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

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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

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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:

$$(1) \qquad p_t^* - p_t = e_t,$$

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:

$$(2) \qquad ppp_t = p_t^* - p_t - e_t$$

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:

$$(3) \qquad E_t^e(\Delta_l e_{t+l}) / l - (R_t^{l*} - R_t^l) = 0,$$

or, with a risk premium term added:

$$(4) \qquad E_t^e(\Delta_l e_{t+l}) / l - (R_t^{l*} - R_t^l) = \upsilon_t .$$

If the difference between $E_t^e(\Delta_l e_{t+l})$ and $\Delta_l e_{t+l}$ is stationary and the differenced process $(e_{t+l} - e_t) / l$ is stationary, it follows that Δe_t is stationary, which implies that $(R_t^{l*} - R_t^l)$ is stationary, unless the term υ_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:

$$(5) \qquad (R_t^l - E_t^e(\Delta_l p_{t+l}) / l) = (R_t^{l*} - E_t^e(\Delta_l p_{t+l}^*) / l) + \upsilon_t ,$$

or

$$(6) \qquad (R_t^l - R_t^{l*}) = (E_t\, (\Delta_l p_{t+l}) / l - E_t\, (\Delta_l p_{t+l}^*) / l) + \upsilon_t ,$$

where υ_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

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:

$$(7) \qquad E_t^e(\Delta_l e_{t+l}) = \omega_1 \Delta(p_t - p_t^*) + \omega_2 ppp_t + v_t \,,$$

that leads to the empirically testable relation:

$$(8) \qquad (R_t^l - R_t^{l*}) = \omega_1 \Delta(p_t - p_t^*) + \omega_2 ppp_t + v_t \,.$$

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:

$$(9) \qquad \Delta \mathbf{y}_t = \sum_{i=1}^{n-1} \mathbf{\Gamma}_i \Delta \mathbf{y}_{t-i} + \mathbf{\Pi} \mathbf{y}_{t-1} + \boldsymbol{\mu}_0 + \boldsymbol{\mu}_1 t + \mathbf{\Phi} \mathbf{D}_t + \boldsymbol{\varepsilon}_t, \quad \boldsymbol{\varepsilon}_t \sim IN_p(\mathbf{0}, \mathbf{\Omega})$$

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

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 $\boldsymbol{\beta}'\mathbf{y}_{t-1}$ and the equations $\Delta\mathbf{y}_t$. As Juselius (2006, pp. 95-100) shows, the vector of constants $\boldsymbol{\mu}_0$, as well as the vector of parameters $\boldsymbol{\mu}_1$, can be considered as the sum of two vectors, one accounting for the mean value of the relations $\boldsymbol{\beta}'\mathbf{y}_{t-1}$ and the other for the mean value of the equations $\Delta\mathbf{y}_t$, as follows:

$$(10) \quad \boldsymbol{\mu}_0 = \boldsymbol{\alpha}\boldsymbol{\beta}_0 + \boldsymbol{\gamma}_0, \quad \boldsymbol{\mu}_1 = \boldsymbol{\alpha}\boldsymbol{\beta}_1 + \boldsymbol{\gamma}_1 \,.$$

As a consequence the mean of the equilibrium error is given by $E(\boldsymbol{\beta}'\mathbf{y}_{t-1} + \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1 t)$ and the mean of the equations is given by $E(\Delta\mathbf{y}_t) = \boldsymbol{\gamma}_0 + \boldsymbol{\gamma}_1 t$

[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 $\boldsymbol{\beta}_0$ restricted to the cointegrating space and no linear trends in the variables, consistent with $E(\Delta \mathbf{y}_t)=0$.

The weaker form can correspond either to a significant constant term $\boldsymbol{\beta}_0$ restricted to the cointegrating space and no linear trends in the data, to or to a significant $\boldsymbol{\beta}_1$ and no quadratic trends in the variables, which implies a non significant $\boldsymbol{\gamma}_1$, leaving the constant term unrestricted.

