} \) the same jointly with \( ppp \).

Table 1: Tests of stationarity of the single hypothesis, Czech Republic

<table>
<thead>
<tr>
<th>( \Delta p_{i}^{cz} )</th>
<th>( \Delta p_{i}^{eu} )</th>
<th>( R_{i}^{cz} )</th>
<th>( R_{i}^{eu} )</th>
<th>( ppp )</th>
<th>( \chi^2(v) )</th>
<th>p-val.</th>
</tr>
</thead>
<tbody>
<tr>
<td>( H_1 )</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>11.314 (4)</td>
</tr>
<tr>
<td>( H_2 )</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>19.248 (4)</td>
</tr>
<tr>
<td>( H_3 )</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>12.167 (4)</td>
</tr>
<tr>
<td>( H_4 )</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>21.605 (4)</td>
</tr>
<tr>
<td>( H_5 )</td>
<td>1</td>
<td>-1</td>
<td>-1</td>
<td>1</td>
<td>0</td>
<td>8.541 (4)</td>
</tr>
<tr>
<td>( H_6 )</td>
<td>1</td>
<td>-1</td>
<td>-1.123</td>
<td>1.123</td>
<td>0</td>
<td>8.290 (3)</td>
</tr>
<tr>
<td>( H_7 )</td>
<td>1</td>
<td>-1.005</td>
<td>-1</td>
<td>1.005</td>
<td>0</td>
<td>8.350 (3)</td>
</tr>
<tr>
<td>( H_8 )</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>14.261 (3)</td>
</tr>
<tr>
<td>( H_9 )</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>-0.065</td>
<td>9.216 (3)</td>
</tr>
<tr>
<td>( H_{10} )</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>-0.031</td>
<td>20.861 (3)</td>
</tr>
<tr>
<td>( H_{11} )</td>
<td>1</td>
<td>-1</td>
<td>-1</td>
<td>1</td>
<td>-0.020</td>
<td>7.960 (3)</td>
</tr>
<tr>
<td>( H_{12} )</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>-2.456</td>
<td>2.140 (2)</td>
</tr>
<tr>
<td>( H_{13} )</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>-0.051</td>
<td>7.888 (2)</td>
</tr>
<tr>
<td>( H_{14} )</td>
<td>0</td>
<td>1</td>
<td>-1.005</td>
<td>-1.005</td>
<td>0</td>
<td>9.417 (3)</td>
</tr>
<tr>
<td>( H_{15} )</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>8.815 (2)</td>
</tr>
<tr>
<td>( H_{16} )</td>
<td>1</td>
<td>-1</td>
<td>-1</td>
<td>1</td>
<td>-2.456</td>
<td>2.140 (2)</td>
</tr>
<tr>
<td>( W. E. )</td>
<td>6.903</td>
<td>0.226</td>
<td>7.088</td>
<td>2.063</td>
<td>6.218</td>
<td>6.903 (0.009)</td>
</tr>
<tr>
<td>p-val.</td>
<td>(0.009)</td>
<td>(0.008)</td>
<td>(0.151)</td>
<td>(0.013)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: all relations are estimated with a constant

As we can see from the p-values, only two hypotheses are significant at the 5% level, \( H_5 \) and \( H_{13} \). It’s interesting to note that the real parity condition is accepted, though with a low p-value. With just one stationary relation there is no problem of identification, anyway we restricted the parameters in order to interpret the relation in terms of the parities. The
estimation results are reported in Table 2.

Table 2 : Structural representation for the cointegrating relation: Czech Republic

<table>
<thead>
<tr>
<th>Eigenvectors $\beta$</th>
<th>Weights $\alpha$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>$\hat{\beta}_1$</td>
</tr>
<tr>
<td>$\Delta p^C_z$</td>
<td>1</td>
</tr>
<tr>
<td>$\Delta p^e_u$</td>
<td>-1</td>
</tr>
<tr>
<td>$R^C_z$</td>
<td>-2.526 (-11.198)</td>
</tr>
<tr>
<td>$R^e_u$</td>
<td>2.526 (11.198)</td>
</tr>
<tr>
<td>$ppp_t$</td>
<td>-0.111 (-7.027)</td>
</tr>
<tr>
<td>constant</td>
<td>-0.370 (-6.903)</td>
</tr>
<tr>
<td>$\chi^2 = 5.411$, $p-value = 0.248$</td>
<td></td>
</tr>
</tbody>
</table>

Note: $t$-values in brackets

The resulting cointegrating relation is of the following form:

$$ (11) \quad (\Delta p^C_z - \Delta p^e_u) = 0.370 + 2.526(R^C_z - R^e_u) + 0.111 ppp_t + v_t $$

It represents a variant of the real interest parity, in which full proportionality has not been imposed, parity which is largely accepted as stationary when the $ppp$ term is included, that is when real exchange rate is taken into account. In other words, the two parities, a variant of the RIP and the PPP, result to be stationary when considered jointly. The significant constant term shows that the two parities considered, on average, maintain a certain distance over the sample period, in other words the equilibrium mean is different from zero. We could state that the convergence between the parities is just a relative one.

The short run adjustment to (11) indicates that a positive equilibrium error adjusts significantly in the Czech inflation equation, significantly, but less strongly, in the Czech interest rate equation and significantly, and rather strongly, in the $ppp$ equation.

On the matrix $\alpha$ have been imposed the weak exogeneity restrictions$^8$ as given in the last row of Table 1. The LR test on the overidentifying restrictions is equal to 5.411, with a $p-value = 0.248$, therefore all the restrictions on $\beta$ and $\alpha$ are empirically accepted.

