The Academy of Economic Studies
The Faculty of Finance, Insurance, Banking and Stock Exchange
Doctoral School of Finance and Banking

ESTIMATING EQUILIBRIUM EXCHANGE RATE

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I. The objectives of this paper

1. **Estimation of Equilibrium Exchange Rate in four Central and Eastern European Countries: Czech Republic, Hungary, Poland and Romania;**
   - → Establishing the most suitable estimation methods for CEECs;
   - → Setting central parity => joining ERM II and Euro Monetary Union perspective => the values should be close to equilibrium exchange rate;

2. **Behavioral Equilibrium Exchange Rate:**
   - → Finding the characteristic fundamentals factors;
   - → Estimating the long run relationship;
   - → Calculating exchange rate misalignment and equilibrium exchange rate;

3. **Permanent Equilibrium Exchange Rate:**
   - → SVAR approach => estimating structural shocks;
   - → Establishing the sources of real exchange rate fluctuation;
   - → Calculating exchange rate misalignment and equilibrium exchange rate;

1. **Computing a combined measure for ERER (**Principal Components Analysis**)**
   - → Analyzing the extent to which the two estimated misalignments are similar;
   - → Estimating a common misalignment and ERER.

II.1. Equilibrium Exchange Rate Measures

- **RER Misalignment - percentage deviation of the RER from its equilibrium value;**

1. **The Purchasing Power Parity** => Balassa (1964), Samuelson (1964) proved the inability of the PPP theory to provide the definition of the equilibrium exchange rate → misleading indicator for equilibrium exchange rate => *Balassa- Samuelson Effect;*
2. **Methods estimating the short-term equilibrium exchange rate –** *Behavioral Equilibrium Exchange Rate* (MacDonald – 1997, MacDonald and Clark – 1998), *Capital Enhanced Equilibrium Exchange Rate* (Juselius - 1991, 1995, Johansen and Juselius – 1992, MacDonald and Marsh – 1997, 1999, Juselius and MacDonald - 2000);
3. **Methods estimating medium-term equilibrium -** *Fundamental Equilibrium Exchange Rate* (Williamson – 1983, 1994), *Desired Equilibrium Exchange Rate* (Bryant – 1983);
4. **Methods estimating long-term equilibrium -** *Natural Equilibrium Exchange Rate* (Stein – 1994, 1999);
5. **Derived Concepts** - *Permanent Equilibrium Exchange Rate* (MacDonald and Clark – 2000.

II.2. Estimating methods applied for CEECs

Author	Countries	Methodologies
Alberola (2003)	*CZ,HU,PL*	BEER/PEER
Avallone and Lahrèche (1999)	*HU*	BEER
Braumann (1998)	*SK*	BEER
Coudert (1999)	*HU*	BEER
Coudert and Couharde (2002)	*CZ,HU,PL,SK,SI*	FEER
Csajbók and Kovács (2003)	*HU*	FEER
Égert, Lahrèche-Révil (2003)	*CZ,HU,PL,SK,SI*	BEER
Égert and Lommatzsch (2003)	*CZ.HU,PL,SK,SI*	BEER
Égert (2005b)	*BL,RO,RU,UKR*	BEER
Halpern-Wyplosz (1997)	*CZ,PL,HU,SK,SI*	BEER
Halpern-Wyplosz (2001)	*CZ,PL,HU,SK,SI,BL,RO*	BEER
Karádi (2003)	*HU*	BEER/NATREX
Kovacs(2001)	*HU*	BEER
Kim and Korhonen (2005)	*CZ,PL,HU,SK,SI*	BEER
Lommatzsch and Tober (2004)	*CZ,PL,HU*	BEER

II.2. Estimating methods

1. **Clarida and Gali (1994) –** *sources of real exchange rate fluctuations – estimation of demand, supply and nominal shocks.*

2. **Funke** (2000), **Soto** (2003), **Stazka** (2006), **Inoue and Hamori** (2009), **Stazka-Gawrysiak** (2009), **Mumtaz and Sunder-Plassamann** (2010) – *real exchnage rate: shock source or absorber instrument.*

3. **MacDonald and Swagel** (2000) – trivariate SVAR in order to estimate demand, supply and nominal shocks => computation of **cyclical component of the exchange rate => calculating equilibrium exchange rate.**

III.1. BEER Methodology

- **a statistical approach** due to the fact that the main aim of the approach is the estimation of a single equation relationship between real exchange rate and its fundamentals;
- it is quite **simple to implement** from the econometrical point of view by using different cointegration techniques;
- this approach **does not need complex theoretical framework**, for example multi-country models, two-country models or general equilibrium models like FEER or DEER approaches.

It supposes to take the following steps:

1. **Estimating the long-run relationship** between real exchange rate and its fundamental factors which may determine its level on the long run. (Johansen's Cointegration Methodology). (I used the CPI based real exchange rate of the national currencies against the euro);

2. **Determining the long-run or sustainable value of the fundamental factors**. (The Hodrick -Prescott filter);

3. **Computing the real equilibrium exchange rate** by substituting the sustainable value of the fundamental factors obtained in the second step into the long-run relationship estimated in the first step;

4. **Calculating the real exchange rate misalignment** as the percentage deviation of the actual RER from its fitted value.

III.1. The Fundamentals

- **The Fundamentals** were chosen as proposed in the literature with the expected signs:

1. **Net foreign assets** – ambiguous sign into the long-term relationship equation;
2. **The degree of openness** - positive sign of the coefficient;
3. **Terms of trade indicator** – negative sign into the long-run equation;
4. **Real interest rate differential** - ambiguous sign into the long-term relationship equation;
5. **Productivity differential** - quantifies the Balassa- Samuelson effect in each country => negative coefficient in the long-run equation;
6. **Private consumption expenditure** - negative sign into the long-run equation.

III.2. PEER Methodology – SVAR approach

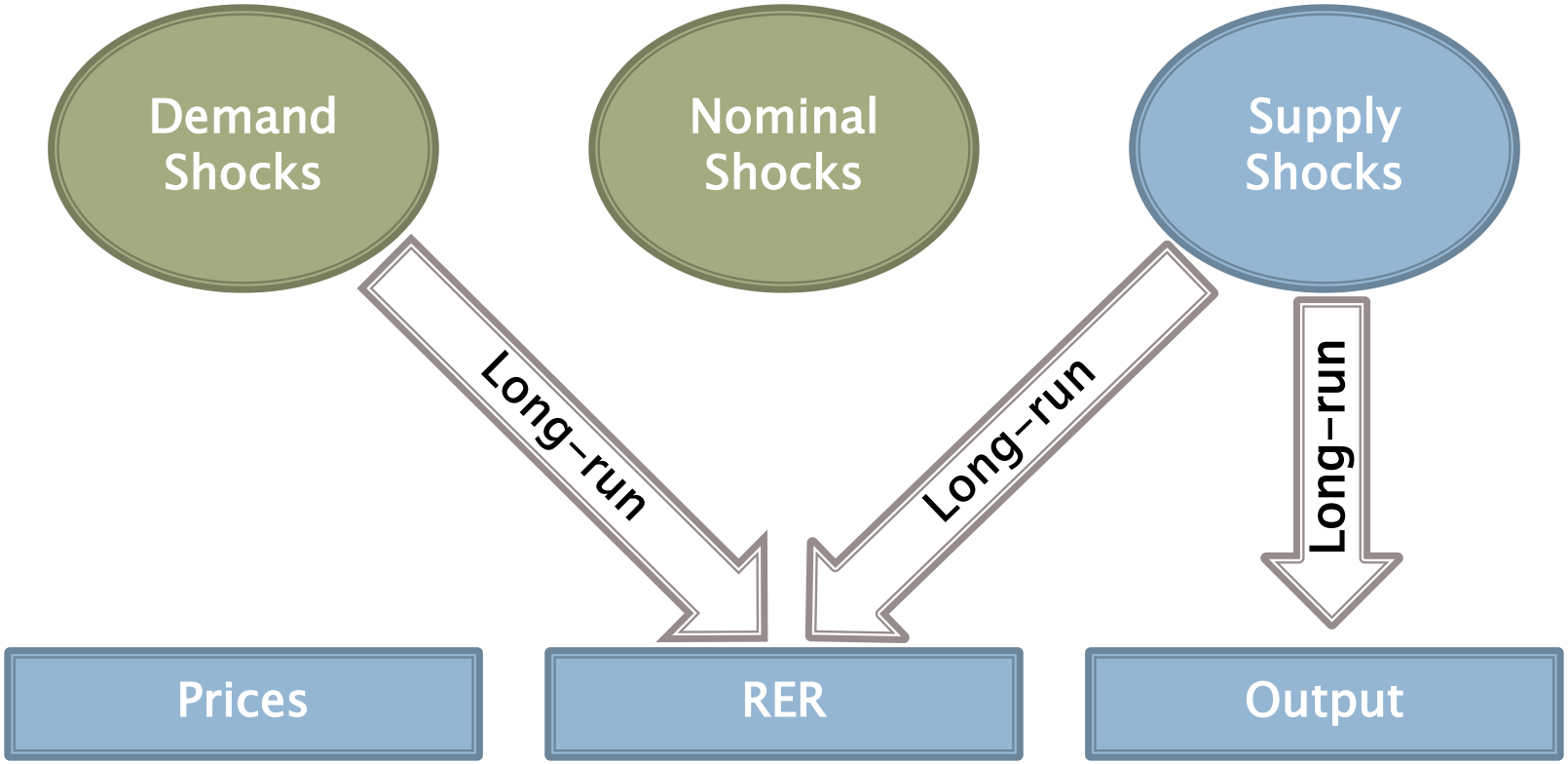
- Based on **Clarida and Gali** (1994) estimation method, developed by **MacDonald and Swagel** (2000);
- The impact of **demand, supply and nominal shocks** over the exchange rate fluctuations.
- Setting the estimation hypotheses in order to obtain a exactly identified model.