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

The *p*-dimensional (p = 5) observed process $\mathbf{y}_t$ is given by [$\Delta_{12}p_t^*$, $\Delta_{12}p_t^{Eu}$, R_t^*, R_t^{Eu}, ppp_t], where the variables are observed monthly for t = 1999/I – 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_t^{Eu} = the logarithm of the eurozone HICP price index;

R_t^* = the "home" annual long-term bond yield[5];

R_t^{Eu} = the euro-zone annual long-term bond yield;

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

The difference operator Δ_{12} applied to the log of the price indices gives a measure of the annual inflation rates[6]. 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[7], 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

[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 $H_i\colon \boldsymbol{\beta} = \mathbf{H}_i \boldsymbol{\varphi}_i$. 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

	Δp^{Cz}	Δp^{eu}	R_l^{Cz}	R_l^{eu}	*ppp*	$\chi^2(v)$	*p-val.*
H_1	1	-1	0	0	0	11.314 (4)	0.023
H_2	0	0	1	-1	0	19.248 (4)	0.001
H_3	1	0	-1	0	0	12.167 (4)	0.016
H_4	0	1	0	-1	0	21.605 (4)	0.000
H_5	1	-1	-1	1	0	8.541 (4)	**0.074**
H_6	1	-1	-1.123	1.123	0	8.290 (3)	0.040
H_7	1	-1.005	-1	1.005	0	8.350 (3)	0.039
H_8	1	-1	0	0	0.039	10.400 (3)	0.015
H_9	0	0	1	-1	0.060	14.261 (3)	0.003
H_{10}	1	0	-1	0	-0.065	9.216 (3)	0.027
H_{11}	0	1	0	-1	-0.031	20.861 (3)	0.000
H_{12}	1	-1	-1	1	-0.020	7.960 (3)	0.047
H_{13}	1	-1	-2.456	2.456	-0.102	2.140 (2)	**0.343**
H_{14}	1	-0.688	-1	0.688	-0.035	7.482 (2)	0.024
H_{15}	1	-0.515	-0.485	0	0	9.417 (3)	0.024
H_{16}	1	-0.210	-0.790	0	-0.044	8.815 (2)	0.012
W. E. *p-val.*	6.903 (0.009)	0.226 (0.634)	7.088 (0.008)	2.063 (0.151)	6.218 (0.013)		

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

Eigenvectors β		Weights α	
Variable	$\hat{\beta}_1$	Equation	$\hat{\alpha}_1$
Δp_t^{Cz}	1	$\Delta^2 p_t^{Cz}$	-0.153 (-2.871)
Δp_t^{eu}	-1	$\Delta^2 p_t^{eu}$	0
R_t^{Cz}	-2.526 (-11.198)	ΔR_t^{Cz}	0.051 (2.352)
R_t^{eu}	2.526 (11.198)	ΔR_t^{eu}	0
ppp_t	-0.111 (-7.027)	Δppp_t	0.508 (2.912)
constant	-0.370 (-6.903)		
$\chi_4^2 = 5.411, \quad p-value = 0.248$			

Note: *t*-values in brackets

The resulting cointegrating relation is of the following form:

$$(11) \quad (\Delta p_t^{Cz} - \Delta p_t^{eu}) = 0.370 + 2.526(R_t^{Cz} - R_t^{eu}) + 0.111 ppp_t + v_t$$

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 α 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 β and α are empirically accepted.

Hungary

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

[8] The weak exogeneity restrictions take the form $\mathbf{R}'\boldsymbol{\alpha}=\mathbf{0}$, where **R** is a $(p \times (p-s))$ matrix with $s \geq r$. The *LR* test statistic is distributed as a χ_r^2. A weakly exogenous variable is characterized by a corresponding zero row in α, 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 $H_i\colon \boldsymbol{\beta} = \mathbf{H}_i\boldsymbol{\varphi}_i$. The testing results are in Table 3.

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

	Δp^{Hu}	Δp^{eu}	R_l^{Hu}	R_l^{eu}	*ppp*	$\chi^2(v)$	*p-val.*
H_1	1	-1	0	0	0	17.177 (4)	0.002
H_2	0	0	1	-1	0	20.937 (4)	0.000
H_3	1	0	-1	0	0	14.673 (4)	0.005
H_4	0	1	0	-1	0	20.223 (4)	0.000
H_5	1	-1	-1	1	0	17.353 (4)	0.002
H_6	1	-1	-0.251	0.251	0	16.848 (3)	0.001
H_7	1	2.335	-1	-2.335	0	7.847 (3)	0.049
H_8	1	-1	0	0	1.112	6.912 (3)	**0.075**
H_9	0	0	1	-1	-2.786	9.895 (3)	0.019
H_{10}	1	0	-1	0	0.786	5.541 (3)	**0.136**
H_{11}	0	1	0	-1	3.943	9.939 (3)	0.019
H_{12}	1	-1	-1	1	1.284	7.298 (3)	**0.063**
H_{13}	1	-1	0.106	-0.106	1.111	6.787 (2)	0.034
H_{14}	1	2.301	-1	-2.301	0.400	0.404 (2)	**0.817**
H_{15}	1	2.288	-3.288	0	0	10.840 (3)	0.013
H_{16}	1	1.258	-2.258	0	0.660	4.594 (2)	**0.101**
W. E. *p-val.*	17.907 (0.000)	1.191 (0.275)	0.198 (0.657)	0.216 (0.642)	0.233 (0.629)		