**Hungary**

The specification search for the Hungarian model, after having controlled for

---

$^8$ The weak exogeneity restrictions take the form $R'\alpha = 0$, where $R$ is a $(p \times (p-s))$ matrix with $s \geq r$. The LR test statistic is distributed as $\chi^2_r$. A weakly exogenous variable is characterized by a corresponding zero row in $\alpha$, which means that the variable doesn't adjust to the long-run relations and can be considered as a common driving force in the system.
extraordinary large observations with proper intervention dummies\(^9\), has given a number of lags \(n\) equal to 3. The graphs of the series in the Appendix show some linear trend in the variables and no exclusion test has rejected it. Therefore we chose a linear trend restricted to the cointegrating space and unrestricted constants.

The cointegration rank final choice is still \(r = 1\), which implies the empirical relevance of just one stationary linear combination of the parities, and the existence of \((p - r) = 4\) common stochastic trends characterizing the system. Looking for the empirical relevant stationary relation we have proceeded, as for the Czech Republic, by testing each possible relevant hypothesis of the form \(H_i: \mathbf{\beta} = \mathbf{H}_i\mathbf{\phi}_i\). The testing results are in Table 3.

Table 3: Tests of stationarity of the single hypothesis: Hungary

<table>
<thead>
<tr>
<th>(H_i)</th>
<th>(\Delta p_{Hu}^i)</th>
<th>(\Delta p_{eu}^i)</th>
<th>(R_{H}^{Hu}^i)</th>
<th>(R_{eu}^i)</th>
<th>(ppp)</th>
<th>(\chi^2(v))</th>
<th>p-val.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>17.177 (4)</td>
<td>0.002</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>20.937 (4)</td>
<td>0.000</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>14.673 (4)</td>
<td>0.005</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>20.223 (4)</td>
<td>0.000</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>-1</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>17.353 (4)</td>
<td>0.002</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>-1</td>
<td>-0.251</td>
<td>0.251</td>
<td>0</td>
<td>16.848 (3)</td>
<td>0.001</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>2.335</td>
<td>-1</td>
<td>-2.335</td>
<td>0</td>
<td>7.847 (3)</td>
<td>0.049</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>11.122 (3)</td>
<td>0.075</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>-2.786</td>
<td>9.895 (3)</td>
<td>0.019</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>0.786</td>
<td>5.541 (3)</td>
<td>0.136</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>3.943</td>
<td>9.939 (3)</td>
<td>0.019</td>
</tr>
<tr>
<td>12</td>
<td>1</td>
<td>-1</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>1.284 (3)</td>
<td>0.063</td>
</tr>
<tr>
<td>13</td>
<td>1</td>
<td>-1</td>
<td>0.106</td>
<td>-0.106</td>
<td>1.111</td>
<td>6.787 (2)</td>
<td>0.034</td>
</tr>
<tr>
<td>14</td>
<td>1</td>
<td>2.301</td>
<td>-1</td>
<td>-2.301</td>
<td>0.400</td>
<td>0.404 (2)</td>
<td>0.817</td>
</tr>
<tr>
<td>15</td>
<td>1</td>
<td>2.288</td>
<td>-3.288</td>
<td>0</td>
<td>0</td>
<td>10.840 (3)</td>
<td>0.013</td>
</tr>
<tr>
<td>16</td>
<td>1</td>
<td>1.258</td>
<td>-2.258</td>
<td>0</td>
<td>0.660</td>
<td>4.594 (2)</td>
<td>0.101</td>
</tr>
<tr>
<td>W. E.</td>
<td>17.907</td>
<td>1.191</td>
<td>0.198</td>
<td>0.216</td>
<td>0.233</td>
<td>0.216 (0.629)</td>
<td>0.817</td>
</tr>
</tbody>
</table>

Note: all relations are estimated with a trend

As we can see from the tests \(p\)-values, there are five hypotheses significant at the 5% level, \(H_8\), \(H_{10}\), \(H_{12}\), \(H_{14}\) and \(H_{16}\), all with the \(ppp\) term included. Having chosen, as more acceptable, a cointegration rank \(r = 1\), we restricted the parameters of the single relation as in \(H_{14}\). The estimation results are reported in Table 4.

The cointegrating relation is of the following form:

\[
(R_t^{Hu} - \Delta p_t^{Hu}) = -2.088(R_t^{eu} - \Delta p_t^{eu}) + 0.358 ppp_t - 0.001t + v_t
\]

It represents a significant stationary empirical relation between the real interest parity and the

\(^9\) In order to obtain residuals close to Normality, in the Hungarian data set we introduced four permanent intervention dummies defined for 2003/VI, 2005/I, 2006/VI and 2007/I.
real exchange rate, represented by the *ppp* term, though with no full proportionality as required by the RIP condition. To make the relation between the two parities stationary we need the trend component, whose coefficient is significant and negative, a clear signal that some convergence between them is in act over the sample period.

