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Real Interest Parity in New Europe

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Abstract

In this paper we investigate the real interest parity condition in ten Eastern European transition countries during 1997-2009 period. Our sample is interesting for three reasons: It covers the second stage of economic transition in the aftermath of the collapse of socialism; the establishment of Euroland at the turn of the century: and enlargement of Euroland to include the Eastern European countries of Slovenia and Slovakia. The data enables us to investigate how the introduction of market mechanisms in the early nineties and the establishment and enlargement of Euroland acted on real interest rate convergence. We test the real interest parity condition with unit root test with and without structural breaks. Inflationary expectations are estimated in two ways: (i) under assumption of rational expectations with *ex-post* inflation rates and (ii) with *ex-ante* estimated inflation expectation using ARIMA/ARCH model. Preliminary results suggest that there is a strong evidence of stationarity and relatively weaker evidence of structural breaks.

Keywords
Real interest parity condition, Transition countries, Unit root test, Structural breaks

JEL classification
E31, E43, F32, F41

1. INTRODUCTION

Tests of the interest rate parity in emerging economies usually result with puzzling outcome. According to the theoretical assumptions - perfect capital mobility, risk neutrality, and transaction costs - it is realistic to expect that interest rate parity will hold in developed economies, and that incomplete institutional reforms, relatively volatile economic conditions, weaker macroeconomic fundamentals and shallow financial markets will create major obstacles for the mean reversion of the interest rate differential in developing countries.

Contrary to theoretical implications, early empirical results have offered opposite evidence. Early studies for developed countries usually resulted in wrong signs of estimated coefficients (Sarno and Taylor 2002; Alper et al. 2007), while more recent estimates indicate non-linear mean reversion (Obstfeld and Taylor 2002; Nakagawa 2002). In the developing countries even linear methodology resulted with mean reverting estimates (Bansal and Dahlquist 2000; Flood and Rose 2002; Frankel and Poonawala 2006). When it comes to transition countries, environment for the estimation of interest rate parity is even more puzzling. Transition countries performed wide range of market based reforms during last 20 years, removing obstacles to capital mobility, reducing risk premiums and performing institutional reforms. Obviously, such an environment provides interesting opportunity to estimate effects of reforms on the real interest rate convergence.

The fact that we are dealing with developing countries should indicate that there might be a case for linear mean reversion, while numerous institutional reforms (EU and EMU enlargement) might indicate possibility of structural breaks or nonlinear convergence (transaction costs).

Hitherto, several studies investigated real interest rate parity (RIRP) in transitional countries. Arghyrou, Gregoriou and Kontonikas (2008) tested real interest parity with rational inflation expectation in EU25 countries during 1996-2005 with structural break unit root tests. They used three months money market interest rate for nominal interest rate and EMU average as numeraire country.

Cuestas and Harrison (2009) tested real interest rate parity during 1994:1-2007:12 with nonlinear smooth transition autoregression unit root test. They used adaptive $E_t(\Delta p_{t+1}) = \Delta p_t$ and rational inflation expectations. Due to data availability money market interest rate was used as nominal interest rate for most of the countries, and treasury bill rate, deposit rate and interbank rate for other countries. Results pointed to the existence of evidence in favor of the empirical fulfillment of the RIRP when possibility of nonlinearities is taken into account.

In this paper in order to explore the effect of maturity on real interest parity convergence we will used month, three months, six months and twelve months money market interest rate. Also, as a reality check we use fit, adaptive, inflation expectations using ARIMA/ARCH methods and compare these results side-by-side with rational inflation expectation. We adopt three methodologies: standard unit root tests; Lee and Strazicich (2004) minimum LM-unit tests with a structural break; and the Horvath and Watson (1995) cointegration test with a pre-specified cointegrating vector.

The remainder of the paper is as follows, in Section 1 we summarize the theoretical underpinnings of real interest rate parity; Section 2 discusses the data and provides some descriptive statistics; in Section 3 we outline the statistical tests and provide a summary of inflation expectations; Section 4 summarizes the results; finally Section 5 provides some summary remarks.

2. THEORETICAL MOTIVATION

The real interest parity (RIRP) condition can be derived from *ex ante* relative purchasing power parity (ERPPP), the Fisher relation, and the uncovered interest parity (UIP) condition. We define the exchange rate as units of domestic currency per unit of foreign currency, which we take to be the (German) deutschmark/euro. For any variable x let $x^e_{t+k} = E_t(x_{t+k} | \Omega_t)$ be the k period ahead rational expectations of the variable conditional on the information set available in time t, Ω_t. Foreign variables will be assigned a *, thus, x^* is the foreign variable x. We begin with the period $t+k$ *ex post* real interest rate, r_{t+k}, from the Fisher relation, in the home country

$$r^e_{t+k} = i_{t+k} - \pi_{t+k} \qquad (1)$$

where i_{t+k} is the nominal interest rate on a $k-$period domestic bond issued in time t and matures k periods hence; π_{t+k} is the rate of inflation between t and $t+k$, $\pi_{t+k} = \ln(P_{t+k}/P_t)$, where P is the price level, say the CPI. Likewise, we can write the *ex post* real interest rate, r^*, in the foreign country as

$$r^{*e}_{t+k} = i^*_{t+k} - \pi^*_{t+k} \qquad (2)$$

where the variables are described above.

Real interest rate parity in an open economy relies on equilibrium in the goods and services market and asset markets, given by the ERPPP and UIP conditions respectively. The UIP hypothesis relates the expected depreciation of the (log) spot exchange rate, s_t, to the interest rate differential:

$$\Delta s^e_{t+k} = i_{t+k} - i^*_{t+k} \qquad (3)$$

where $\Delta s^e_{t+k} = s^e_{t+k} - s_t$ is the expected depreciation of the home currency and $i_{t+k} - i^*_{t+k}$ is the interest rate differential. UIP is the asset market equilibrium condition and states that foreign and home bonds expected returns must be the same if the risk structure is equal.[1] ERPPP is given in equation (4)

$$\Delta s^e_{t+k} = \pi^e_{t+k} - \pi^{*e}_{t+k} \qquad (4)$$

thus changes in the exchange rate are due to adjustment in the goods and services markets and hold them in equilibrium. Combining equations (1) – (4) yields the real–interest parity (RIP) condition,

$$(i_{t+k} - \pi_{t+k}) - (i^*_{t+k} - \pi^*_{t+k}) = 0$$

or

$$r^e_{t+k} - r^{*e}_{t+k} = 0 \qquad (5)$$

which requires that, in the long run, both asset and goods markets are in equilibrium. Equation (5) is the basis for our empirical analysis.