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:

$$(12)\quad (R_t^{Hu} - \Delta p_t^{Hu}) = -2.088(R_t^{eu} - \Delta p_t^{eu}) + 0.358 ppp_t - 0.001t + v_t$$

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

Eigenvectors β		Weights α	
Variable	$\hat{\beta}_1$	Equation	$\hat{\alpha}_1$
Δp_t^{Hu}	-1	$\Delta^2 p_t^{Hu}$	0.119 (6.401)
Δp_t^{eu}	-2.088 (-3.950)	$\Delta^2 p_t^{eu}$	0
R_t^{Hu}	1	ΔR_t^{Hu}	0
R_t^{eu}	2.088 (3.950)	ΔR_t^{eu}	0
Δppp_t	-0.358 (-4.103)	Δppp_t	0
trend	0.001 (5.038)		
$\chi_6^2 = 1.624, \quad p - value = 0.951$			

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 $H_i\colon \beta = \{\mathbf{H}_i \varphi_i,\ \psi_i\}$, 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

	Δp^{Pl}	Δp^{eu}	R_l^{Pl}	R_l^{eu}	*ppp*	$\chi^2(v)$	*p-val.*
H_1	1	-1	0	0	0	15.713 (3)	0.001
H_2	0	0	1	-1	0	7.958 (3)	0.047
H_3	1	0	-1	0	0	7.211 (3)	0.065
H_4	0	1	0	-1	0	22.418 (3)	0.004
H_5	1	-1	-1	1	0	16.190 (3)	0.001
H_6	1	-1	-3.162	3.162	0	6.678 (2)	0.035
H_7	1	0.101	-1	-0.101	0	7.124 (2)	0.028
H_8	1	-1	0	0	-0.06	14.100 (2)	0.001
H_9	0	0	1	-1	-0.064	2.315 (2)	**0.314**
H_{10}	1	0	-1	0	0.032	5.099 (2)	**0.078**
H_{11}	0	1	0	-1	-0.030	21.987 (2)	0.000
H_{12}	1	-1	-1	1	0.032	15.417 (2)	0.000
H_{13}	1	-1	-3.568	3.568	0.171	0.563 (1)	**0.453**
H_{14}	1	0.170	-1	-0.170	0.035	4.852 (1)	0.028
H_{15}	1	0.153	-1.153	0	0	6.729 (2)	0.035
H_{16}	1	0.396	-1.396	0	0.060	2.766 (1)	**0.096**
W. E. *p-val.*	13.096 (0.001)	1.016 (0.602)	9.353 (0.009)	5.094 (0.078)	13.734 (0.001)		

Note: all relations are estimated with a trend

Table 6 : Structural representation for the cointegrating relations: Poland

Eigenvectors β			Weights α		
Variable	$\hat{\beta}_1$	$\hat{\beta}_2$	Equation	$\hat{\alpha}_1$	$\hat{\alpha}_2$
Δp_t^{Pl}	1	0	$\Delta^2 p_t^{Pl}$	-0.114 (-4.554)	-0.261 (-4.672)
Δp_t^{eu}	-1	0	$\Delta^2 p_t^{eu}$	0	0
R_t^{Pl}	-3.089 (-17.186)	1	ΔR_t^{Pl}	0.067 (2.668)	0.052 (0.917)
R_t^{eu}	3.089 (17.186)	-2.052 (-12.690)	ΔR_t^{eu}	0.030 (2.125)	0.078 (2.769)
Δppp_t	0.127 (5.152)	0	Δppp_t	-0.052 (-0.337)	0.964 (2.779)
trend	-0.0011 (-7.331)	0.0003 (4.585)			
$\chi_5^2 = 2.606, \quad p-value = 0.760$					

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:

(13) $(\Delta p_t^{Pl} - \Delta p_t^{eu}) = 3.089(R_t^{Pl} - R_t^{eu}) - 0.127 ppp_t + 0.0011t + v_t$

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) $R_t^{Pl} = 2.052 R_t^{eu} - 0.003t + v_t$

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 $p - value = 0.760$, therefore they are largely empirically accepted.

Slovakia

The specification search for Slovakia, after having controlled for extraordinary large observations with proper intervention dummies[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: $\boldsymbol{\beta}_i = \{\mathbf{H}_i \boldsymbol{\varphi}_i, \ \boldsymbol{\psi}_i\}$. The relative results are in Table 7.