Table 4: Structural representation for the cointegrating relation: Hungary

<table>
<thead>
<tr>
<th>Eigenvectors $\beta$</th>
<th>Equation</th>
<th>Weights $\alpha$</th>
<th>$\hat{\alpha}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>$\beta_1$</td>
<td>$\Delta^2 p_t^{Hu}$</td>
<td>0.119</td>
</tr>
<tr>
<td>$\Delta p_t^{Hu}$</td>
<td>-1</td>
<td></td>
<td>(6.401)</td>
</tr>
<tr>
<td>$\Delta p_t^{eu}$</td>
<td>-2.088</td>
<td>$\Delta^2 p_t^{eu}$</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(-3.950)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R_t^{Hu}$</td>
<td>1</td>
<td>$\Delta R_t^{Hu}$</td>
<td>0</td>
</tr>
<tr>
<td>$R_t^{eu}$</td>
<td>2.088</td>
<td>$\Delta R_t^{eu}$</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(3.950)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta p_{ppp_t}$</td>
<td>-0.358</td>
<td>$\Delta p_{ppp_t}$</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(-4.103)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>trend</em></td>
<td>0.001</td>
<td></td>
<td>(5.038)</td>
</tr>
</tbody>
</table>

$\chi^2 = 1.624, \ p-value = 0.951$

Note: *t*-values in brackets

The short run adjustment to (12), after having imposed the weak exogeneity restrictions as given in the last row of Table 3, indicates that a positive equilibrium error adjusts significantly only in the Hungarian inflation equation. The LR test on all the overidentifying restrictions is equal to 1.624, with a $p-value = 0.951$, therefore they are largely empirically accepted.

**Poland**

The specification search for Poland, after having controlled for extraordinary large observations with proper intervention dummies\(^{10}\), has given a number of lags $n$ equal to 2. The graphs of the series in the Appendix show some linear trend in the variables and no exclusion test has rejected it. Therefore we chose a linear trend restricted to the cointegrating space and unrestricted constants.

The cointegration rank final choice is $r = 2$, which implies $(p - r) = 3$ common stochastic trends characterizing the system, which is more theoretically acceptable than the preceding cases (Juselius, MacDonald, 2000a). Looking for the empirical relevant stationary relations we have proceeded by testing each possible relevant hypothesis of the form $H_j: \beta = \{H, \phi_1, \psi_1\}$, that is we test the stationarity of a single hypothetical cointegrating relation, while leaving the remaining unrestricted. The relative results are in Table 5.

As we can see from the tests $p$-values, there are four hypotheses significant at the 5% level, $H_9, H_{10}, H_{13}$ and $H_{16}$, with $H_9$ contained in $H_{13}$. No parity results stationary as such.

The two more likely hypotheses for the identification of the two cointegrating relations

\(^{10}\) In order to obtain residuals close to Normality, in the Polish data set we introduced six permanent intervention dummies defined for 2001/VI, 2001/VII, 2001/VIII, 2002/V, 2005/IV and 2006/IX.
Table 5: Tests of stationarity of the single hypothesis: Poland

<table>
<thead>
<tr>
<th></th>
<th>$\Delta p^P_l$</th>
<th>$\Delta p^{eu}$</th>
<th>$R^P_l$</th>
<th>$R^{eu}$</th>
<th>ppp</th>
<th>$\chi^2(v)$</th>
<th>p-val.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_1$</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>15.713 (3)</td>
<td>0.001</td>
</tr>
<tr>
<td>$H_2$</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>7.958 (3)</td>
<td>0.047</td>
</tr>
<tr>
<td>$H_3$</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>7.211 (3)</td>
<td>0.065</td>
</tr>
<tr>
<td>$H_4$</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>22.418 (3)</td>
<td>0.004</td>
</tr>
<tr>
<td>$H_5$</td>
<td>1</td>
<td>-1</td>
<td>-1</td>
<td>1</td>
<td>0</td>
<td>16.190 (3)</td>
<td>0.001</td>
</tr>
<tr>
<td>$H_6$</td>
<td>1</td>
<td>-1</td>
<td>-3.162</td>
<td>3.162</td>
<td>0</td>
<td>6.678 (2)</td>
<td>0.035</td>
</tr>
<tr>
<td>$H_7$</td>
<td>1</td>
<td>0.101</td>
<td>-1</td>
<td>-0.101</td>
<td>0</td>
<td>7.124 (2)</td>
<td>0.028</td>
</tr>
<tr>
<td>$H_8$</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-0.06</td>
<td>14.100 (2)</td>
</tr>
<tr>
<td>$H_9$</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>-0.064</td>
<td>2.315 (2)</td>
<td>0.314</td>
</tr>
<tr>
<td>$H_{10}$</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>0.032</td>
<td>5.099 (2)</td>
</tr>
<tr>
<td>$H_{11}$</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>-0.030</td>
<td>21.987 (2)</td>
<td>0.000</td>
</tr>
<tr>
<td>$H_{12}$</td>
<td>1</td>
<td>-1</td>
<td>-1</td>
<td>1</td>
<td>0</td>
<td>0.032</td>
<td>15.417 (2)</td>
</tr>
<tr>
<td>$H_{13}$</td>
<td>1</td>
<td>-1</td>
<td>-3.568</td>
<td>3.568</td>
<td>0.171</td>
<td>0.563 (1)</td>
<td>0.453</td>
</tr>
<tr>
<td>$H_{14}$</td>
<td>1</td>
<td>0.170</td>
<td>-1</td>
<td>-0.170</td>
<td>0</td>
<td>0.035</td>
<td>4.852 (1)</td>
</tr>
<tr>
<td>$H_{15}$</td>
<td>1</td>
<td>0.153</td>
<td>-1.153</td>
<td>0</td>
<td>0</td>
<td>0.030</td>
<td>6.729 (2)</td>
</tr>
<tr>
<td>$H_{16}$</td>
<td>1</td>
<td>0.396</td>
<td>-1.396</td>
<td>0</td>
<td>0</td>
<td>0.060</td>
<td>2.766 (1)</td>
</tr>
</tbody>
</table>