Methodology:

1. **Estimating demand, supply and nominal shocks** using a trivariare SVAR and Blanchard and Quah identification scheme;
2. **Calculating the cyclical component** based on the observed impact of the three estimated shocks over the exchange rate fluctuations;
- **Calculating the exchange rate misalignment** from its fitted value.

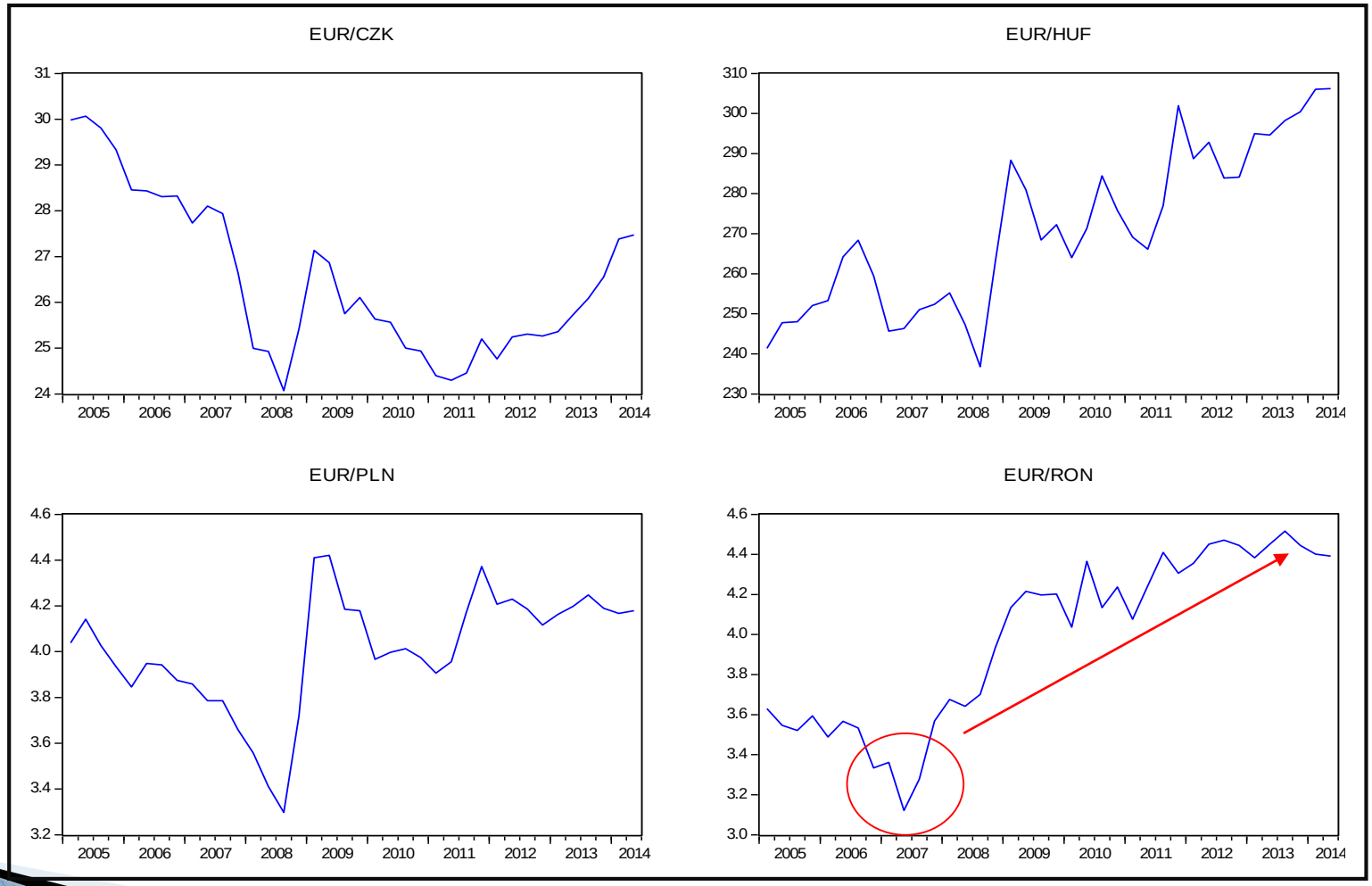
III.2. PEER Methodology – SVAR approach

- **Blanchard and Quah long-term identification scheme** => C(1) matrix



IV. Estimation Results

$$RER_t = \frac{P_t^{EA} S_t}{P_t}$$



IV. Estimation Results – BEER

- **Johansen Cointegration Results:** **There is only one cointegration relation between the variables** indicated by both the Trace and Max tests => **VEC models** can be used in order to estimate the long-run relationship

Țară	Null Hypothesis	Eigenvalue	Trace test statistic			Maximum Eigenvalue test statistic		
			Computed value	5% critical value	p-value *	Computed value	5% critical value	p-value *
Czeck Republic	None**	0.56415	56.58959	47.85613	0.00610	29.8967	27.5843	0.0248
	At most 1	**0.40024**	**26.69285**	**29.79707**	**0.10940**	**18.4040**	**21.1316**	**0.1155**
LRER, PROD_DIFF, OPENESS, NFA	At most 2	0.19658	8.288881	15.49471	0.43500	7.87938	14.2646	0.3911
Hungary	None**	0.54811	51.84410	47.85613	0.02010	28.5951	27.5843	0.0370
	At most 1	**0.29289**	**23.24902**	**29.79707**	**0.23400**	**12.4767**	**21.1316**	**0.5014**
LRER, TOT, RIRD, NFA	At most 2	0.15529	10.772370	15.49471	0.22590	6.07548	14.2646	0.6035
Poland	None**	0.54342	55.69827	47.85613	0.00770	28.2234	27.5843	0.0414
	At most 1	**0.39371**	**27.47484**	**29.79707**	**0.09050**	**18.0145**	**21.1316**	**0.1293**
LRER, PROD_DIFF, RIRD, TOT	At most 2	0.19188	9.460318	15.49471	0.32450	7.66942	14.2646	0.4133
Romania	None**	0.59348	61.52751	47.85613	0.00160	32.4046	27.5843	0.0111
	At most 1	**0.38897**	**29.12290**	**29.79707**	**0.05970**	**17.7339**	**21.1316**	**0.1401**
LRER, NFA, PROD_DIFF, TOT	At most 2	0.21218	11.388980	15.49471	0.18870	8.58551	14.2646	0.3223

IV. Estimation Results – BEER

- **VEC Models estimation results:** the obtained relations are according to the economic literature, the coefficients are statistically significant with the correct economic sign.