As we can see from the tests *p-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) $(\Delta p_t^{Pl} - \Delta p_t^{eu}) = -8.526 R_t^{Pl} + 13.904 R_t^{eu} + 1.512 ppp_t - 0.011t + v_t$

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

[11] In order to obtain residuals close to Normality, in the Slovakian data set we introduced nine permanent intervention dummies defined for 2002/II, 2003/I, 2004/I, 2004/VIII, 2005/I, 2006/VII, 2006/IX, 2006/X and 2007/I.

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

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

Note: all relations are estimated with a trend

Table 8 : Structural representation for the cointegrating relations: Slovakia

Eigenvectors β			Weights α		
Variable	$\hat{\beta}_1$	$\hat{\beta}_2$	Equation	$\hat{\alpha}_1$	$\hat{\alpha}_2$
Δp_t^{Sk}	1	0	$\Delta^2 p_t^{Sk}$	0	0
Δp_t^{eu}	-1	-2.303 (-3.769)	$\Delta^2 p_t^{eu}$	0.016 (3.863)	0.070 (4.734)
R_t^{Sk}	8.526 (5. 320)	1	ΔR_t^{Sk}	-0.015 (-4.110)	0.003 (0.220)
R_t^{eu}	-13.904 (-4.281)	-1	ΔR_t^{eu}	0	0
Δppp_t	-1.512 (-5.396)	0.467 (3.751)	Δppp_t	0.146 (6.090)	0.011 (0.135)
trend	0.011 (7.313)	-0.002 (-2.831)			
$\chi^2_5 = 6.851, \quad p-value = 0.232$					

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:

$$(16)\quad (R_t^{Pl} - R_t^{eu}) = 2.303\Delta p_t^{eu} - 0.467 ppp_t + 0.002t + v_t$$

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 $\Delta\mathbf{y}_t$. 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:

$$(17)\quad \mathbf{y}_t = \mathbf{C}\sum_{i=1}^{t}\boldsymbol{\varepsilon}_i + \mathbf{C}\boldsymbol{\mu}_0 t + \mathbf{C}\boldsymbol{\Phi}\sum_{i=1}^{t}\mathbf{D}_i + stat.\ comp.$$

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 $\mathbf{C} = \tilde{\boldsymbol{\beta}}_\perp \boldsymbol{\alpha}'_\perp$, a decomposition similar to that relative to $\boldsymbol{\Pi}$[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

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[12] In the decomposition $\tilde{\boldsymbol{\beta}}_\perp = \boldsymbol{\beta}_\perp(\boldsymbol{\alpha}'_\perp \boldsymbol{\Gamma}\ \boldsymbol{\beta}_\perp)^{-1}$, where $\boldsymbol{\Gamma} = -\mathbf{I}_p + \sum_{i=1}^{n-1}\boldsymbol{\Gamma}_i$ and $\boldsymbol{\beta}_\perp$ and $\boldsymbol{\alpha}_\perp$ are $(p \times (p - r))$ orthogonal matrices, defined by $\boldsymbol{\alpha}'\boldsymbol{\alpha}_\perp = \mathbf{0}$ and $\boldsymbol{\beta}'\boldsymbol{\beta}_\perp = \mathbf{0}$.

interest rate, while, from the $\alpha'_{\perp}$ matrix[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 **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 **C** matrix: Czech Republic

	$\sum\varepsilon_{\Delta p^{Cz}}$	$\sum\varepsilon_{\Delta p^{eu}}$	$\sum\varepsilon_{R_l^{Cz}}$	$\sum\varepsilon_{R_l^{eu}}$	$\sum\varepsilon_{ppp}$
Δp^{Cz}	**0.751** (3.373)	**1.408** (3.253)	1.884 (1.982)	-0.510 (-0.662)	0.037 (0.670)
Δp^{eu}	-0.047 (-0.473)	**1.133** (5.922)	-0.318 (-0.757)	0.420 (1.234)	0.018 (0.726)
R_l^{Cz}	**0.248** (2.048)	0.408 (1.736)	**1.167** (2.260)	0.736 (1.758)	-0.042 (-1.401)
R_l^{eu}	-0.014 (-0.181)	0.282 (1.886)	-0.032 (-0.098)	**1.377** (5.186)	-0.001 (-0.050)
ppp	1.226 (1.656)	-0.406 (-0.282)	**-7.428** (-2.351)	**6.205** (2.424)	**1.112** (6.018)

Also for **Hungary** the rank of the matrix **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 **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 **C** matrix: Hungary