3. DATA

Entire dataset dof inflation and nominal interest rates is downloaded from Eurostat. We use monthly data for one, three, six and twelve month annual money market interest rates for Bulgaria (BUL), the Czech Republic (CZE), Estonia (EST), Hungary (HUN), Latvia (LAT), Lithuania (LIT), Poland (POL), Romania (ROM), Slovakia (SLK), and Slovenia (SLO) and Euroland as the numeraire country.[2]

Since all interest rates are published as annualized series, we have adjusted one, three and six months bonds to get compatible maturity/span with inflation rates.[3]

Data for inflation are based on monthly data for Harmonised Index of Consumer Prices (HICP, 2005=100). Four different measures of inflation are calculated from HICP: monthly, quarterly, semi-annual inflation rate, and annual inflation rates as

[1] A risk premium, σ, can easily be added to equation (3) as $\Delta s^e_{t+k} = (i_{t+k} - i^*_{t+k}) - \sigma$. This formulation is more relevant given the degree of risk in the Eastern European countries.

[2] In order to increase number of observations, we have used Euroland interest rates for Slovenia and Slovakia after they joined EMU.

[3] It is possible to annualize one, three, six months' inflation rates instead.

$$\pi_{t+k} = HICP_{t+k} - HICP_t HICP_t, k = 1,3,6,12 \quad (6)$$

and used in equation (5).

Because data on expected inflation is not readily available we use *ex-post* and *ex ante* inflation expectation. Former assumes perfect forecasting skills which means that inflation expectations are equal to the realized inflation. On the other hand in the relatively highly volatile and inflation environment of Eastern Europe, we might be better served to use adaptive expectations, which is discussed below.

Table 1 shows the mean, the standard deviation and the number of usable data, N , of the relative real interest rate for each of the countries in the sample, for example, with twelve month interest rates, Bulgaria only has 38 months of usable data. Given the nature of the data, as can be seen there is a considerable amount of missing data and no country has usable observations for each period. As a word of caution, this is likely to influence some of our results. Generally, we can see that Slovenia has the most stable real interest rate, likely due to that country's move towards Euroland and its successful entry in 2007 required it meet certain convergence criteria.

Figure 1 shows the real interest rates standard deviation across all countries for periods where *every country* has an observation -- there are a considerable number of missing observations and at unpredictable intervals. Thus, in a given month if all countries have data except for one, the standard deviation is not calculated. For the one and three month real interest rates there are 98 observations, for six month $T = 17$, and for twelve month, $T = 10$. The most striking observation is the relative stability of the standard deviations between real interest rates with rational expectations versus those using adaptive expectations. The overall standard deviation for one month real interest rates are (0.212, 0.124) when using rational and adaptive expectations respectively; for three month (0.541, 0.537); six month (0.644, 0.576); and for twelve months (0.769, 0.690). Furthermore, we the volatility of real interest rates decline over the period, suggesting converging inflation and risk premia - though the lack of observations for the six and twelve month real interest rates do not yield that much information.

Figure 2 presents the standard deviation of real interest rates for all data (whether or not some data is missing) with rational expectations. From this figure we can clearly see a convergence of interest rates over time. We can also see how stable twelve month real interest rates over the entire sample period.

3.1. Fitted Inflation Expectations

To model adaptive expectations we employ ARMA/ARCH models to generate inflation forecasts. The $ARMA(p, q_m)/ARCH(q_c)$ model is given by

$$\pi^e_{t+k} = \alpha + \sum_{i=0}^{p} \alpha_i \pi_{t-i} + \sum_{i=0}^{q_m} \beta_i \varepsilon_{t-i} + \varepsilon_t \quad (7)$$

$$\varepsilon_t = \nu_t \sqrt{\gamma_0 + \sum_{i=1}^{q_c} \gamma_i \varepsilon^2_{t-1}}$$

ARMA/ARCH models were estimated for all countries separately using grid-search methodology. All possible combination of $ARMA(p, q_m)/ARCH(q_c)$ has been estimated with all possible variations of p and q_m between 0 to 12, and q_c between 1 to 9. The best ARMA model has been selected using Akaike Information Criterion and then tested for ARCH errors.

Table 2 shows models that were selected with Akaike Information Criterion in the grid search. Most of the selected models have four regressors and only nine of them have significant ARCH process. Fitted values from the models presented in Table 2 are used as *ex ante* estimated expected inflation for each period in RIRP test.

3.2. Descriptive statistics

Table 1 shows the mean and standard deviation of the relative real interest rate for each of the countries in the sample. Generally, we can see that Slovenia has the most stable real interest rate, likely due to that country's move towards Euroland and its successful entry in 2004 required it meet certain convergence criteria.

Figure, 1 shows the real interest rates standard deviation across all countries for periods where *every country* has an observation -- there are a considerable number of missing observations and at unpredictable intervals. Thus, in a given month if all countries have data except for one, the standard deviation is not calculated. For the one and three month real interest rates there are 98 observations, for six month $T = 17$, and for twelve month, $T = 10$. The most striking observation is the relative stability of the standard deviations between real interest rates with rational expectations versus those using adaptive expectations. The overall standard deviation for one month real interest rates are (0.212, 0.124) when using rational and adaptive expectations respectively; for three month (0.541, 0.537); six month (0.644, 0.576); and for twelve months (0.769, 0.690). Furthermore, we the volatility of real interest rates decline over the period, suggesting converging inflation and risk premia - though the lack of observations for the six and twelve month real interest rates do not yield that much information.

Figure 2 shows the standard deviation of real interest rates for all data (whether or not some data is missing) with rational expectations. From this figure we can clearly see a convergence of interest rates over time. We can also see how stable twelve month real interest rates over the entire sample period.

4. STATISTICAL METHODOLOGY

4.1. Unit Root Tests

Equation (5) is the testable hypothesis. We can rewrite this in two different formats. Most generally, rewrite equation (5) as the model

$$r_t = \alpha_0 + \alpha_1 r_t^* + u_t \qquad (8)$$

where $u_t : I(0)$ is an iid process. Under the assumption that r_t and r_t^* are stationary standard OLS methods can be used. However, if either of these variables is $I(1)$ the model violates the standard statistical assumptions and cointegration methods are required to test for long run equilibrium RIP. RIP requires that r and r^* are cointegrated with a cointegrating vector of $(1,0,-1)'$. A less restrictive version of RIP is the result of regressing r_t on r_t^* to allow the data to `choose' the cointegrating vector $(1,-\hat{\alpha},-\hat{\beta})'$.

Alternatively, we can define a new variable $R_t = r_{t+k} - r_{t+k}^*$ and run unit root tests to test $R_t : I(0)$. If the data generating process (DGP) of R_t is written as a $AR(p)$ process we can employ a variety of different unit root tests to examine the stationarity of the data using the DGP

$$R_t = \alpha + \rho R_{t-1} + \sum_{i=1}^{p} \gamma_i R_{t-i} + v_t \quad (9)$$

under the null that the $AR(1)$ coefficient is equal to one, that is a nonstationary process. The statistic of interest is the Studentized $t-$statistic of ρ which follows a non-standard distribution as the null of nonstationarity violates the classic statistical assumptions. Note, the specification in (9) implicitly restricts the cointegrating vector to $(1,0,-1)'$.