Czech Republic	Cointegrating Relationship				
Lag interval 1 2	LRER (-1)	PROD_DIFF (-1)	OPENESS (-1)	NFA (-1)	C
Coeficient	**1.0000**	**1.800103**	**-0.076379**	**-0.00645**	**-5.08926**
Eroarea standard		(0.35775)	(0.05213)	(0.02317)	
t-stat		[5.03170]	[-1.46526]	[-0.27840]	

Hungary	Cointegrating Relationship				
Lag interval 1 2	LRER (-1)	TOT (-1)	RIRD (-1)	NFA (-1)	C
Coeficient	**1.0000**	**-0.777541**	**2.767511**	**-1.819491**	**-5.02597**
Eroarea standard		(0.43266)	(0.70330)	(0.38311)	
t-stat		[-1.79710]	[3.93501]	[-4.74923]	

Poland	Cointegrating Relationship				
Lag interval 1 2	LRER (-1)	PROD_DIFF (-1)	RIRD (-1)	TOT (-1)	C
Coeficient	**1.0000**	**0.224506**	**-1.550129**	**1.411797**	**-3.12453**
Eroarea standard		(0.16796)	(1.01677)	(0.29617)	
t-stat		[1.33668]	[-1.52456]	[4.76677]	

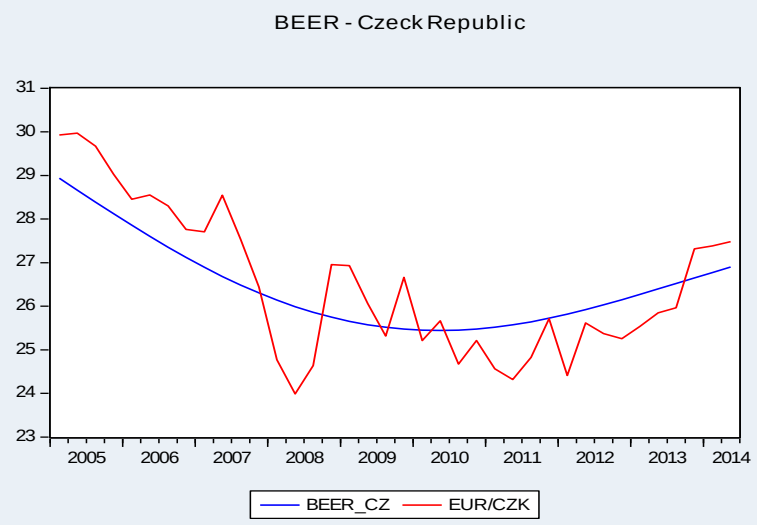
Romania	Cointegrating Relationship				
Lag interval 1 2	LRER (-1)	PROD_DIFF (-1)	NFA	TOT (-1)	C
Coeficient	**1.0000**	**0.300358**	**0.082758**	**0.197676**	**-1.77083**
Eroarea standard		(0.23967)	(0.01480)	(0.08124)	
t-stat		[1.25319]	[5.59226]	[2.43332]	

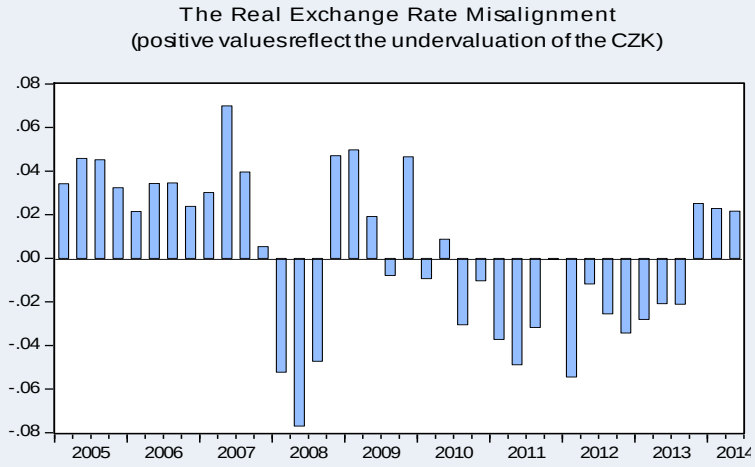
Czech koruna – BEER

LRER=5.089257- 1.800103 PROD_DIFF+ 0.076379 OPENESS+ 0.006450 NFA

1. **Increasing the productivity differential leads to an appreciation of Czech koruna against the euro; Increasing the NFA and the openness indicator conducts to the depreciation of the Czech currency against the euro.**

2. **EUR/CZK was undervalued at the beginning of the period, in Q3 2008 changing it's direction to a overvalued maximum (8%). Starting 2009 the EUR/CZK fluctuated against it's equilibrium value.**



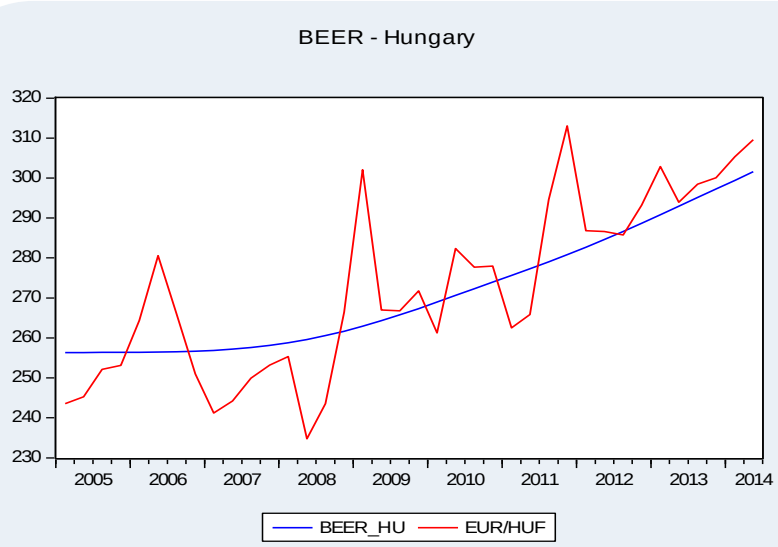


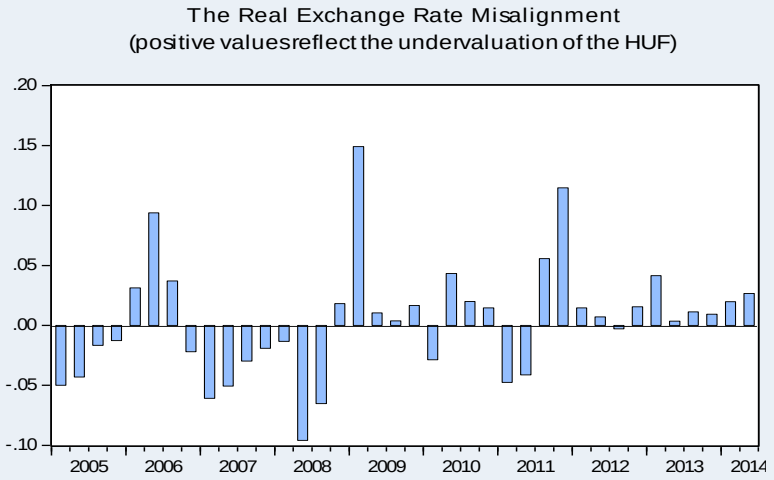
Hungarian forint– BEER

LRER=5.025965+ 0.777541 TOT-2.767511 RIRD + 1.819491 NFA

1. **Increasing the RIRD leads to an appreciation of Hungarian forint against the euro; Increasing the NFA and the TOT indicator conducts to the depreciation of the Hungarian currency against the euro.**

2. **EUR/HUF was fluctuated during the analyzed period around it's equilibrium value, fluctuating into a (+15%,-10%), band.**