	$\sum\varepsilon_{\Delta p^{Hu}}$	$\sum\varepsilon_{\Delta p^{eu}}$	$\sum\varepsilon_{R_l^{Hu}}$	$\sum\varepsilon_{R_l^{eu}}$	$\sum\varepsilon_{ppp}$
Δp^{Hu}	0.000 (0.000)	**-1.971** (-2.307)	0.032 (0.057)	**2.632** (2.460)	**-0.367** (-3.280)
Δp^{eu}	0.000 (0.000)	**1.233** (4.266)	0.035 (0.187)	-0.310 (-0.857)	0.022 (0.573)
R_l^{Hu}	0.000 (0.000)	0.058 (0.141)	**1.061** (3.971)	0.321 (0.621)	-0.031 (-0.567)
R_l^{eu}	0.000 (0.000)	0.140 (0.693)	-0.044 (-0.334)	**1.104** (4.377)	-0.004 (-0.168)
ppp	0.000 (0.000)	-0.706 (-0.548)	**2.416** (2.896)	1.793 (1.111)	**0.786** (4.658)

[13] The $\alpha_{\perp}$ matrices are not reported but available upon request.

For **Poland** the rank of the matrix **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 $\alpha'_{\perp}$ 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 *ppp* term and with some, almost insignificant contribution, from the Polish inflation. From the estimate of the matrix **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 *ppp* term.

Table 11 : The estimate of the long-run **C** matrix: Poland

	$\sum\varepsilon_{\Delta p^{Pl}}$	$\sum\varepsilon_{\Delta p^{eu}}$	$\sum\varepsilon_{R_l^{Pl}}$	$\sum\varepsilon_{R_l^{eu}}$	$\sum\varepsilon_{ppp}$
Δp^{Pl}	0.730 (1.553)	**1.255** (2.696)	-0.174 (-0.169)	3.031 (1.931)	-0.068 (-0.730)
Δp^{eu}	0.164 (0.732)	**1.031** (4.641)	0.548 (1.110)	-0.498 (-0.664)	0.060 (1.347)
R_l^{Pl}	**0.879** (2.309)	0.007 (0.022)	1.215 (1.582)	0.222 (0.202)	0.101 (1.554)
R_l^{eu}	**0.424** (2.371)	0.012 (0.078)	0.508 (1.406)	0.270 (0.520)	0.039 (1.283)
ppp	4.561 (1.207)	-0.365 (-0.097)	**18.126** (2.180)	-19.683 (-1.559)	**2.049** (2.718)

Also for **Slovakia** the rank of the matrix **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 $\alpha'_{\perp}$ matrix, we have that the other is given by cumulated shocks to the Slovakian interest rate with a significant contribution from the *ppp* term. From the estimate of the matrix **C** in Table 12, we note that the *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 C: Slovakia

	$\sum\varepsilon_{\Delta p^{Sk}}$	$\sum\varepsilon_{\Delta p^{eu}}$	$\sum\varepsilon_{R_l^{Sk}}$	$\sum\varepsilon_{R_l^{eu}}$	$\sum\varepsilon_{ppp}$
Δp^{Sk}	**1.162** (14.923)	-0.013 (-0.024)	0.225 (0.233)	-0.644 (-1.250)	0.024 (0.175)
Δp^{eu}	0.069 (1.570)	-0.080 (-0.268)	**1.414** (2.571)	**-0.972** (-3.325)	0.150 (1.931)
R_l^{Sk}	-0.056 (-0.831)	-0.097 (-0.213)	**1.709** (2.039)	0.695 (1.561)	0.181 (1.532)
R_l^{eu}	-0.005 (-0.132)	-0.028 (-0.111)	0.488 (1.068)	**0.920** (3.787)	0.052 (0.802)
ppp	**0.452** (2.938)	-0.247 (-0.238)	**4.365** (2.279)	**-4.318** (-4.243)	0.462 (1.712)

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 and from the Polish inflation

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.