Note: all relations are estimated with a trend

Table 6: Structural representation for the cointegrating relations: Poland

<table>
<thead>
<tr>
<th>Variable</th>
<th>$\hat{\beta}_1$</th>
<th>$\hat{\beta}_2$</th>
<th>$\mathbf{\Delta^2 p^P_l}$</th>
<th>$\mathbf{\Delta^2 p^{eu}}$</th>
<th>$\mathbf{\Delta R^P_l}$</th>
<th>$\mathbf{\Delta R^{eu}}$</th>
<th>$\mathbf{\Delta ppp_l}$</th>
<th>trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta p^P_l$</td>
<td>1</td>
<td>0</td>
<td>$\Delta^2 p^P_l$</td>
<td>-0.114</td>
<td>-0.261</td>
<td>$\Delta^2 p^{eu}$</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$\Delta p^{eu}$</td>
<td>-1</td>
<td>0</td>
<td>$\Delta^2 p^{eu}$</td>
<td>0</td>
<td>0</td>
<td>$\Delta R^P_l$</td>
<td>0.067</td>
<td>(2.668)</td>
</tr>
<tr>
<td>$R^P_l$</td>
<td>-3.089</td>
<td>-2.052</td>
<td>$\Delta R^P_l$</td>
<td>0.030</td>
<td>(2.125)</td>
<td>$\Delta R^{eu}$</td>
<td>0.078</td>
<td>(2.769)</td>
</tr>
<tr>
<td>$R^{eu}$</td>
<td>3.089</td>
<td>0.964</td>
<td>$\Delta ppp_l$</td>
<td>0.964</td>
<td>(2.779)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>trend</td>
<td>-0.0011</td>
<td>(4.585)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$\chi^2 = 2.606, \ p-value = 0.760$

Note: $t$-values in brackets

are $H_{13}$ and $H_{16}$. The estimation results are reported in Table 6.

The first cointegrating relation is the following:
It is a significant stationary empirical relation very similar to the one characterizing the Czech Republic: it represents a variant of the real interest parity, in which full proportionality has not been imposed, parity which is accepted as stationary when PPP is analyzed jointly. To make the relation stationary we need the trend component, whose coefficient is significant and positive. If we had normalized on the interest rate spread the trend coefficient would have been negative, a clear indication of a convergence in act over the sample period.

The second cointegrating relation, which, for identification reasons, looses the spread restriction, is the following:

\[(14) \quad R_{t}^{Pl} = 2.052 R_{t}^{eu} - 0.003 t + v_t\]

and represents a significant stationary empirical relation between the two nominal long-term interest rates. The trend component shows a significant and negative coefficient, a sign of a likely convergence in act.

The short run adjustments to (13) and (14) after having imposed the weak exogeneity restrictions as given in the last row of Table 5, indicates that a positive equilibrium error in the first relation adjusts significantly in the Polish inflation equation and, less strongly, in the Polish bond yield equation. A positive equilibrium error in the second relation adjusts significantly in the Polish inflation equation and, less strongly in the eurozone bond yield equation. It adjusts also in the \( ppp \) equation. The LR test on all the overidentifying restrictions is equal to 2.606, with a \( p - \text{value} = 0.760 \), therefore they are largely empirically accepted.

**Slovakia**

The specification search for Slovakia, after having controlled for extraordinary large observations with proper intervention dummies\(^\text{11}\) has given a number of lags \( n \) equal to 2. The graphs of the series in the Appendix show some linear trend in the variables and no exclusion test has rejected it. Therefore we chose a linear trend restricted to the cointegrating space and unrestricted constants.

The cointegration rank final choice is still \( r = 2 \), which implies, as for Poland, \((p - r) = 3\) common stochastic trends characterizing the system. Looking for the empirical relevant stationary relations we have proceeded by testing each possible relevant hypothesis of the form \( H_i: \beta_i = \{H_i \varphi_i, \psi_i\} \). The relative results are in Table 7.

As we can see from the tests \( p - \text{values} \), there are just two hypotheses significant at the 5% level, \( H_9 \) and \( H_{13} \), with \( H_9 \) contained in \( H_{13} \). For identification reasons we leave the parameter associated with eurozone inflation unrestricted. The estimation results are reported in Table 8.

The first cointegrating relation is the following:

\[(15) \quad (\Delta p_{t}^{Pl} - \Delta p_{t}^{eu}) = -8.526 R_{t}^{Pl} + 13.904 R_{t}^{eu} + 1.512 ppp_t - 0.011 t + v_t\]

It represents a significant empirical relation among the inflation spread, the interest rates not