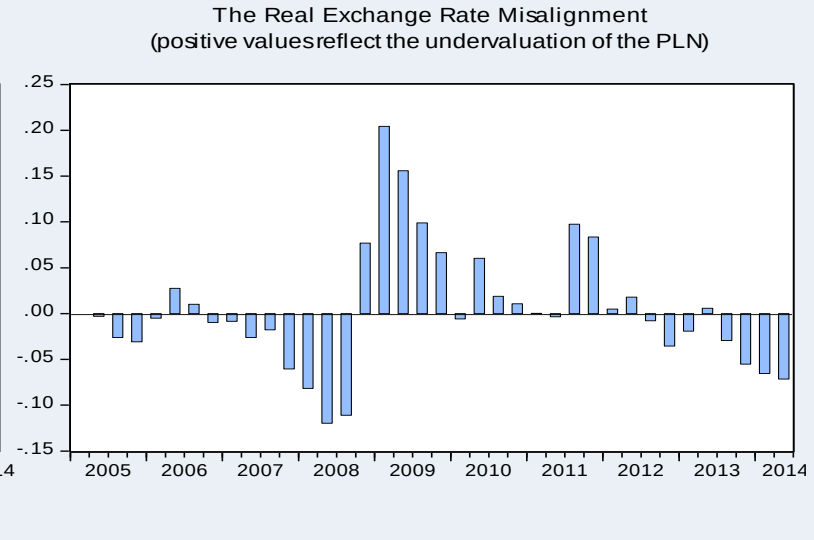


Polish zloty– BEER

LRER=3.124534- 0.224506 PROD_DIFF+ 1.550129 RIRD–1.411797 TOT

1. **Increasing the productivity differential and TOT indicator leads to an appreciation of the Polish zloty against the euro; Increasing the NFA conducts to the depreciation of the Czech currency against the euro.**

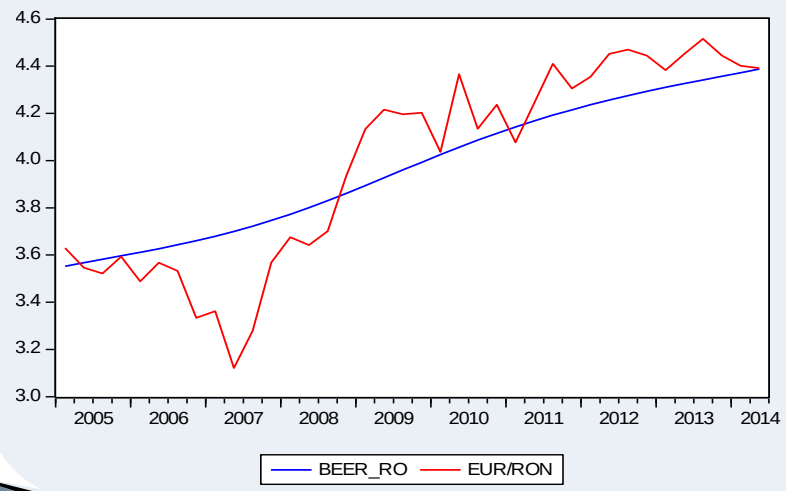
2. **EUR/PLN had two under/overvaluation peaks (2008Q2 and 2009Q2) afterwards fluctuating around it's equilibrium value.**

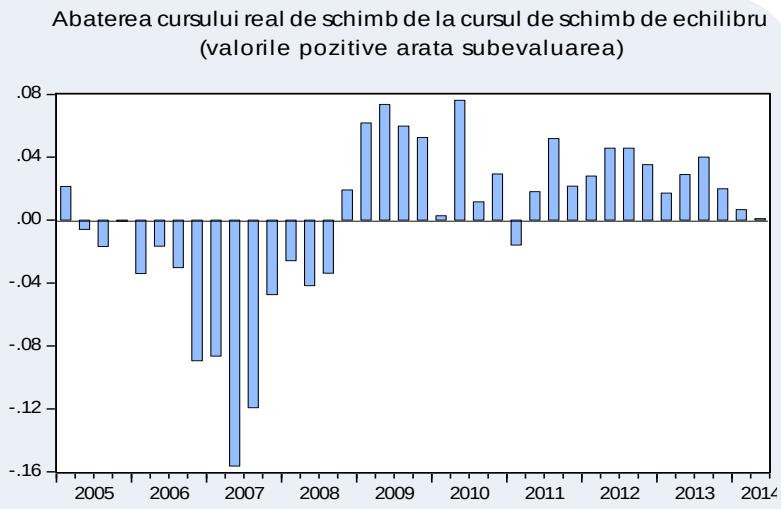


Romanian lei – BEER

LRER=1.770826- 0.082758 NFA- 0.300358 DIFF_PROD- 0.197676 TOT

1. **Increasing the productivity differential leads, NFA or TOT indicator leads to an appreciation of the Romanian lei against the euro;**
2. **EUR/RON was overvalued at the beginning of the period, in Q2 2007 changing it's direction to undervaluation starting 2009, afterwards showing a small amount of misalignment against it's steady value.**





IV. Estimation Results – PEER

1. **Testing Stationarity: Augmented Dickey Fuller test**

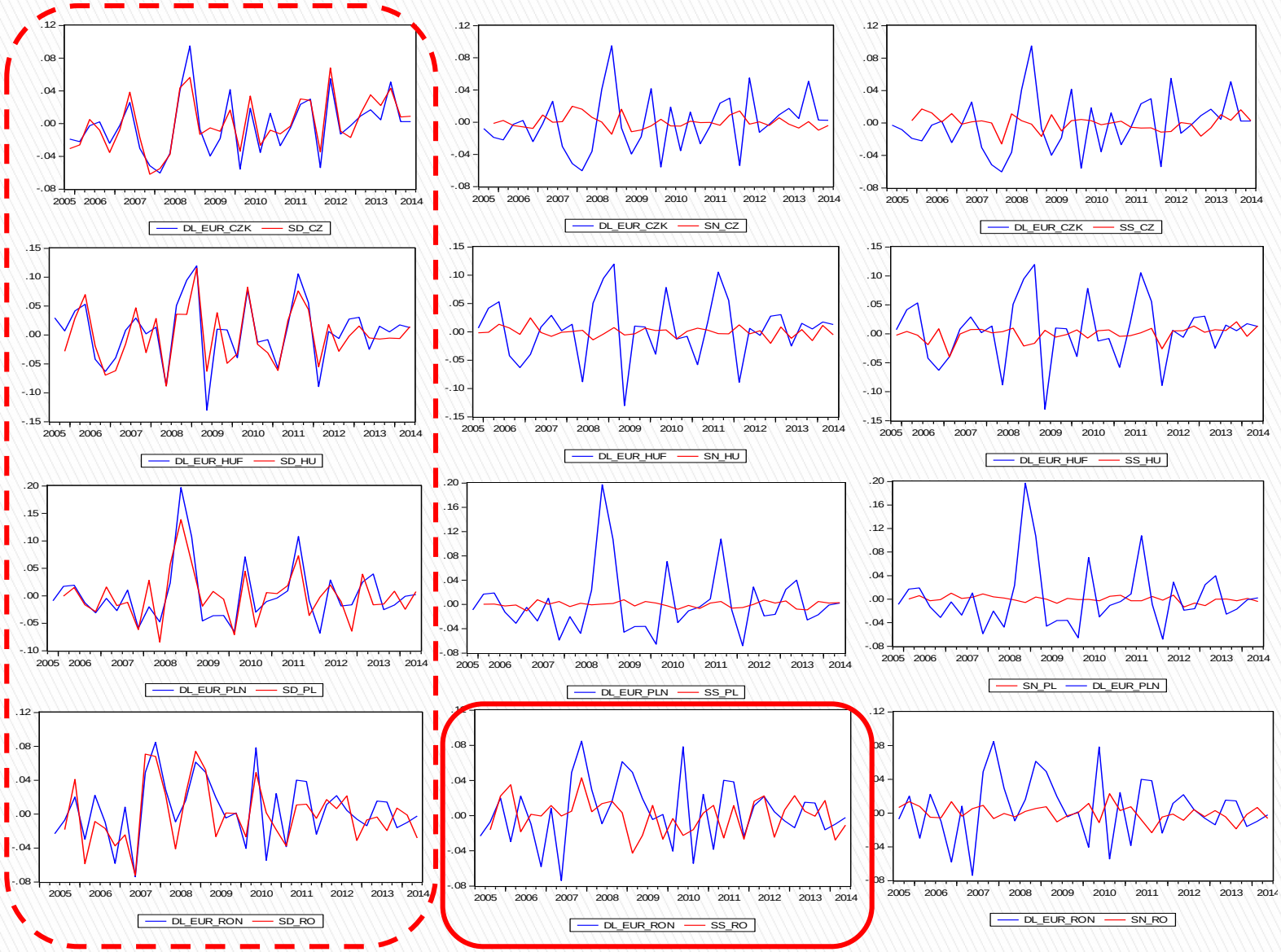
2. **Testing Model Stability:** No root lies outside the unit circle => **VAR models satisfy the stability condition.**