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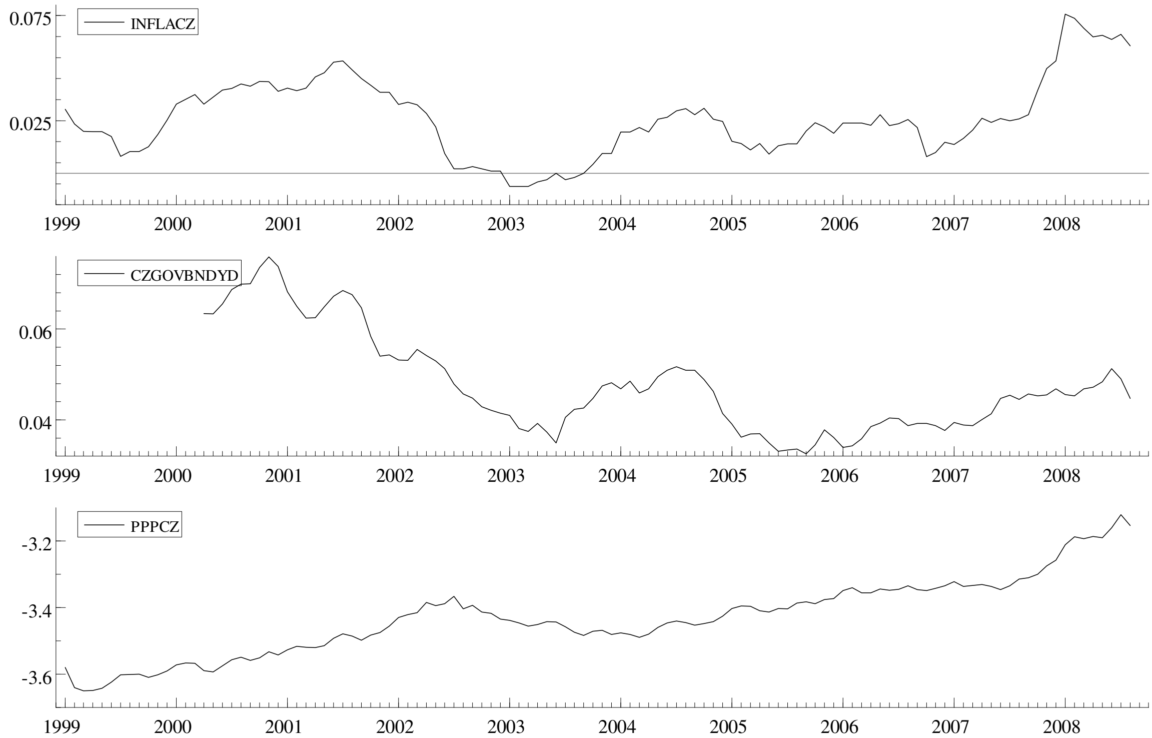
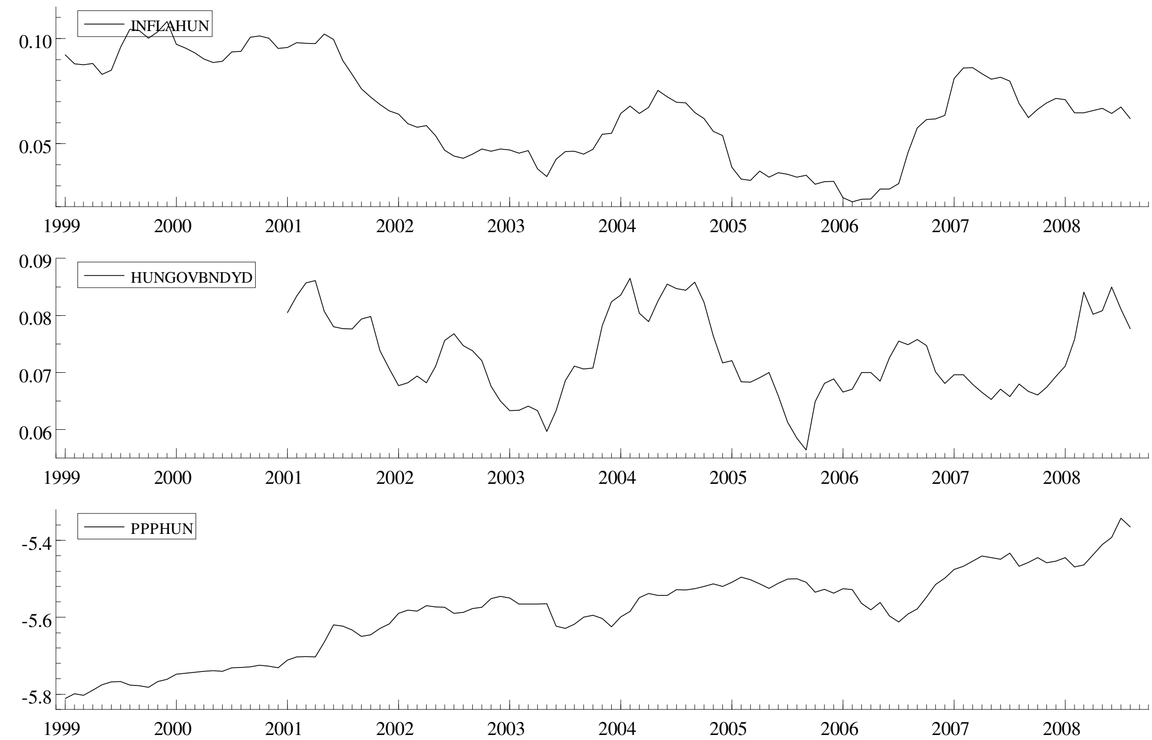
Appendix: The data