4.2. Unit Tests with a Structural Break

As discussed above, most of the Eastern European and former Yugoslavian economies have undergone dramatic shifts in their structure. Previous research suggests there is some evidence for long term productivity changes, via the HBS effect. Given the exposure to foreign capital and rising incomes over the sample period, especially in post-war Yugoslavia, both of these effects are likely to play a role in price dynamics and a good test case for understanding price behavior under, sometimes, a less than ideal environment.

Perron (1989) was the first to demonstrate that structural breaks in the data might be misinterpreted as a permanent stochastic process. He considered three models which explain changes in the deterministic process. In Model ``A" the time series undergoes a single level shift; Model ``B" exhibits a change in the slope; and Model ``C" nests both processes. While his test was successful at rejecting unit roots in the standard Nelson and Plosser (1982) data, the test itself requires rather savvy use of the eyeball metric by the econometrician to exogenously choose the break point. The Zivot and Andrews (1992) test, on the other hand, allows the data to endogenously choose the break using a ``minimum" t-test, checking for a break in each period.

We employ the Amsler and Lee (1995) single break LM test under both the null and alternative hypotheses. Consider the following DGP:

$$y_t = \delta' Z_t + e_t,\ e_t = \beta e_{t-1} + \varepsilon_t \quad (10)$$

where Z is vector of exogenous variables. In Model A we allow for one level shifts, $Z_t = (1, D_t)'$ where D_t represents an intercept break, $D_t = 0$ if $t < TB_j$ and 1 otherwise. With this specification, the DGP breaks under the null, $\beta = 1$, and the alternative, $\beta < 1$, hypotheses.

We use LM specification as break test which is estimated using

$$\Delta y_t = \delta' \Delta Z_t + \phi \tilde{S}_{t-1} + \sum_{j=1}^{p} \rho_j \Delta \tilde{S}_{t-j} + u_t \quad (11)$$

where $\tilde{S}_t = y_t - \hat{\psi} - Z_t \hat{\delta}$; $\hat{\delta}$ is the estimated coefficients from the regression of Δy_t on ΔZ_t and $\hat{\psi}$ is given by $y_1 - Z_1 \hat{\delta}$, y_1 *and* Z_1 are the first period observations of y and Z. Under the null, $\phi = 0$ which is tested using as the Studentized $t-$statistic τ. The number of lagged $\tilde{S}$ is chosen using the standard method of starting with a p_{max} (12 months) and working backwards using the 10% $t-$statistic critical value. As is standard in the literature, the breakpoint is chosen from the interval $[0.1T, 0.9T]$ to avoid endpoints.

4.3. Cointegrating Methods

The standard cointegration test is the The Jöhansen estimator which is calculated from a standard VAR into its' error correction model (VECM) form. However, Horvath and Watson (1995) argue that pre-specifying a cointegrating vector of 1s, 0s, and --1s with no unknown parameters, such as is hypothesized here improves the power of standard cointegration tests, such as the Jöhansen (1988) test. They devise a Wald based test statistic derived from the standard VECM representation of the vector $X = (r, r^*)'$:

$$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{\ell-1} \Phi \Delta X_{t-i} + \varepsilon_t \quad (12)$$

where $\Pi = -I_n + \sum_{i=1}^{\ell} \Pi_i$ is a matrix of coefficients with the restrictions

$$\Pi = \alpha\beta' = \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \end{pmatrix} (1,0,-1).$$

and $\varepsilon_t : NIID(0, \Sigma_\varepsilon)$.

The HW procedure tests for the known cointegrating vector under the null that α_1, α_2 and α_3 are equal to zero. The Wald statistic is then calculated using the estimated covariance matrix. Equation (12) is conducted using maximum likelihood estimation for each pair of variables. The HW test is a Wald test which is given by $W(1,-1)$ for the restricted test and $W(1,\beta)$ for the unrestricted test. The advantage of pre-specifying the restricted cointegrating vector, $\beta = (1,0,-1)'$, is the gains in power, a shortcoming for many tests using short data series.

Unfortunately, using pre-determined cointegrating vectors precludes us from using the data to estimate the cointegrating vector. Happily, the HW test can also be used to estimate an unrestricted cointegrating vector $\hat{\beta}$, but at a loss of power. Regardless, the hypothesis suggests that $\hat{\beta}$ should be in the neighborhood of -1. Both the restricted and unrestricted HW tests on equation (12) are used.

5. RESULTS

5.1. Unit Root Results

Our analysis begins with results of unit root tests using the standard specification in equation (9). Results of these tests, with no constant can be found in Table 3 and Figures 3 -- 6. The estimated autoregressive coefficient, ρ, (dashed line) is plotted against the right axis, the $ADF-t$ Statistics (solid line) and the 5% critical values (dotted line) are on the left axis. Figures for the results using rational inflation expectations are on the left and the fitted (adaptive) inflation expectations, from section 2.1, on the right. Countries are organized alphabetically.

As can be seen in the figures, at 5% level of significance, in total 21 series is stationary with rational expectation and 25 with fitted expectation. In total 28 series is stationary with fitted *and/or* rational expectation. If we analyze data according to the maturity, the largest number of nonstationary variables (5) is with 12 months parity, which can be justified with risk premium (long run) and small number of observation for Hungary and Bulgaria. Six months interest rate has three (LAT, LIT and POL) nonstationary parities, and one and three months parities has only two nonstationary variables (POL, ROM at three months and HUN, POL at one month).

5.2. Results of structural break tests

Having in mind that there is at least 12 nonstationary real interest rate parities in ADF unit root test, testing procedure was continued with unit root test that allows for single break under both the null and alternative hypotheses.

Results of the Amsler and Lee (1995) single break LM test are presented in Tables 5 and 4 and Figure 7. For obvious reasons, Figure 7 presents LM unit root results only for 12 series that were $I(1)$ in the ADF unit root test.

With single break under both the null and alternative hypotheses, 4 out 12 otherwise $I(1)$ series appear to be stationary after breaks are accounted for. Three series for Poland (1, 3 and 6 months) and 1 month series for Hungary are stationary with single break. Also, 3 and 6 months parity for Poland is stationary with rational and fitted expectation. Other 8 series, 3 months ROM, 6 months LAT and LIT, 12 months BUL, HUN, LAT, LIT and SLO, remained nonstationary even after single breaks are accounted for. In the same way as in the case of ADF test, the largest number of nonstationary series is in the 12 months maturity, while only three short run series that are not mean reverting.

5.3. Cointegration Results

Results of the cointegration tests can be found in Table 6. The results of both versions are provided: Wald$(1,\beta)$ is the Wald cointegration test statistic for the unrestricted cointegration test; CIV is the estimated cointegrating vector; and Wald$(1,-1)$ is the restricted cointegration statistic.