Table 7: Tests of stationarity of the single hypothesis: Slovakia

<table>
<thead>
<tr>
<th></th>
<th>$\Delta p^{Sk}$</th>
<th>$\Delta p^{eu}$</th>
<th>$R_l^{Sk}$</th>
<th>$R_l^{eu}$</th>
<th>ppp</th>
<th>$\chi^2(v)$</th>
<th>p-val.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_1$</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9.175 (3)</td>
<td>0.027</td>
</tr>
<tr>
<td>$H_2$</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>16.038 (3)</td>
<td>0.001</td>
</tr>
<tr>
<td>$H_3$</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>9.942 (3)</td>
<td>0.019</td>
</tr>
<tr>
<td>$H_4$</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>13.251 (3)</td>
<td>0.004</td>
</tr>
<tr>
<td>$H_5$</td>
<td>1</td>
<td>-1</td>
<td>-1</td>
<td>1</td>
<td>0</td>
<td>10.168 (3)</td>
<td>0.017</td>
</tr>
<tr>
<td>$H_6$</td>
<td>1</td>
<td>-1</td>
<td>0.698</td>
<td>-0.698</td>
<td>0</td>
<td>8.747 (2)</td>
<td>0.013</td>
</tr>
<tr>
<td>$H_7$</td>
<td>1</td>
<td>0.635</td>
<td>-1</td>
<td>-0.635</td>
<td>0</td>
<td>9.902 (2)</td>
<td>0.007</td>
</tr>
<tr>
<td>$H_8$</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>0</td>
<td>2.941</td>
<td>6.396 (2)</td>
<td>0.041</td>
</tr>
<tr>
<td>$H_9$</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>-1</td>
<td>-0.597</td>
<td>3.980 (2)</td>
<td>0.137</td>
</tr>
<tr>
<td>$H_{10}$</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>0</td>
<td>4.863</td>
<td>6.277 (2)</td>
<td>0.043</td>
</tr>
<tr>
<td>$H_{11}$</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>-0.882</td>
<td>6.065 (2)</td>
<td>0.048</td>
</tr>
<tr>
<td>$H_{12}$</td>
<td>1</td>
<td>-1</td>
<td>-1</td>
<td>1</td>
<td>4.665</td>
<td>6.076 (2)</td>
<td>0.048</td>
</tr>
<tr>
<td>$H_{13}$</td>
<td>1</td>
<td>-1</td>
<td>4.558</td>
<td>-4.558</td>
<td>-2.000</td>
<td>2.168 (1)</td>
<td>0.141</td>
</tr>
<tr>
<td>$H_{14}$</td>
<td>1</td>
<td>-8.742</td>
<td>-1</td>
<td>8.742</td>
<td>6.479</td>
<td>5.588 (1)</td>
<td>0.018</td>
</tr>
<tr>
<td>$H_{15}$</td>
<td>1</td>
<td>-1.114</td>
<td>0.114</td>
<td>0</td>
<td>0</td>
<td>9.128 (2)</td>
<td>0.010</td>
</tr>
<tr>
<td>$H_{16}$</td>
<td>1</td>
<td>-8.836</td>
<td>7.836</td>
<td>0</td>
<td>-13.621</td>
<td>6.416 (1)</td>
<td>0.011</td>
</tr>
<tr>
<td>W. E.</td>
<td>2.533 (0.282)</td>
<td>14.201 (0.001)</td>
<td>9.493 (0.009)</td>
<td>3.980 (0.137)</td>
<td>27.499 (0.000)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: all relations are estimated with a trend

Table 8: Structural representation for the cointegrating relations: Slovakia

<table>
<thead>
<tr>
<th>Variable</th>
<th>Eigenvectors $\hat{\beta}$</th>
<th>Weights $\alpha$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\hat{\beta}_1$</td>
<td>$\hat{\beta}_2$</td>
</tr>
<tr>
<td>$\Delta p^{Sk}$</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>$\Delta p^{eu}$</td>
<td>-1</td>
<td>-2.303 (-3.769)</td>
</tr>
<tr>
<td>$R^Sk$</td>
<td>8.526 (5.320)</td>
<td>1</td>
</tr>
<tr>
<td>$R^{eu}$</td>
<td>-13.904 (-4.281)</td>
<td>-1</td>
</tr>
<tr>
<td>$\Delta ppp$</td>
<td>-1.512 (-5.396)</td>
<td>0.467 (3.751)</td>
</tr>
<tr>
<td>trend</td>
<td>0.011 (7.313)</td>
<td>-0.002 (-2.831)</td>
</tr>
</tbody>
</table>

$\chi^2 = 6.851, \quad p-value = 0.232$

Note: t-values in brackets

restricted to have equal and opposite coefficients, and the real exchange rate. To make the relation stationary we need the trend component which results to be significant and negative. It is still a case where stationarity is recovered between a modified RIP and the PPP, if a trend
component is added, indicating a significant convergence in act.

The second cointegrating relation is the following:

\[ (16) \quad (R_{tP}^{eu} - R_{t}^{eu}) = 2.303\Delta p_{t}^{eu} - 0.467 ppp_{t} + 0.002t + v_{t} \]

and represents a significant empirical relation among the nominal interest rate spread, the eurozone inflation and the real exchange rate. The trend component shows a significant and positive coefficient. As (16) doesn't really represent a relation between parity conditions and the trend coefficient is the result of a combination of the series sample means, we cannot state anything in terms of convergence between parities.

The short run adjustments to (15) and (16) after having imposed the weak exogeneity restrictions as given in the last row of Table 7, indicates that a positive equilibrium error in the first relation adjusts significantly, but rather slowly, in the eurozone inflation equation and in the Slovakian interest rate equation, and significantly in the ppp equation. A positive equilibrium error in the second relation adjusts significantly only in the eurozone inflation equation. This adjustment dynamics leaves some questions open for further research. The LR test on all the overidentifying restrictions is equal to 6.851, with a $p-value = 0.232$, therefore they are accepted.