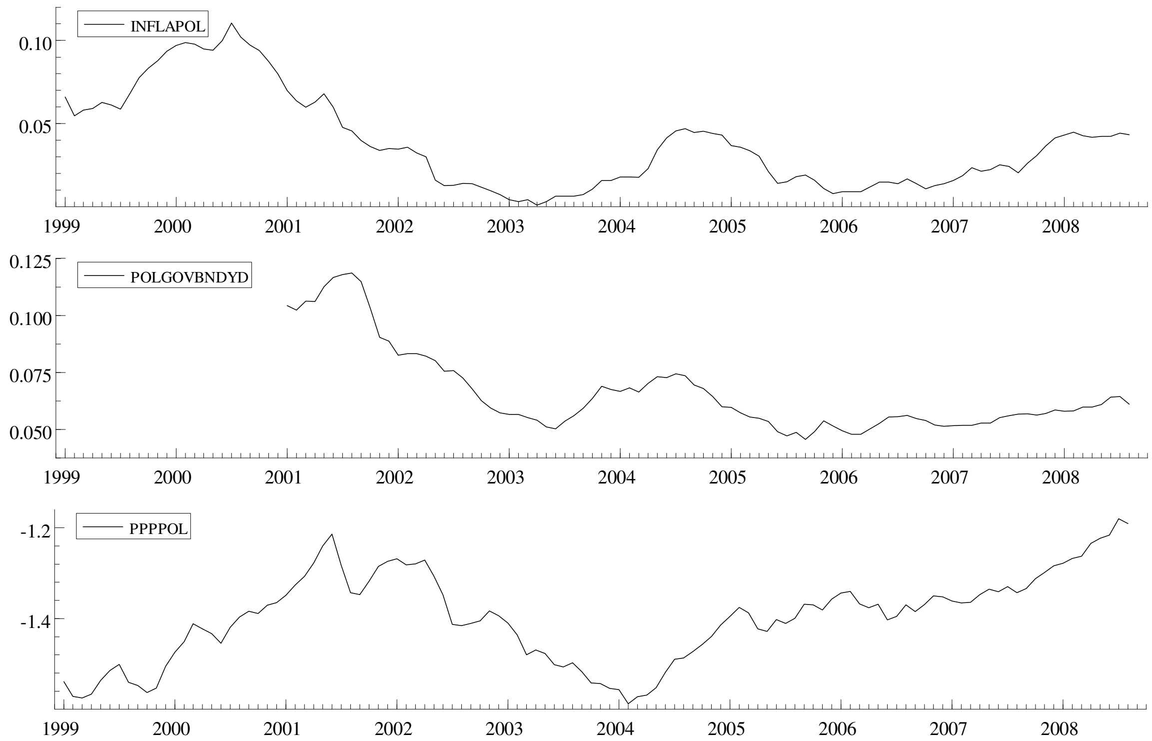
Graph 1 : Data in levels for the Czech Republic