Turning our attention to the cointegration tests with an unknown cointegrating vector, we can see that we can reject the null of nonstationarity for 13 series with rational expectation and 18 series with fitted expectation. We also see that the cointegrating vectors are far from those hypothesized in the real interest rate literature, particularly for rational expectations. Indeed many of the estimated coefficients $|\hat{\beta}|>3$. We interpret this divergence from the hypothesized vector as a considerable inflation and systemic idiosyncratic risk premia associated with these countries. There are notable exceptions: Fitted one month Czech and Slovak real interest rates; Estonia three month, with both types of inflation expectations; Estonian and Hungarian fitted six month real interest rates; and Slovak and Hungarian 12 month rational and Bulgarian, Hungarian, and Slovak 12 month fitted real interest rates. Overall, we do see, however, that using fitted expectations fits the model better than does rational expectations for many of the series.

Turning our attention to statistical significance we see that, as predicted, the restricted model rejects the null of no cointegration in almost all series with rational expectation and almost all using fitted expectation with the exception of Poland.

6. SUMMARY

We consider real interest parities for ten Eastern European countries with various maturities for money market interest rates one, three, six and twelve months rather than simply look at three month real interest rates. Secondly, given the underlying economic environment of these countries and the corresponding relatively high rates of inflation we consider a both rational and adaptive expectations. Models which utilize adaptive expectations are more successful than using rational expectations while in the midst of high inflation regimes. Indeed, a goal of monetary policy is to reduce inflation to allow economic actors to better formulate rational expectations.

And this is further explained in the data. While we can reject a unit root in real interest rate parity in 21 of the series using rational expectations when using fitted expectations we add seven more stationary series. Moreover, given the nature of the data, when we introduced a structural break into the analysis four more series are stationary.

Of the remaining non stationary series: Five of the remaining nonstationary variables are for 12 months maturity, and two are for six months maturity, which might indicate that risk premium might have influenced longer span maturities in our sample. Also, two of nonstationary variables have really a small number of observations which might reduce the power of the test.

The most significant results from cointegration tests is the large deviation from hypothesized cointegrating vector and when allowing the data to choose the cointegrating vector many of the series estimate coefficient larger then three in absolute value. In addition we are unable to reject the null of no cointegration when the coitnegrating vector is unknown. However, when restricting the cointegrating vector to the hypothesized values, the results fall in line more with standard unit root tests.

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TABLES

Table 1: Summary Statistics

	One Month			Three Month			Six Month			Twelve Month		
	Mean	StDev	N	Mean	StDev	N	Mean	StDev	N	Mean	StDev	N
	Rational Expectations											
BUL	-0.228	1.020	139	-0.724	1.891	120	-0.068	2.807	48	-0.455	3.692	38
CZE	0.068	0.735	156	0.174	1.273	156	0.355	1.784	154	0.857	3.495	148
EST	-0.064	0.570	156	-0.096	1.278	156	-0.001	2.250	134	-0.591	3.535	123
LAT	-0.055	0.742	152	0.066	1.711	152	0.375	3.401	144	-1.047	5.324	112
LIT	0.078	0.653	132	0.427	1.526	132	0.902	3.057	126	0.604	4.509	110
HUN	0.215	0.666	150	0.640	1.171	136	1.435	1.747	82	2.349	2.602	45
POL	0.395	0.577	156	1.178	1.316	156	2.326	2.410	153	3.150	4.135	100
ROM	0.823	2.865	156	2.482	7.046	156	4.667	9.647	154	7.674	13.426	148
SLO	0.013	0.451	104	0.104	0.759	140	0.250	1.074	121	0.784	1.953	106
SLK	0.093	0.965	152	0.340	1.795	152	0.771	2.824	150	-0.306	1.900	107
	Fitted Expectations											
BUL	-0.102	0.652	139	-0.890	1.730	120	0.686	1.967	48	-0.528	3.730	38
CZE	0.017	0.595	145	0.005	1.130	155	0.357	1.685	153	0.827	3.464	148
EST	-0.074	0.389	145	-0.230	1.185	154	-0.046	2.149	134	-0.623	3.501	123
LAT	-0.028	0.535	145	-0.062	1.638	147	0.410	3.307	144	-1.000	5.330	112
LIT	0.108	0.372	132	0.284	1.404	132	0.894	2.859	126	0.636	4.482	110
HUN	0.130	0.553	139	0.515	1.186	127	1.291	1.828	81	2.276	2.542	45
POL	0.373	0.441	145	1.039	1.232	147	2.287	2.340	153	3.125	4.046	100
ROM	1.080	1.508	145	2.351	3.480	149	4.406	6.263	148	9.897	13.099	148
SLO	-0.027	0.284	104	-0.046	0.707	140	0.271	1.134	121	0.796	1.905	106
SLK	0.089	0.550	145	0.269	1.579	151	0.813	2.720	149	-0.281	1.879	107

Table 2: Estimated ARIMA/ARCH models for inflation

Variable	1 Month		3 Months		6 Months		12 Months	
	ARMA	ARCH	ARMA	ARCH	ARMA	ARCH	ARMA	ARCH
BUL	(1,11;6,12)		(1,2,11;3)		(1,2,7;6)	(6)	(1,2,12;12)	
CZE	(3,6,12;12)		(1,3,4;6)		(1,6,7;12)		(1,6,7;12)	
EST	(1,6,7;6)		(1,2,5;3)		(1,2,5;6)		(1,2,8;12)	
EURO	(9,10,12;12)	(7)	(1,3,4;6)	(9)	(1,6,7;12)	(8)	(1,3;6,12)	
HUN	(2,11,12;12)		(1,12;1,2)		(1,6,7;12)		(1,2,7;12)	
LAT	(12;4,6,12)	(1)	(1,12;1,2)	(4)	(1,5;6,12)		(1,5;12)	(2)
LIT	(12;3,4,12)		(1,7;3)		(1,6,7;12)		(1,7;12)	
POL	(12;1,2,12)	(1)	(1,12;1,2)	(2)	(1,6,7;12)		(1,2,8;12)	
ROM	(1,6,12;10)	(8)	(1,2,10;3)	(9)	(1,2,12;6)	(9)	(1,2,12;12)	(9)
SLK	(6,12;12)		(1;2,3,10)		(1,6,7;12)		(1,2;12)	
SLO	(1,9,12;12)		(1,3,4;6)		(1,6,7;12)		(1,2,3;12)	

Notes: AR and MA lags are separated by a `;'.