3. **Testing Residuals Hypotheses:**

	Autocorrelation LM test	**Cholesky (Lutkepohl) Normality test**	**White Heteroskedasticity test**
	H0 no errors correlation for the choice lag	H0 the residual VAR has a normal distribution	H0 no heteroskedasticity
Czeck Republic	0.6585	0.8443	0.4198
Hungary	0.1835	*0.0033*	0.8357
Poland	0.4795	0.3200	0.1135
Romania	0.7217	0.9067	0.2400

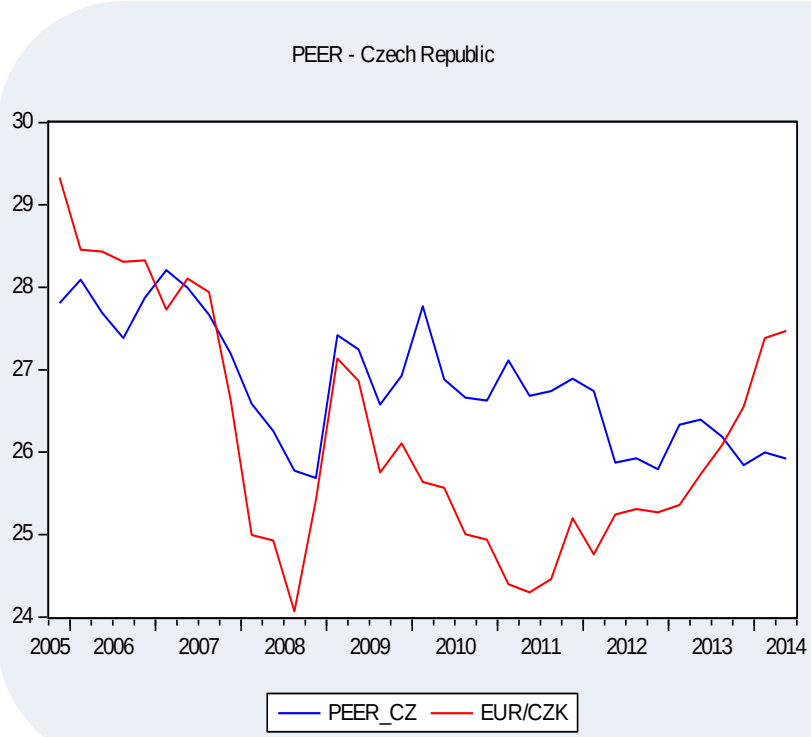
IV. Estimation Results – PEER

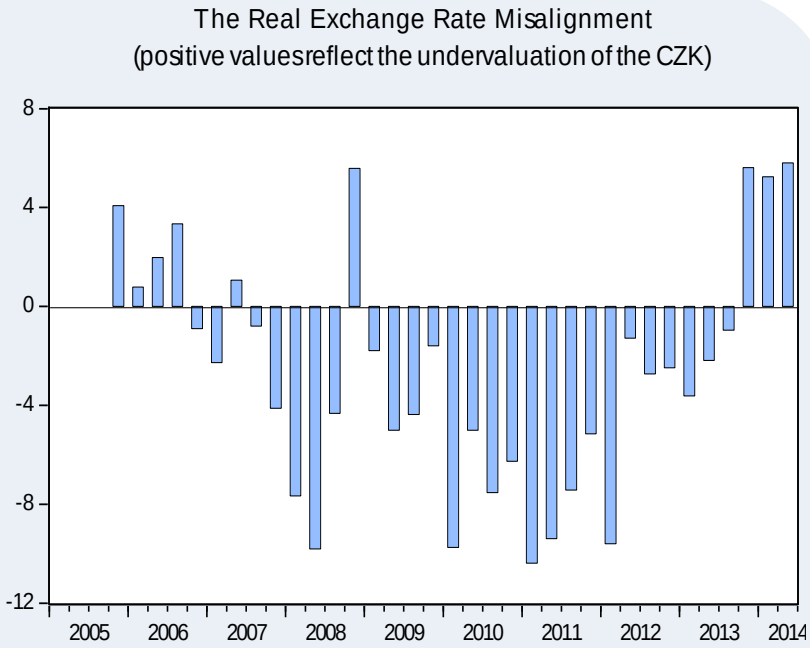
- The Impact of Demand, Supply and Nominal Shocks over the RER:



Czech koruna – PEER

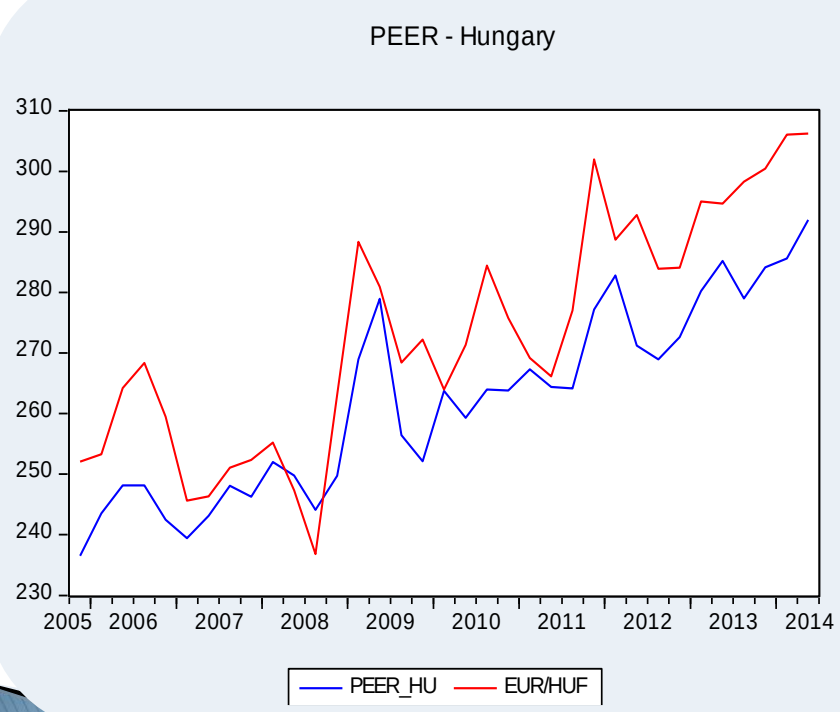
1. **The results indicate generally an overvaluation against the estimated equilibrium values;**
2. **Results are similar to BEER;**
3. **Small degree of undervaluation of the currency against the euro at the end of the analyzed period.**