5. The long-run effects of cumulated shocks

Interesting information on the effects of cumulated shocks to the system variables can be gained from the inverted CVAR (9), yielding the vector moving average (VMA) representation for $\Delta y_{t}$. Rewriting it in terms of the levels of the variables by recursive substitution and focusing the attention just on the non-stationary components of the VMA representation, the common stochastic and deterministic trends and the dummies, i.e. on:

\[ (17) \quad y_{t} = C \sum_{i=1}^{t} e_{i} + C\mu_{0}t + C\Phi \sum_{i=1}^{t} D_{i} + \text{stat. comp.} \]

we note that it's characterized by the $(p \times p)$ matrix $C$. The existence of $r$ cointegrating vectors implies that $C$ has reduced rank given by $(p - r)$. It's interesting to show that it can be written as $C = \tilde{\beta}_{\perp} \alpha_{\perp}'$, a decomposition similar to that relative to $\Pi_{12}$.

The matrix $C$ plays an important role: its rank correspond to the number of driving forces or common stochastic trends and its elements convey information about the long-run impact of cumulated shocks to the system variables. In other words, the matrix $C$ allows us to determine which empirical shocks have permanent effects on the system variables.

For the Czech Republic the rank of the matrix $C$ is equal to four, that is there are four common stochastic trends characterizing the system. Two of them can be identified as cumulated shocks to the weakly exogenous variables, the eurozone inflation and the eurozone

\[ \text{12 In the decomposition } \tilde{\beta}_{\perp} = \beta_{\perp}(\alpha'_{\perp} \Gamma \beta_{\perp})^{-1}, \text{ where } \Gamma = -I_{p} + \sum_{i=1}^{n-1} \Gamma_{i} \text{ and } \beta_{\perp} \text{ and } \alpha_{\perp} \text{ are } (p \times (p - r)) \text{ orthogonal matrices, defined by } \alpha'\alpha_{\perp} = 0 \text{ and } \beta'\beta_{\perp} = 0. \]
interest rate, while, from the $\mathbf{a}'_\perp$ matrix\textsuperscript{13}, we have that the other two are given by cumulated shocks to the Czech interest rate with some, borderline significant, contribution from the $ppp$ term, and by cumulated shocks to the Czech inflation rate with some contribution from the $ppp$ term. From the estimate of the matrix $\mathbf{C}$ in Table 9, we note significant effects, with opposite sign, of cumulative shocks to the two interest rates on the $ppp$ term, a clear signal that exchange rates are involved in capital movements (Hoover et al., 2008, p. 255). There are some significant effects of shocks to the Czech inflation on the Czech interest rate and of shocks to the eurozone inflation on the Czech inflation.

Table 9 : The estimate of the long-run $\mathbf{C}$ matrix: Czech Republic

<table>
<thead>
<tr>
<th></th>
<th>$\sum \varepsilon_{\Delta p_{Cz}}$</th>
<th>$\sum \varepsilon_{\Delta p_{eu}}$</th>
<th>$\sum \varepsilon_{R_{Cz}^i}$</th>
<th>$\sum \varepsilon_{R_{eu}^i}$</th>
<th>$\sum \varepsilon_{ppp}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta p_{Cz}$</td>
<td>0.751</td>
<td>1.408</td>
<td>1.884</td>
<td>-0.510</td>
<td>0.037</td>
</tr>
<tr>
<td>$\Delta p_{eu}$</td>
<td>-0.047</td>
<td>1.133</td>
<td>-0.318</td>
<td>0.420</td>
<td>0.018</td>
</tr>
<tr>
<td>$R_{Cz}^i$</td>
<td>0.248</td>
<td>0.408</td>
<td>1.167</td>
<td>0.736</td>
<td>-0.042</td>
</tr>
<tr>
<td>$R_{eu}^i$</td>
<td>-0.014</td>
<td>0.282</td>
<td>-0.032</td>
<td>1.377</td>
<td>-0.001</td>
</tr>
<tr>
<td>$ppp$</td>
<td>1.226</td>
<td>-0.406</td>
<td>-7.428</td>
<td>6.205</td>
<td>1.112</td>
</tr>
</tbody>
</table>

Also for Hungary the rank of the matrix $\mathbf{C}$ is equal to four. The four common stochastic trends can be identified as cumulated shocks to the four weakly exogenous variables. As we can see from the estimate of matrix $\mathbf{C}$ in Table 10, cumulative shocks to the Hungarian inflation have no long-run effects on the other variables, while it is significantly and negatively affected by cumulated shocks to eurozone inflation, positively by shocks to eurozone interest rate and negatively by shocks to the $ppp$ term. The $ppp$ term results to be significantly and positively affected by shocks to the Hungarian interest rate.

Table 10 : The estimate of the long-run $\mathbf{C}$ matrix: Hungary

<table>
<thead>
<tr>
<th></th>
<th>$\sum \varepsilon_{\Delta p_{Hu}}$</th>
<th>$\sum \varepsilon_{\Delta p_{eu}}$</th>
<th>$\sum \varepsilon_{R_{Hu}^i}$</th>
<th>$\sum \varepsilon_{R_{eu}^i}$</th>
<th>$\sum \varepsilon_{ppp}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta p_{Hu}$</td>
<td>0.000</td>
<td>-1.971</td>
<td>0.032</td>
<td>2.632</td>
<td>-0.367</td>
</tr>
<tr>
<td>$\Delta p_{eu}$</td>
<td>(0.000)</td>
<td>(-2.307)</td>
<td>(0.057)</td>
<td>(2.460)</td>
<td>(-3.280)</td>
</tr>
<tr>
<td>$R_{Hu}^i$</td>
<td>0.000</td>
<td>1.233</td>
<td>0.035</td>
<td>-0.310</td>
<td>0.022</td>
</tr>
<tr>
<td>$R_{eu}^i$</td>
<td>(0.000)</td>
<td>(4.266)</td>
<td>(0.187)</td>
<td>(-0.857)</td>
<td>(0.573)</td>
</tr>
<tr>
<td>$ppp$</td>
<td>0.000</td>
<td>-0.706</td>
<td>2.416</td>
<td>1.793</td>
<td>0.786</td>
</tr>
</tbody>
</table>