Table 3: Unit Root Tests of Real Interest Parity

	Rational Expectations		Fitted Expectations	
Country	Constant	None	Constant	None
	One Month			
BUL	-8.612***	-8.419***	-8.286***	-8.221***
CZE	-1.863	-1.833*	-4.381***	-4.001***
EST	-2.936**	-2.971***	-4.003***	-3.330***
HUN	-2.798*	-0.760	-1.893	-1.334
LAT	-1.790	-1.856*	-2.541	-2.519**
LIT	-9.335***	-9.260***	-4.253***	-4.434***
POL	-1.437	-1.092	-1.349	-1.312
ROM	-5.705***	-4.800***	-3.174**	-2.805***
SLK	-3.817***	-3.896***	-2.339	-2.387**
SLO	-10.511***	-10.561***	-1.082	-0.628
	Three Months			
BUL	-1.474	-0.800	-5.844***	-4.773***
CZE	-2.722*	-2.676***	-2.505	-2.500**
EST	-3.431**	-3.445***	-3.376**	-3.324***
HUN	-2.697*	-1.046	-5.582***	-4.503***
LAT	-1.133	-1.186	-2.763*	-2.779***
LIT	-2.119	-2.187**	-2.462	-2.500**
POL	-1.442	-1.017	-2.718*	-1.936*
ROM	-3.626***	-1.211	-2.645*	-1.890*
SLK	-4.106***	-4.194***	-4.027***	-4.123***
SLO	-2.236	-2.312**	-5.658***	-5.575***
	Six Months			
BUL	-3.000**	-2.963***	-2.076	-1.827*
CZE	-2.636*	-2.545**	-3.585***	-3.464***
EST	-2.589*	-2.544**	-2.625*	-2.620***
HUN	-3.462**	-2.262**	-0.824	-3.170***
LAT	-1.652	-1.671*	-1.717	-1.707*
LIT	-1.301	-1.294	-1.683	-1.660*
POL	-1.598	-1.269	-1.706	-1.242
ROM	-9.341***	-7.529***	-5.707***	-2.043**
SLK	-4.527***	-4.628***	-4.282***	-4.374***
SLO	-1.546	-1.564	-2.120	-2.065**
	Twelve Months			
BUL	-0.277	-1.092	-0.196	-1.171
CZE	-2.542	-2.367**	-2.807*	-2.607***
EST	-1.626	-1.602	-2.720*	-2.564**
HUN	-2.393	-0.571	-2.340	-0.591
LAT	-0.375	-0.614	-0.061	-0.334
LIT	-1.680	-1.681*	-1.180	-1.160
POL	-2.200	-2.583**	-2.299	-2.606***
ROM	-9.221***	-1.997**	-2.048	-1.763*
SLK	-2.698*	-2.739***	-3.954***	-3.711***
SLO	-0.277	-0.290	-0.446	-0.433

Notes: Note: ***, **, and * represent rejection of the null hypothesis at the 1%, 5%, and 10% level respectively; $R-$ represents real interest rate parity for 1, 3, 6 and 12 months interest rate.

Table 4: LM Unit Root with Break: Rational Expectations

	T	ρ	t -stat	Half	Break	$t-$ stat
	One Month					
BUL	139	0.067*	-3.490	0.257	2001.02***	3.142
CZE	156	0.619**	-3.768	1.446	1998.05***	3.908
EST	156	0.424**	-4.052	0.808	1998.05***	3.904
LAT	152	0.717	-2.874	2.084	2007.12***	2.866
LIT	132	0.722	-2.490	2.127	2008.11**	-2.046
HUN	150	0.434**	-3.985	0.831	1998.07***	4.123
POL	156	0.581**	-3.957	1.278	1998.07***	4.009
ROM	156	0.968	-1.579	21.032	1999.02	0.340
SLO	104	-0.157	-2.567	NA	2006.05*	1.769
SLK	152	0.523	-2.807	1.068	1998.11***	2.846
	Three Month					
BUL	120	0.749	-2.874	2.398	2002.03	0.483
CZE	156	0.633***	-4.578	1.517	1998.09***	3.037
EST	156	0.797**	-3.652	3.059	2007.12***	3.357
LAT	152	0.861	-2.942	4.625	2007.08	-0.727
LIT	132	0.721	-2.897	2.115	2007.08**	-2.706
HUN	136	0.501***	-5.501	1.003	2007.12***	4.841
POL	156	0.791**	-4.023	2.958	1999.03**	-2.172
ROM	156	0.993	-1.124	94.252	1999.03	-0.172
SLO	140	0.925	-1.517	8.917	2000.07	0.007
SLK	152	0.590	-3.163	1.315	1998.10	-1.498
	Six Month					
BUL	48	0.400***	-4.447	0.756	2003.11***	-4.196
CZE	154	0.909*	-3.218	7.300	1998.05	0.446
EST	134	0.886*	-3.401	5.713	1999.11***	-3.354
LAT	144	0.958	-2.686	16.282	1999.08	-1.515
LIT	126	0.878	-2.578	5.330	2000.10**	-2.558
HUN	82	0.465	-3.172	0.904	1999.06***	2.985
POL	153	0.803***	-5.341	3.162	1998.12***	-4.980
ROM	154	0.989	-1.467	61.912	1999.10	0.356
SLO	121	0.796	-2.235	3.039	2005.10*	1.923
SLK	150	0.723	-4.067	2.140	1999.07***	-3.356
	Twelve Month					
BUL	38	0.776	-1.115	2.738	2008.03	-0.676
CZE	148	0.956*	-3.274	15.496	1998.05	0.080
EST	123	0.908	-2.782	7.144	2003.04***	-2.703
LAT	112	0.978	-1.896	30.750	2007.05	-0.437
LIT	110	0.971	-2.010	23.906	2007.12	-1.528
HUN	45	0.224	-2.446	0.463	2003.01**	2.237
POL	100	0.925	-2.770	8.848	2002.05***	-3.293
ROM	148	0.986	-1.905	47.997	1999.02	0.116
SLO	106	0.921	-1.816	8.394	2005.07	0.703
SLK	107	0.755***	-4.896	2.462	2006.09	-0.708

Notes: ***, **, and * represent rejection of the null hypothesis at the 1%, 5%, and 10% level respectively. LM Model `A' critical values are: -4.239 -3.566 -3.211 at the 1%, 5%, 10% levels respectively. Half-lives are measured in months.