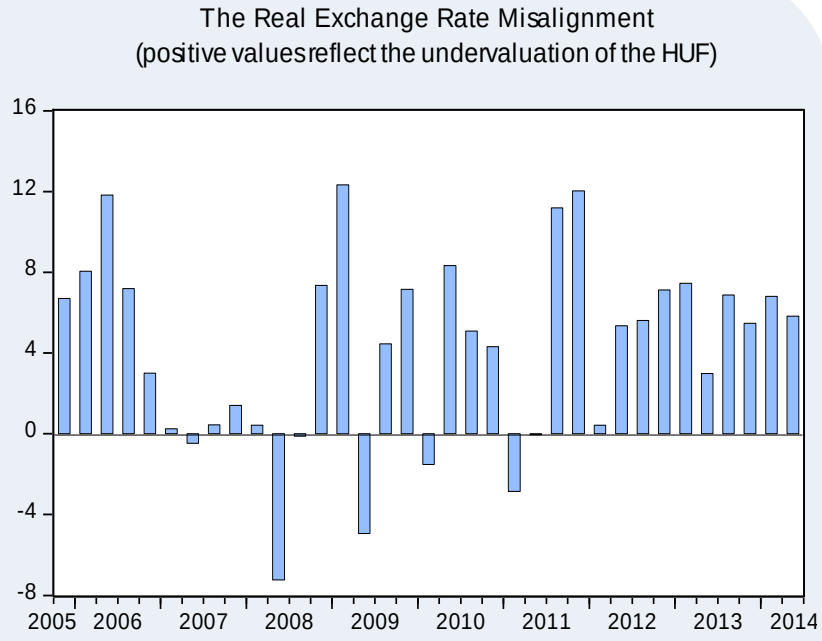




Hungarian forint– PEER

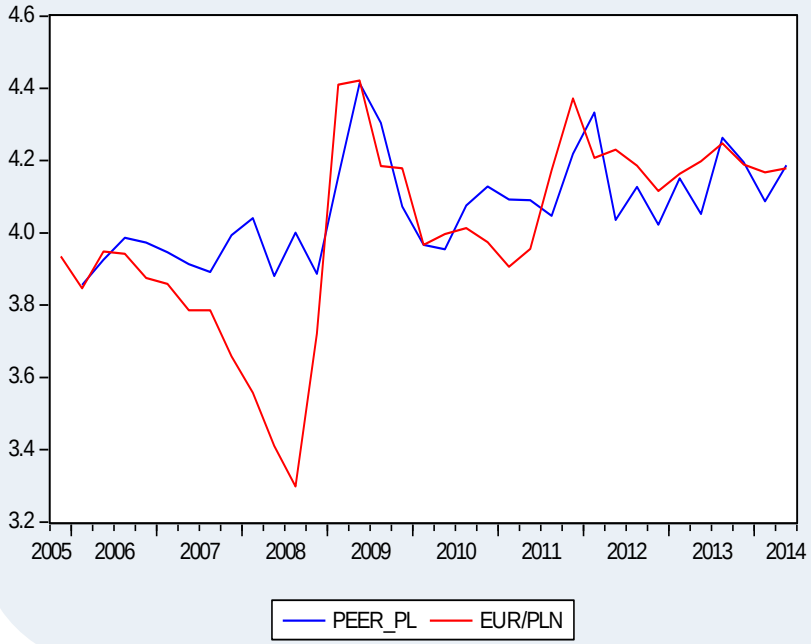
1. **Similar to BEER results, in this case the results indicated and fluctuation around the steady estimated values.**
2. **The RER misalignments fluctuate in a (+12%,-8%) band, while BEER results indicated a (+15%,-10%) fluctuation band.**
3. **Results indicate that overall the analyzed period the exchange rate of the Hungarian forint against the euro was undervalued.**

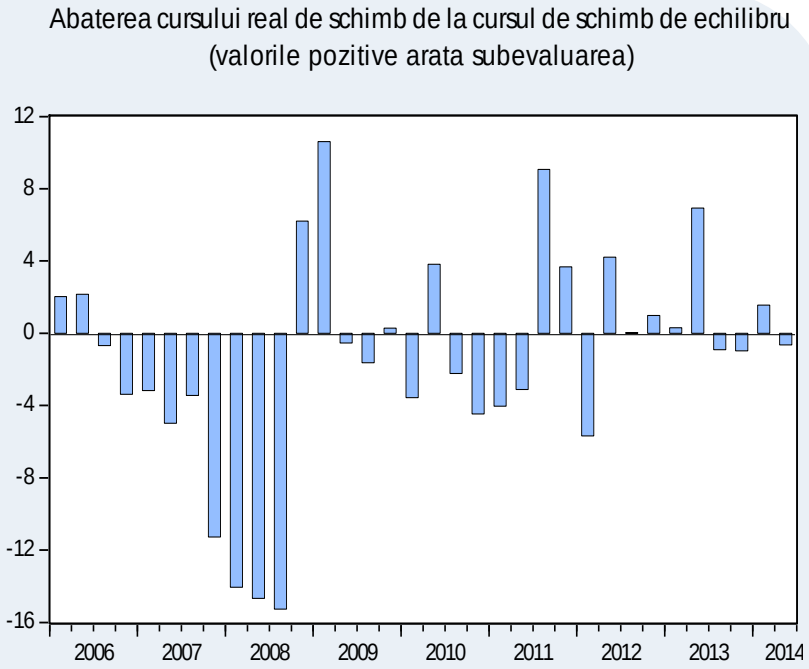




Polish zloty – PEER

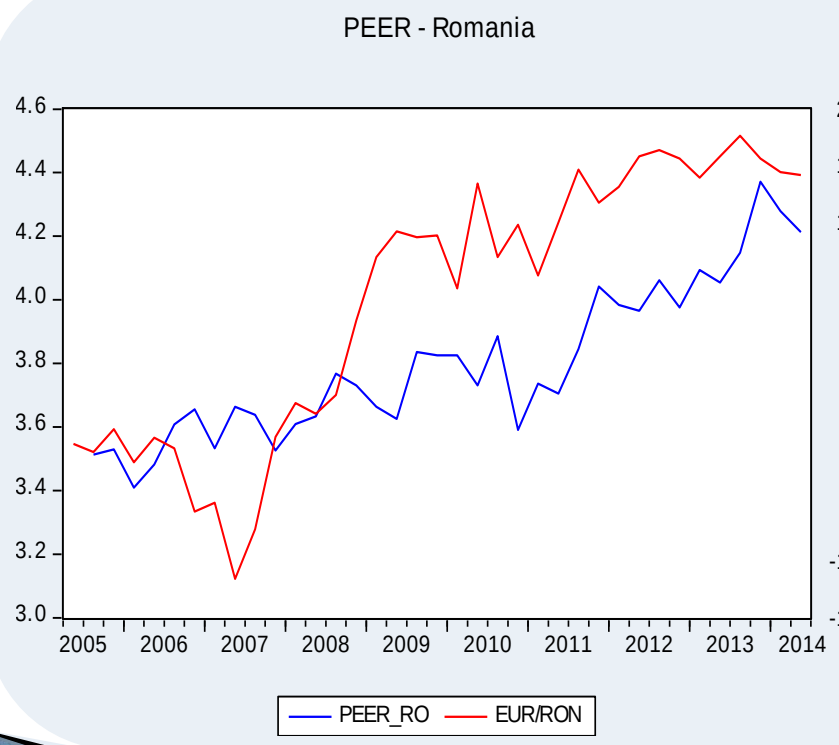
1. **Significant overvaluation during 2008, afterwards slightly fluctuating around it's estimated steady values.**
2. **The results are similar with BEER results, the EUR/PLN exchange rate fluctuating in a (+12%,-5%) misalignments fluctuation band.**

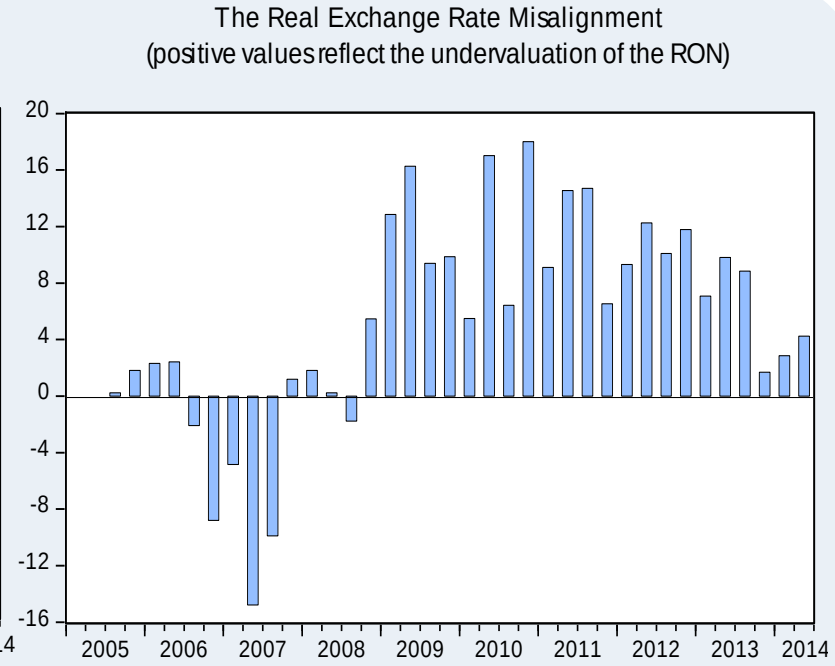




Romanian lei– PEER

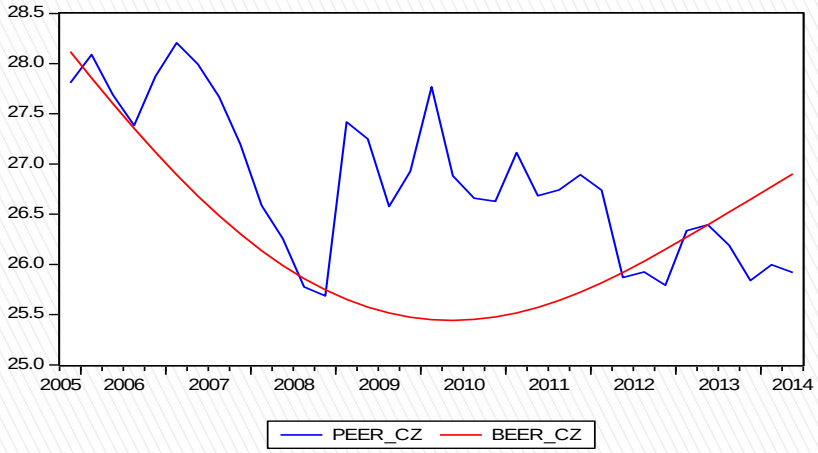
1. **The obtained results are similar with BEER, the Romanian lei against the euro exchange rate being undervalued overall the analyzed period.**
2. **There was a overvaluation at the middle of 2007, but for a small period.**
3. **The maximum overvaluation was in 2007Q2 (-16%) and the maximum undervaluation was in 2010Q4 (+16%).**