\textsuperscript{13} The $\mathbf{a}'_\perp$ matrices are not reported but available upon request.
For **Poland** the rank of the matrix $\mathbf{C}$ is equal to three. One of the three common stochastic trends can be identified as cumulated shocks to the weakly exogenous eurozone inflation, while, from the $\mathbf{a}'_{-1}$ matrix, we have that the other two are given by cumulated shocks to the eurozone interest rate with some, almost insignificant, contribution from the Polish inflation, and by cumulated shocks to the Polish interest rate with contribution from the $\text{ppp}$ term. From the estimate of the matrix $\mathbf{C}$, we note some significant effects of cumulative shocks to the Polish inflation on the two interest rates, significant effects of shocks to the eurozone inflation on the Polish inflation and significant effects of shocks to the Polish interest rates on the $\text{ppp}$ term.

Table 11: The estimate of the long-run impact matrix $\mathbf{C}$: Poland

<table>
<thead>
<tr>
<th></th>
<th>$\sum \varepsilon_{\Delta p_{Pl}}$</th>
<th>$\sum \varepsilon_{\Delta p_{eu}}$</th>
<th>$\sum \varepsilon_{R_{Pl}}$</th>
<th>$\sum \varepsilon_{R_{eu}}$</th>
<th>$\sum \varepsilon_{\text{ppp}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta p_{Pl}$</td>
<td>0.730</td>
<td><strong>1.255</strong></td>
<td>-0.174</td>
<td>3.031</td>
<td>-0.068</td>
</tr>
<tr>
<td></td>
<td>(1.553)</td>
<td>(2.696)</td>
<td>(-0.169)</td>
<td>(1.931)</td>
<td>(-0.730)</td>
</tr>
<tr>
<td>$\Delta p_{eu}$</td>
<td>0.164</td>
<td><strong>1.031</strong></td>
<td>0.548</td>
<td>-0.498</td>
<td>0.060</td>
</tr>
<tr>
<td></td>
<td>(0.732)</td>
<td>(4.641)</td>
<td>(1.110)</td>
<td>(-0.664)</td>
<td>(1.347)</td>
</tr>
<tr>
<td>$R_{Pl}$</td>
<td><strong>0.879</strong></td>
<td>0.007</td>
<td>1.215</td>
<td>0.222</td>
<td>0.101</td>
</tr>
<tr>
<td></td>
<td>(2.309)</td>
<td>(0.022)</td>
<td>(1.582)</td>
<td>(0.202)</td>
<td>(1.554)</td>
</tr>
<tr>
<td>$R_{eu}$</td>
<td><strong>0.424</strong></td>
<td>0.012</td>
<td>0.508</td>
<td>0.270</td>
<td>0.039</td>
</tr>
<tr>
<td></td>
<td>(2.371)</td>
<td>(0.078)</td>
<td>(1.406)</td>
<td>(0.520)</td>
<td>(1.283)</td>
</tr>
<tr>
<td>$\text{ppp}$</td>
<td>4.561</td>
<td>-0.365</td>
<td><strong>18.126</strong></td>
<td>-19.683</td>
<td><strong>2.049</strong></td>
</tr>
<tr>
<td></td>
<td>(1.207)</td>
<td>(-0.097)</td>
<td>(2.180)</td>
<td>(-1.559)</td>
<td>(2.718)</td>
</tr>
</tbody>
</table>

Also for **Slovakia** the rank of the matrix $\mathbf{C}$ is equal to three. Two of the three common stochastic trends can be identified as cumulated shocks to the weakly exogenous Slovakian inflation and eurozone interest rate, while, from the $\mathbf{a}'_{-1}$ matrix, we have that the other is given by cumulated shocks to the Slovakian interest rate with a significant contribution from the $\text{ppp}$ term. From the estimate of the matrix $\mathbf{C}$ in Table 12, we note that the $\text{ppp}$ term is the most affected by cumulative shocks, in particular to the two interest rates, with opposite sign, and to the Slovakian inflation. Eurozone inflation results to be affected by the two interest rates, negatively by the eurozone bond yield, coherent with the theory, and positively by the Slovakian interest rate.