Table 5: LM Unit Root with Break: Fitted Expectations

	T	ρ	t -stat	Half	Break	$t-$ stat
	One Month					
BUL	139	0.239***	-6.146	0.485	2004.08***	5.204
CZE	145	0.432*	-3.308	0.825	1999.05***	3.294
EST	145	0.715	-2.996	2.067	2008.05	-0.198
LAT	145	0.470**	-3.612	0.919	2008.04***	3.611
LIT	132	0.441***	-4.871	0.847	2008.11***	-3.115
HUN	139	0.552	-2.685	1.168	2006.05**	2.574
POL	145	0.813	-2.488	3.354	1999.06*	1.920
ROM	145	0.601**	-4.144	1.363	1999.04**	2.205
SLO	104	0.840	-2.264	3.975	2008.06**	2.107
SLK	145	0.764*	-3.294	2.570	1999.04***	3.008
	Three Month					
BUL	120	0.585***	-6.087	1.292	2003.03***	-3.767
CZE	155	0.540**	-3.806	1.126	1998.09***	3.425
EST	154	0.890	-2.709	5.930	1998.08	1.527
LAT	147	0.892	-2.129	6.087	2007.12	1.119
LIT	132	0.564**	-3.607	1.209	2007.12**	-2.487
HUN	127	0.513***	-5.795	1.039	2005.08***	4.842
POL	147	0.674**	-3.767	1.755	1999.04**	-1.999
ROM	149	0.934	-2.412	10.112	1999.03	1.126
SLO	140	0.809	-1.824	3.270	1999.09	-0.688
SLK	151	0.517*	-3.275	1.051	1999.04***	2.953
	Six Month					
BUL	48	0.310	-3.169	0.591	2003.11***	-3.037
CZE	153	0.900	-2.908	6.591	1998.05	0.646
EST	134	0.867*	-3.293	4.839	2000.07***	-3.062
LAT	144	0.953	-2.426	14.258	1999.08	-1.341
LIT	126	0.874	-2.351	5.137	2001.02**	-2.273
HUN	81	0.725	-2.294	2.155	1998.07	1.578
POL	153	0.804***	-5.073	3.183	1998.12***	-4.783
ROM	148	0.947	-2.250	12.664	1999.02	0.264
SLO	121	0.710**	-3.625	2.026	2001.01	1.278
SLK	149	0.471***	-4.423	0.920	1999.01***	-2.811
	Twelve Month					
BUL	38	0.757	-2.168	2.492	2006.10*	-1.673
CZE	148	0.960	-2.955	16.827	1998.03	-0.072
EST	123	0.885*	-3.294	5.686	2003.05***	-3.039
LAT	112	0.979	-1.801	32.146	2007.08	-0.462
LIT	110	0.964	-2.116	19.151	2001.08	-1.595
HUN	45	0.651	-3.018	1.613	2004.02***	2.619
POL	100	0.895	-2.395	6.266	2002.04***	-2.781
ROM	148	0.983	-2.226	39.397	1999.03	0.787
SLO	106	0.955	-1.316	15.223	2001.12	0.675
SLK	107	0.673**	-4.060	1.750	2006.09	-1.554

Notes: ***, **, and * represent rejection of the null hypothesis at the 1%, 5%, and 10% level respectively. LM Model `A' critical values are: -4.239 -3.566 -3.211 at the 1%, 5%, 10% levels respectively. Half-lives are measured in months.

Table 6: Cointegration Tests

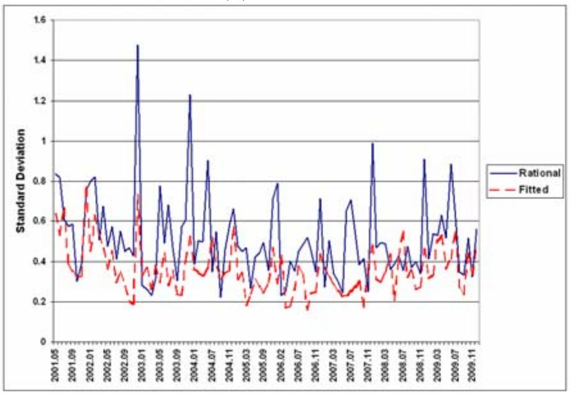
	Rational Expectations			Fitted Expectations		
	Wald $(1,\beta)$	CIV	Wald $(1,-1)$	Wald $(1,\beta)$	CIV	Wald $(1,-1)$
	One Month					
BUL	12.681	(1.0, 3.606)	16.571***	20.905***	(1.0, 0.401)	22.650***
CZE	11.826	(1.0, -5.831)	17.189***	33.515***	(1.0, -1.019)	37.609***
EST	13.635*	(1.0, 0.711)	22.962***	28.982***	(1.0, -0.495)	31.239***
LAT	10.320	(1.0, -11.754)	15.638***	11.853	(1.0, -2.164)	13.651**
LIT	7.442	(1.0, -3.697)	11.985**	17.425**	(1.0, -0.744)	22.965***
HUN	9.745	(1.0, -8.831)	16.035***	6.637	(1.0, -0.030)	10.377**
POL	8.268	(1.0, -10.181)	10.409**	3.601	(1.0, -4.757)	5.177
ROM	14.134*	(1.0, -21.475)	17.843***	13.123*	(1.0, -3.146)	15.725***
SLO	8.355	(1.0, 1.038)	10.344**	10.743	(1.0, 3.751)	11.255**
SLK	10.909	(1.0, -1.832)	15.533***	6.130	(1.0, -1.193)	8.662*
	Three Month					
BUL	10.471	(1.0, 0.752)	13.712**	15.003**	(1.0, 0.513)	19.613***
CZE	10.102	(1.0, -3.232)	14.660***	8.055	(1.0, -1.543)	14.107***
EST	17.227**	(1.0, -1.131)	28.032***	15.655**	(1.0, -1.380)	23.911***
LAT	9.283	(1.0, -14.103)	13.822***	16.735**	(1.0, -4.082)	22.755***
LIT	8.111	(1.0, -3.026)	12.253**	12.049	(1.0, -3.049)	15.136***
HUN	24.575***	(1.0, -0.306)	34.814***	18.355**	(1.0, 0.121)	30.569***
POL	7.632	(1.0, -8.367)	13.007**	4.547	(1.0, -118.905)	7.414
ROM	11.383	(1.0, -20.514)	15.414***	6.505	(1.0, -17.050)	10.603**
SLO	11.612	(1.0, 1.394)	14.873***	7.067	(1.0, 0.209)	10.754**
SLK	22.678***	(1.0, -6.925)	35.287***	13.836*	(1.0, -2.038)	19.680***
	Six Month					
BUL	28.296***	(1.0, -2.179)	28.623***	22.563***	(1.0, -2.064)	22.769***
CZE	9.935	(1.0, -2.209)	17.332***	13.750*	(1.0, -1.884)	20.280***
EST	11.014	(1.0, 0.540)	20.022***	12.383	(1.0, -1.354)	20.135***
LAT	17.986**	(1.0, -6.801)	26.794***	6.206	(1.0, 4.841)	10.622**
LIT	7.269	(1.0, -8.515)	11.385**	7.308	(1.0, -4.701)	11.779**
HUN	11.755	(1.0, -0.590)	15.464***	13.513*	(1.0, -1.474)	19.235***
POL	7.212	(1.0, -13.311)	10.123*	11.318	(1.0, -0.143)	22.074***
ROM	12.255	(1.0, -23.905)	16.882***	9.206	(1.0, -14.133)	11.443**
SLO	12.782	(1.0, 3.013)	14.192***	15.275**	(1.0, 4.760)	16.073***
SLK	18.331**	(1.0, -2.542)	26.230***	12.664	(1.0, -2.034)	18.991***
	Twelve Month					
BUL	26.000***	(1.0, -2.221)	48.396***	26.000***	(1.0, -1.038)	33.153***
CZE	14.625*	(1.0, -2.091)	26.576***	9.880	(1.0, -1.364)	14.150***
EST	13.593*	(1.0, -9.475)	20.357***	15.936**	(1.0, -6.573)	23.232***
LAT	12.107	(1.0, -16.149)	15.379***	11.971	(1.0, -7.993)	16.302***
LIT	13.385*	(1.0, -19.946)	20.620***	16.536**	(1.0, -8.428)	21.669***
HUN	21.242***	(1.0, -0.826)	21.251***	6.685	(1.0, -0.951)	11.095**
POL	9.782	(1.0, 0.230)	11.790**	10.534	(1.0, 0.798)	16.517***
ROM	11.270	(1.0, -14.489)	17.488***	9.763	(1.0, -13.702)	14.138***
SLO	9.955	(1.0, 4.809)	10.907**	7.005	(1.0, 3.378)	8.762*
SLK	8.708	(1.0, -1.777)	14.632***	14.361*	(1.0, -1.052)	17.076***