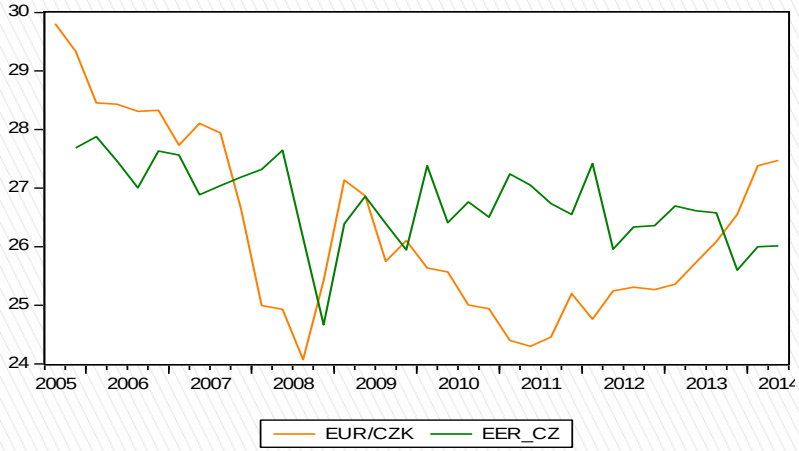


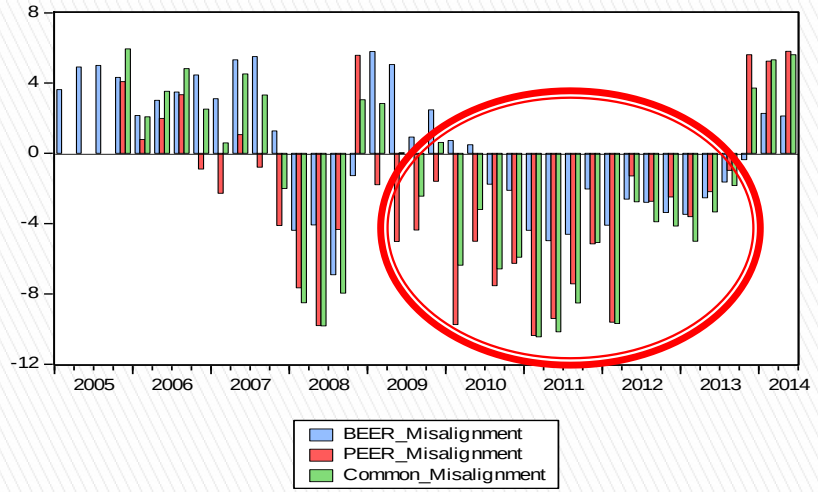


V. Estimated Equilibrium Exchange Rate – PCA

Czech koruna



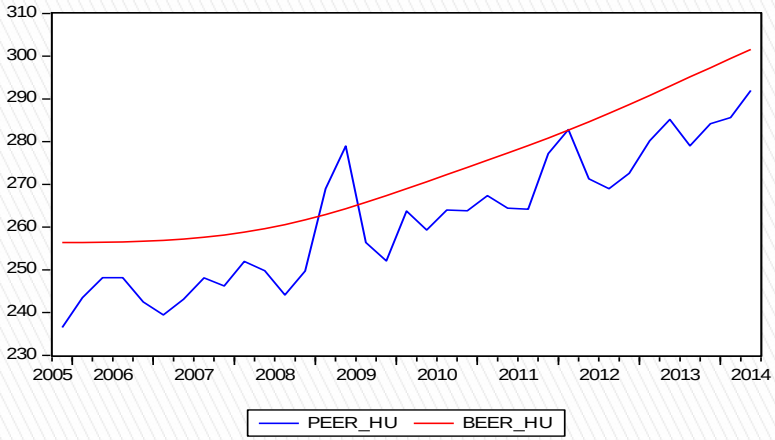


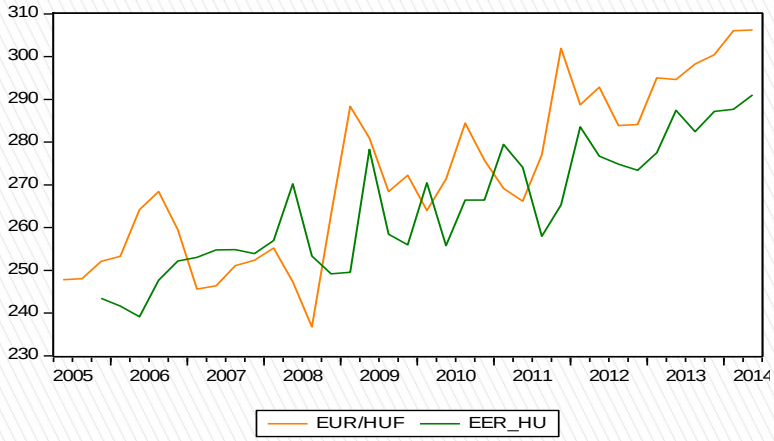


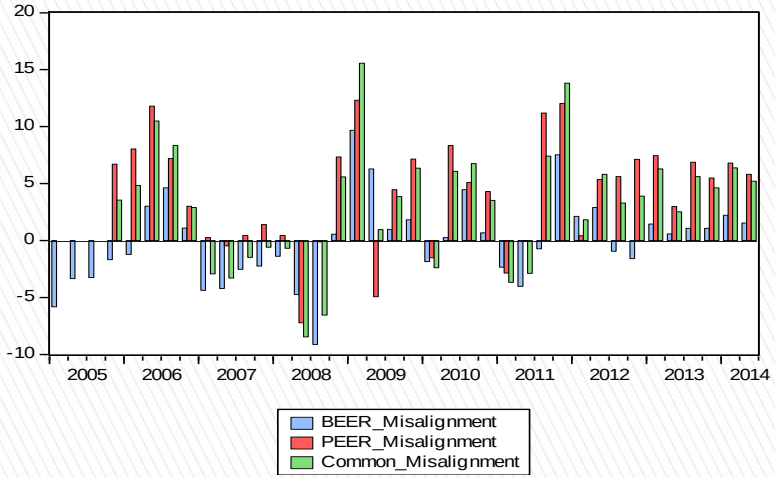
- The principal component explains **77%** of the common variance of the two misalignments series.