Table 12: The estimate of the long-run impact matrix $\mathbf{C}$: Slovakia

<table>
<thead>
<tr>
<th></th>
<th>$\sum \varepsilon_{\Delta p_{Sk}}$</th>
<th>$\sum \varepsilon_{\Delta p_{eu}}$</th>
<th>$\sum \varepsilon_{R_{Sk}}$</th>
<th>$\sum \varepsilon_{R_{eu}}$</th>
<th>$\sum \varepsilon_{\text{ppp}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta p_{Sk}$</td>
<td><strong>1.162</strong></td>
<td>-0.013</td>
<td>0.225</td>
<td>-0.644</td>
<td>0.024</td>
</tr>
<tr>
<td></td>
<td>(14.923)</td>
<td>(-0.024)</td>
<td>(0.233)</td>
<td>(-1.250)</td>
<td>(0.175)</td>
</tr>
<tr>
<td>$\Delta p_{eu}$</td>
<td>0.069</td>
<td>-0.080</td>
<td><strong>1.414</strong></td>
<td><strong>-0.972</strong></td>
<td>0.150</td>
</tr>
<tr>
<td></td>
<td>(1.570)</td>
<td>(-0.268)</td>
<td>(2.571)</td>
<td>(-3.325)</td>
<td>(1.931)</td>
</tr>
<tr>
<td>$R_{Sk}$</td>
<td>-0.056</td>
<td>-0.097</td>
<td><strong>1.709</strong></td>
<td>0.695</td>
<td>0.181</td>
</tr>
<tr>
<td></td>
<td>(-0.831)</td>
<td>(-0.213)</td>
<td>(2.039)</td>
<td>(1.561)</td>
<td>(1.532)</td>
</tr>
<tr>
<td>$R_{eu}$</td>
<td>-0.005</td>
<td>-0.028</td>
<td>0.488</td>
<td><strong>0.920</strong></td>
<td>0.052</td>
</tr>
<tr>
<td></td>
<td>(-0.132)</td>
<td>(-0.111)</td>
<td>(1.068)</td>
<td>(3.787)</td>
<td>(0.802)</td>
</tr>
<tr>
<td>$\text{ppp}$</td>
<td><strong>0.452</strong></td>
<td>-0.247</td>
<td><strong>4.365</strong></td>
<td><strong>-4.318</strong></td>
<td>0.462</td>
</tr>
<tr>
<td></td>
<td>(2.938)</td>
<td>(-0.238)</td>
<td>(2.279)</td>
<td>(-4.243)</td>
<td>(1.712)</td>
</tr>
</tbody>
</table>
6. Summary and conclusions

In the paper we have examined the existence of inflation rate and interest rate linkages between the eurozone and each of the Visegrad-4 countries, during the last ten years, a period that has seen a remarkable appreciation of their currencies with respect to the euro. This was done by trying to identify whether some key international parity conditions, such as purchasing power parity, uncovered interest rate parity and real interest parity, show some evidence on their own or, at least, jointly, through some meaningful long-run equilibrium relations combining the parities. The empirical analysis based on the cointegrated VAR model gave some interesting results, interpretable also in terms of convergence, or convergence in act, between the eurozone economy and each economy in turn.

According to the literature, in our system made up by five variables we would have expected to find two long-run stationary cointegrating relations and three common stochastic trends driving the system. The results have been quite different, because for The Czech Republic and Hungary we found just one long-run relation and four common stochastic trends, while for Poland and Slovakia we found two long-run relations and three common stochastic trends, as expected.

For the Czech Republic, the identified long-run equilibrium relation represents a variant of the real interest parity, which is largely accepted as stationary when the ppp term is included, that is when real exchange rate is taken into account. The significant constant term characterizing the relation shows that the two parities, on average, maintain a certain distance over the sample period, therefore the convergence between the parities is just a relative one. Of the four common stochastic trends, two are identified as shocks to the weakly exogenous variables, the eurozone inflation and bond rate, and two as a combination of shocks to the Czech inflation and to the ppp term, and as a combination of shocks to the Czech bond rate and to the ppp term.

For Hungary, the identified long-run equilibrium relation represents a combination of the real interest parity and of the purchasing power parity, though not with full proportionality as required by the RIP condition. To make the relation between the two parities stationary there is a trend component, whose coefficient is a clear signal that some convergence between them is in act over the sample period. The four common stochastic trends are identified as shocks to the four weakly exogenous variables, the eurozone inflation and bond rate, the Hungarian bond rate and the ppp term.

For Poland, one of the two identified long-run relations is very similar to the one characterizing the Czech Republic, a variant of the real interest parity combined with the purchasing power parity, but, instead of a significant constant, we have a significant trend component, a clear indication of a convergence in act. The other identifies a long-run relation between the two nominal bond rates, with a significant trend component indicating a convergence in act. The three common stochastic trends are identified as shocks to the weakly exogenous eurozone inflation, as cumulated shocks to the eurozone interest rate with some contribution from the Polish inflation, and as cumulated shocks to the Polish interest rate with contribution from the ppp term.

For Slovakia, one of the two identified long-run relations is still a case where stationarity is recovered between a modified RIP and the PPP, if a trend component is added, indicating a significant convergence in act. The other identifies a significant empirical relation among the nominal interest rate spread, the eurozone inflation and the real exchange rate, but it doesn't really represent a relation between parity conditions. In this case the trend coefficient cannot be interpreted in terms of convergence between parities. The three common stochastic trends are identified as shocks to the two weakly exogenous Slovakian inflation and eurozone interest rate, while the other is given by cumulated shocks to the Slovakian interest rate with contribution from the ppp term.
The overall analysis is quite satisfying in terms of meaningful long-run equilibrium relations, emerging when analyzing the stochastic behaviour of the variables of interest: the international parity conditions seem to play a certain role in pulling the variables of each Visegrad-4 countries economy towards a convergence with the corresponding variables of the eurozone economy. Some dissatisfaction regards the pushing or driving forces, whose identification didn't lead to the expected common stochastic trends that should have driven each system of variables according to the economic literature. Further research is needed in this direction, particularly towards the identification of structural shocks hitting the systems.

References


Appendix: The data

Graph 1: Data in levels for the Czech Republic

Graph 2: Data in levels for Hungary
Graph 3: Data in levels for Poland

Graph 4: Data in levels for Slovakia
Graph 5: Data in levels for the eurozone

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