Notes: ***, **, and * represent rejection of the null hypothesis at the 1%, 5%, and 10% level respectively. Wald critical values for the unrestricted model (Case 2) are: 13.01, 14.93 and 19.14, and for restricted model 8.3, 10.18 and 13.73 at the 10%, 5%, 1% levels respectively, see Horwath and Watson (1995).

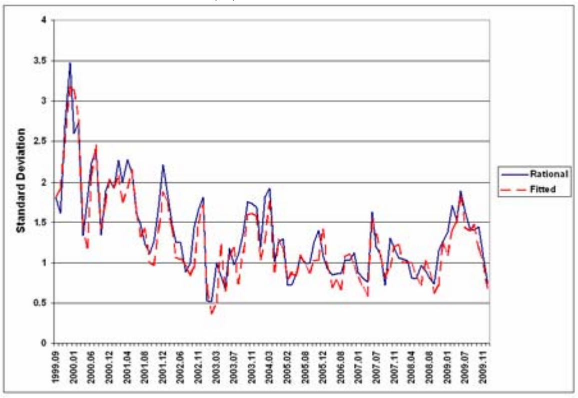
FIGURES

Figure 1: Standard Deviation of Country Real Interest Rates

(a) One month



(b) Three months



(c) Six months

(12) Months

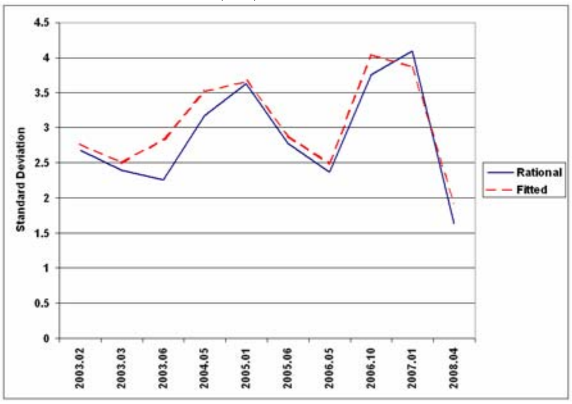


Figure 2: Volatility of ex ante Real Interest Rate

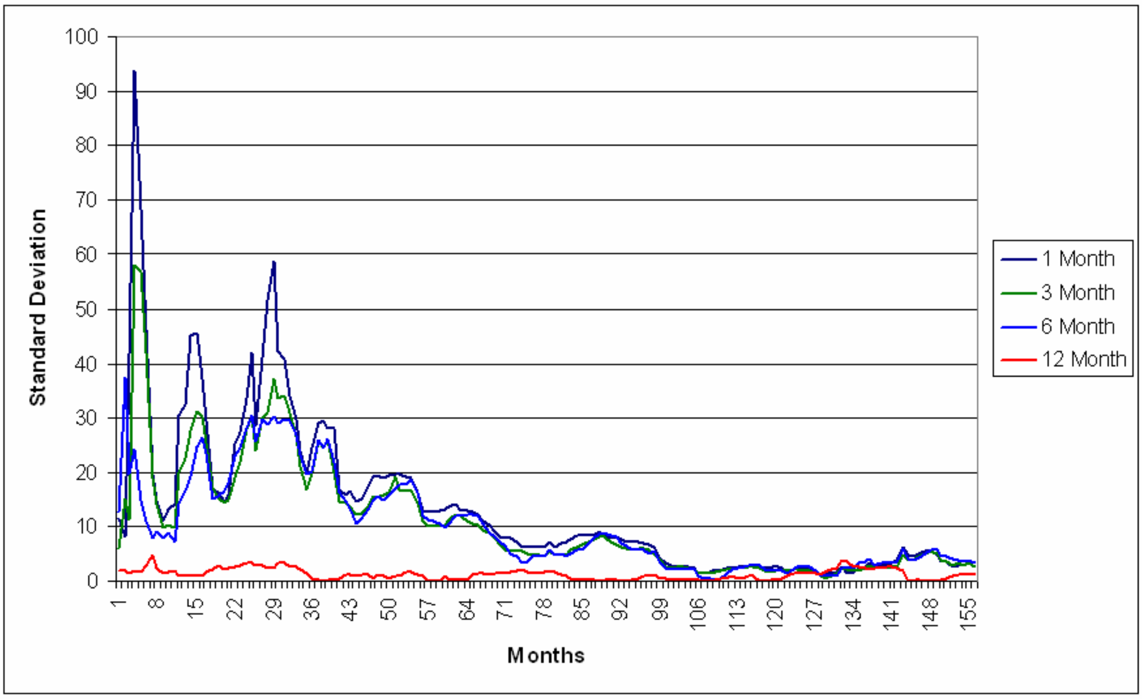
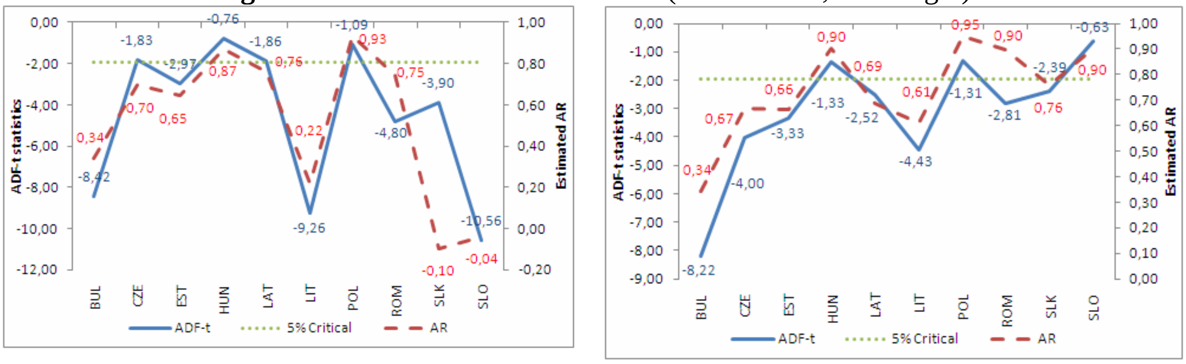
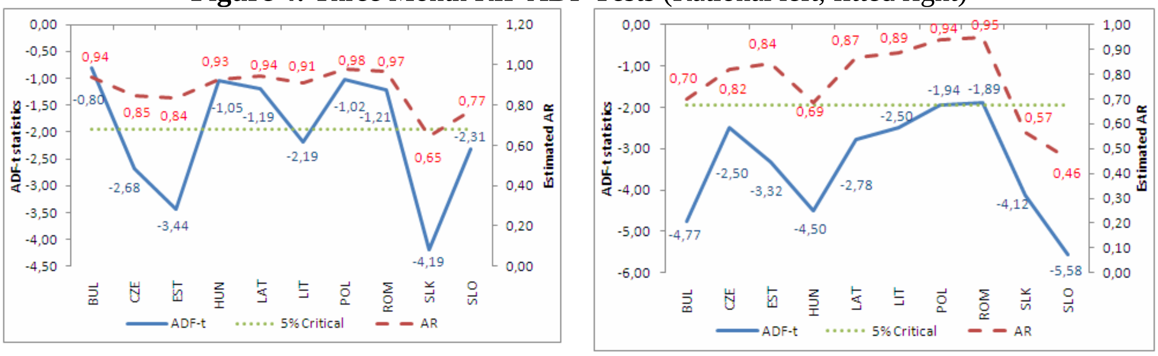