V. Estimated Equilibrium Exchange Rate – PCA

Hungarian Forint



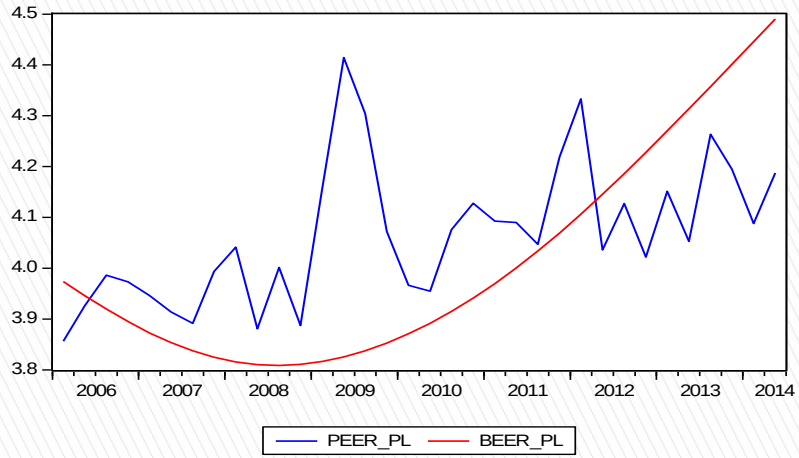


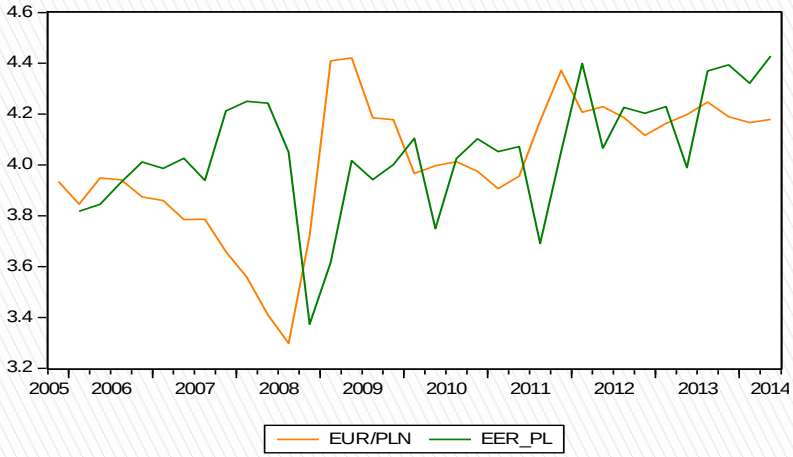


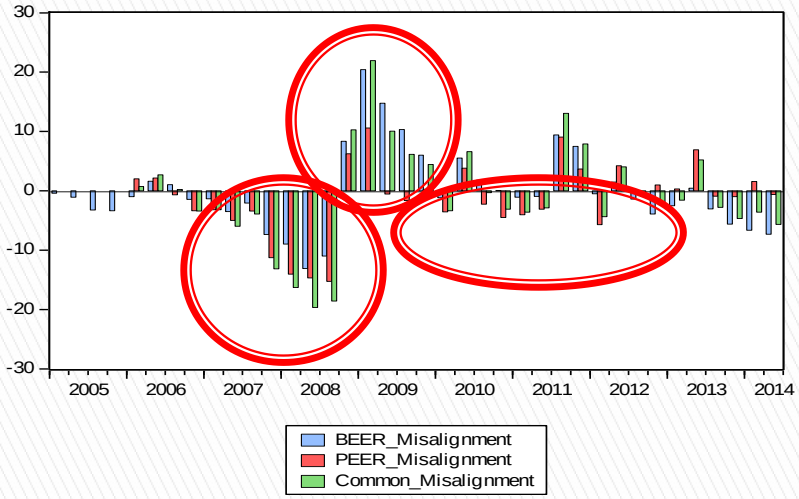
- The principal component explains **76%** of the common variance of the two misalignment series.

V. Estimated Equilibrium Exchange Rate – PCA

Polish zloty



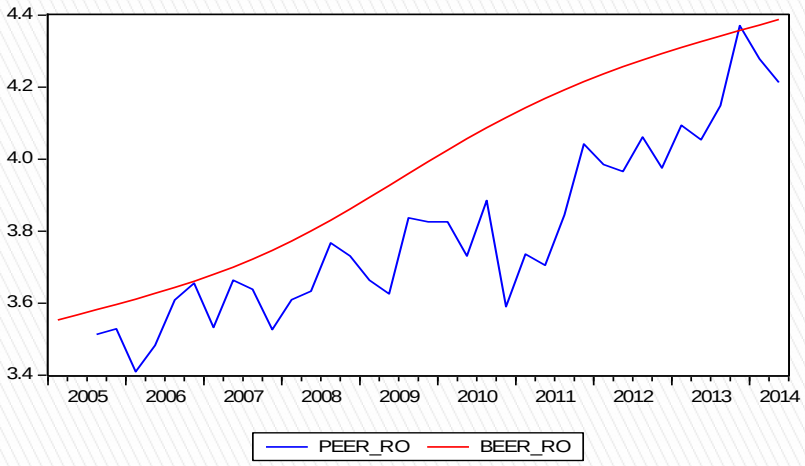


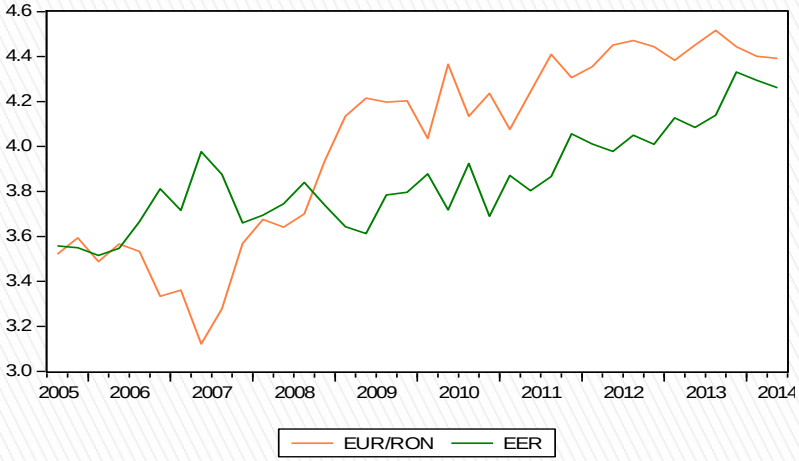


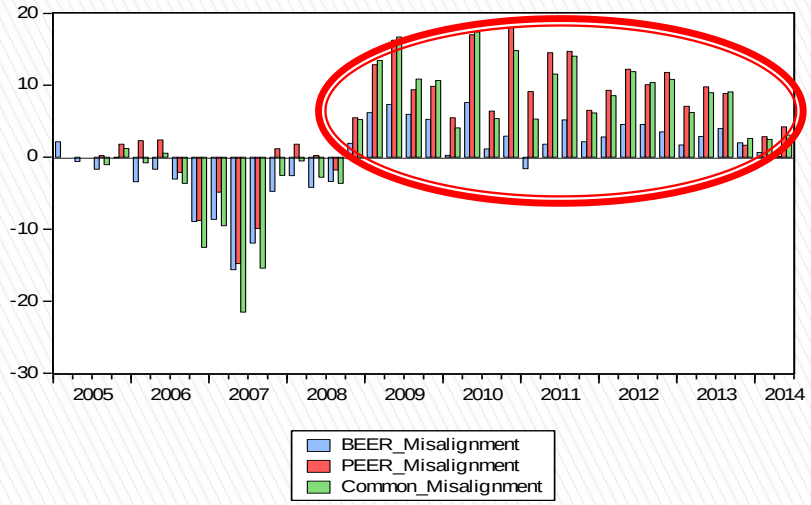
- The principal component explains **86%** of the common misalignments variance.

V. Estimated Equilibrium Exchange Rate – PCA

Romanian lei







- The principal component explains **96%** of the common misalignment.
- The results indicate:
  - Overvaluation until end of 2008 (**peak: Q2 2007**)
  - Undervaluation until the end of the period.

VI. Concluding Remarks

1. The fundamentals obtained for the four countries:
   1. Czech Republic : productivity growth differential ↓, openness ↑, NFA↑ ;
   2. Hungary: RIRD ↓, TOT ↑, NFA ↑ ;
   3. Poland: productivity growth differential ↓, TOT ↓, RIRD ↑ ;
   4. Romania: NFA ↑ , productivity growth differential ↑, TOT,↑ .
2. For **Romania** the cyclical component obtained based on PEER methodology (SVAR approach) indicated that is the sum of both **demand and nominal shocks**;
3. Same direction of the misalignments ⇒ BEER and PEER methodologies high probability in terms of the directions of deviations (MacDonald, 2000).
4. Structural shocks have a significant impact on real exchange rate deviations from its estimated equilibrium values.

Average misalignments	BEER	PEER	Common
Czech Republic	0.3%	-2.7%	-2.0%
Hungary	0.4%	4.2%	3.2%
Poland	0.4%	-1.4%	-0.9%
Romania	0.1%	5.3%	3.8%

5. The importance of taking into account as many determinant factors as possible in order to estimate an equilibrium exchange rate.

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