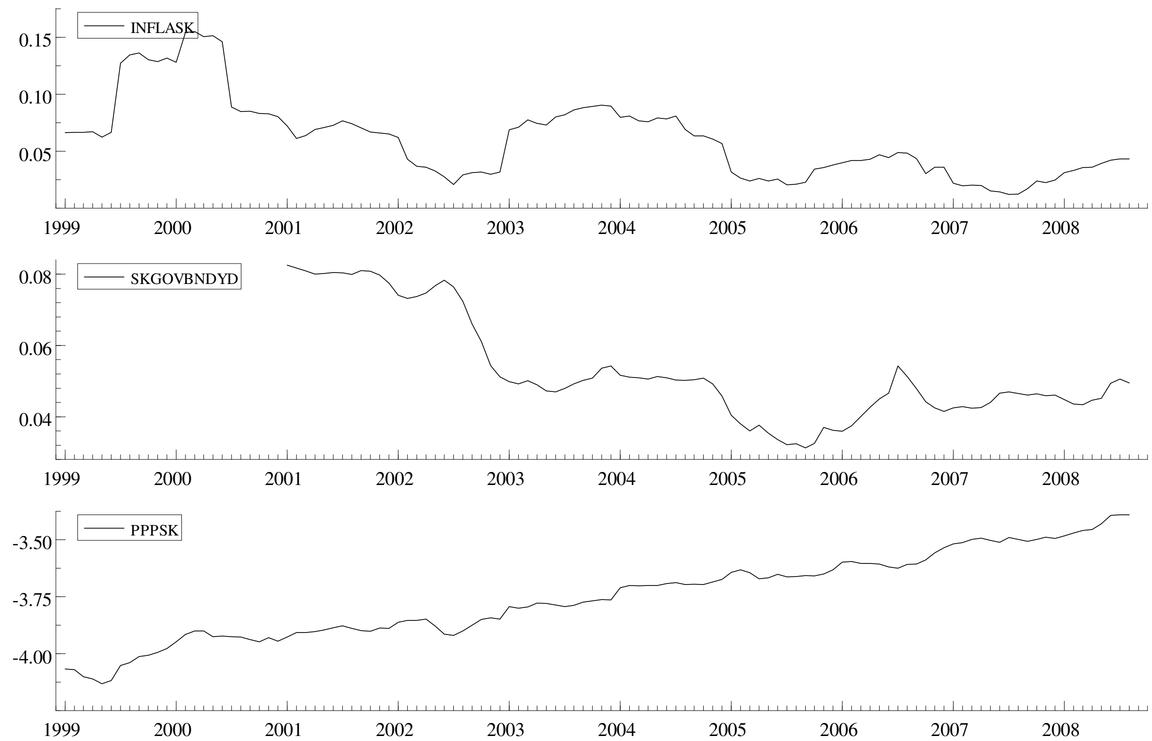
Graph 2 : Data in levels for Hungary



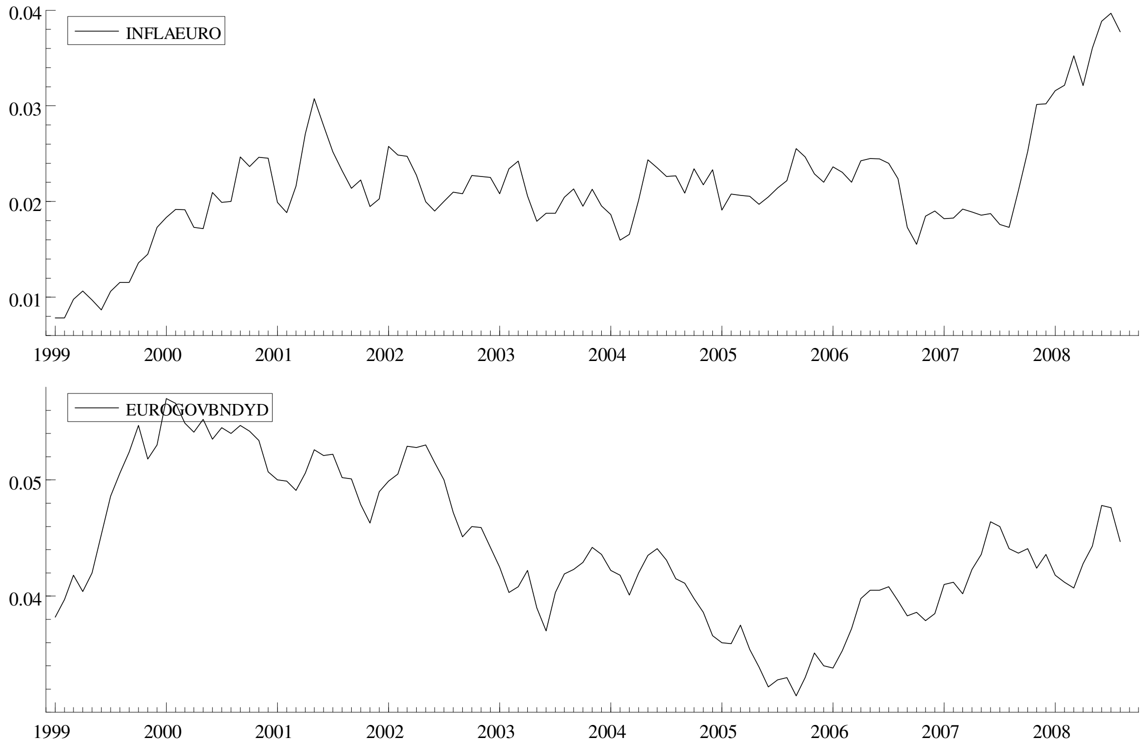
Graph 3 : Data in levels for Poland



Graph 4 : Data in levels for Slovakia



Graph 5 : Data in levels for the eurozone



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