Figure 3: One Month RIP ADF Tests (Rational left, fitted right)



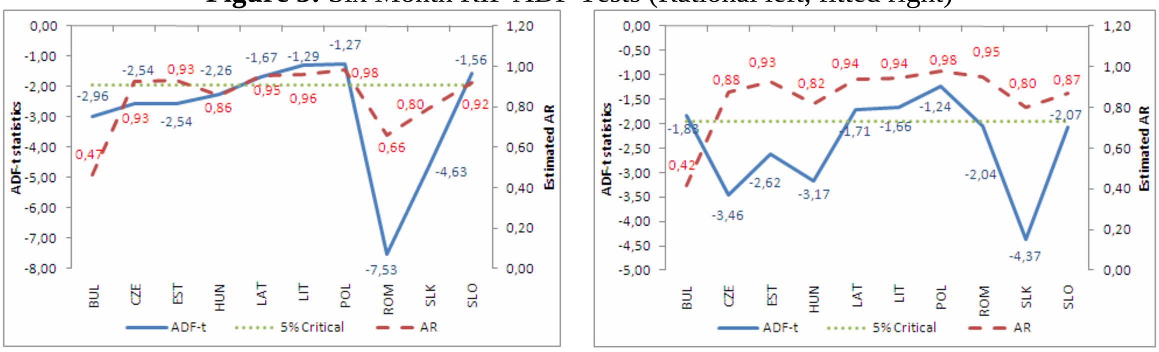
Notes: All results are for ADF unit root test with no constant or trend. The estimated autoregressive coefficient (dashed line) is plotted against the right axis, the $ADF-t$ Statistics (solid line) and the 5% critical values (dotted line) are on the left axis.

Figure 4: Three Month RIP ADF Tests (Rational left, fitted right)



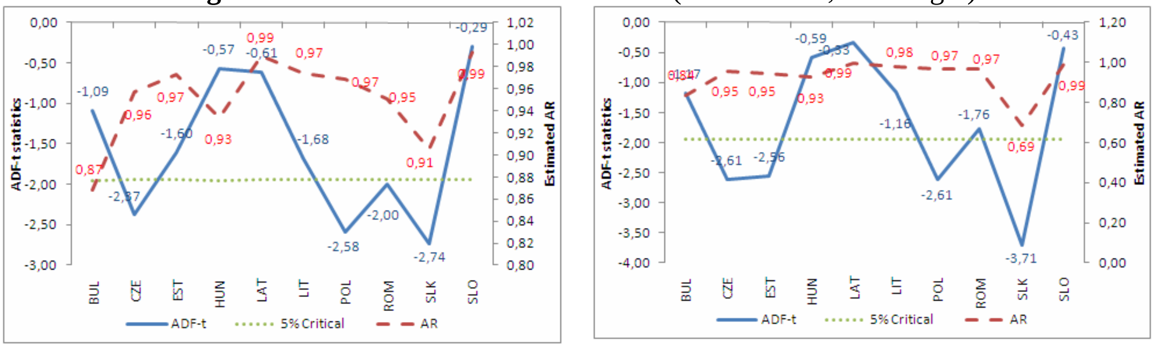
Notes: All results are for ADF unit root test with no constant or trend. The estimated autoregressive coefficient (dashed line) is plotted against the right axis, the $ADF-t$ Statistics (solid line) and the 5% critical values (dotted line) are on the left axis.

Figure 5: Six Month RIP ADF Tests (Rational left, fitted right)



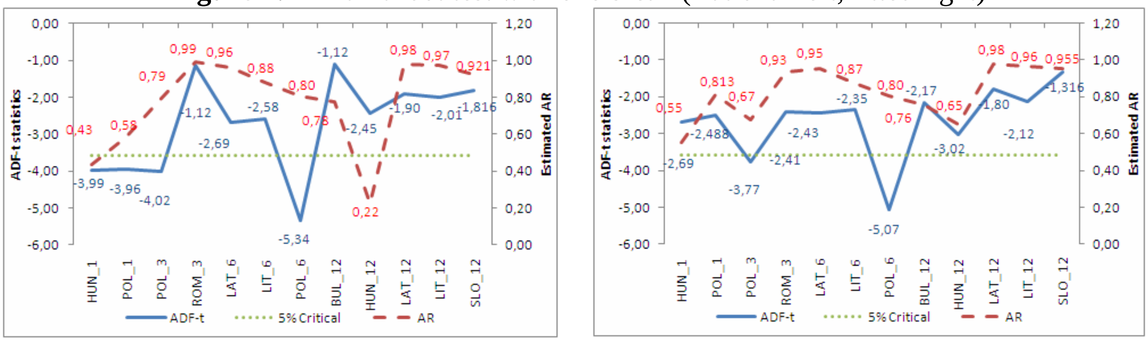
Notes: All results are for ADF unit root test with no constant or trend. The estimated autoregressive coefficient (dashed line) is plotted against the right axis, the $ADF-t$ Statistics (solid line) and the 5% critical values (dotted line) are on the left axis.

Figure 6: Twelve Month RIP ADF Tests (Rational left, fitted right)



Notes: All results are for ADF unit root test with no constant or trend. The estimated autoregressive coefficient (dashed line) is plotted against the right axis, the $ADF-t$ Statistics (solid line) and the 5% critical values (dotted line) are on the left axis.

Figure 7: LM unit root test with one break (Rational left, fitted right)



Notes: All results are for LM unit root test with single break. The estimated autoregressive coefficient (dashed line) is plotted against the right axis, the $ADF-t$ Statistics (solid line) and the 5% critical value (dotted line) are on the left axis.