PERSISTENCE IN TURKISH REAL EXCHANGE RATES: PANEL APPROACHES

Haluk Erlat
Department of Economics
Middle East Technical University
06531 Ankara, Turkey
email: herlat@metu.edu.tr

Real Exchange Rate:

(1) $$q_{it} = e_{it} + p_{t} - p_{it}^{*}$$

e_{it} = logarithm of the nominal exchange rate of Turkey with its i^{th} trading partner (expressed as TL/Foreign Currency)
p_{it}^{*} = the logarithm of the i^{th} trading partner's price level
p_t = the log of the domestic price level.

Autoregressions for the ADF, LLC, IPS, MW and Choi tests:

(2) $$\Delta q_{it} = \beta_{ir}' d_{tr} + \alpha_{i} q_{i,t-1} + \sum_{j=1}^{p_i} \gamma_{ij} \Delta q_{i,t-j} + \varepsilon_{it}, \quad i = 1,\ldots,N;\ r = 0,1,2$$

$d_{t0} = 0$
$d_{t1} = 1$
$d_{t2} = (1, t)'$

The LLC Test:

1. The ε_{it} are corrected for differences in their variances across series.
2. It is assumed that all α_i have a common value α. Thus, the hypothesis tested is

$$H_0: \alpha = 0 \quad \text{vs.} \quad H_1: \alpha < 0.$$

The test statistic is the adjusted t-ratio of α, t_{α}^{*}, which is asymptotically distributed as N(0, 1).

The IPS Test:

1. The null hypothesis to be tested now is

$$H_0: \alpha_1 = \alpha_2 = \ldots = \alpha_N = 0 \quad \text{vs.} \quad H_1: \text{Some but not necessarily all } \alpha_i < 0$$

2. The test statistic is simply the average of the t-ratios of the α_i, $\bar{t}_{NT}$, adjusted to have a standard normal distribution as follows,

$$\bar{t}_{NT}^{*} = \frac{N^{1/2}\left(\bar{t}_{NT} - N^{-1}\sum_{i=1}^{N} E(t_{\alpha_i})\right)}{\left[N^{-1}\sum_{i=1}^{N} Var(t_{\alpha_i})\right]^{1/2}} \qquad (3)$$

The MW Test:

1. The hypothesis tested is the same as in the IPS case.
2. Denoting the p-values of the individual ADF statistics by π_i, the statistic proposed may be expressed as

(4) $$P = -2\sum_{i=1}^{N} \ln \pi_i$$

Under the null hypothesis P is distributed asymptotically as χ^2 with $2N$ degrees of freedom. This result is obtained as $T \to \infty$ while N is taken to be fixed.

The Choi Test:

1. When N also tends to infinity, P may be standardized as

(5) $$P_m = \frac{1}{2\sqrt{N}}\sum_{i=1}^{N}(-2\ln \pi_i - 2) = -\frac{1}{\sqrt{N}}\sum_{i=1}^{N}(\ln \pi_i + 1)$$

to have an asymptotic N(0,1) distribution.

2. An alternative test for the case where N is finite:

(6) $$Z = \frac{1}{\sqrt{N}}\sum_{i=1}^{N}\Phi^{-1}(\pi_i)$$

where Φ is the standard normal cumulative distribution function. Z is asymptotically N(0,1) when $T \to \infty$. Z has the same asymptotic distribution when N also tends to infinity.

The Hadri Test:

1. The equations for the Hadri test are

(7) $$q_{it} = \beta_{irt}'d_{rt} + \varepsilon_{it}, \qquad i = 1,\ldots,N; \quad r = 1,2$$

$\beta_{irt} = \beta_{i1t}$ when r = 1
$\beta_{irt} = (\beta_{i1t}, \beta_i)'$ when r = 2
$\beta_{i1t} = \beta_{i1,t-1} + u_{it}$, $E(u_{it}) = 0$ and $E(u_{it}^2) = \sigma_u^2 \geq 0$

2. The hypothesis to be tested then becomes

$$H_0: \sigma_u^2 = 0 \qquad \text{vs.} \qquad H_1: \sigma_u^2 > 0$$

3. Under the assumption that $E(\varepsilon_{it}) = 0$ and $E(\varepsilon_{it}^2) = \sigma^2 > 0$, the test statistic may be obtained as the ratio of the averages of the numerator and the denominator of the KPSS statistics for each series (*Hadri 1*). When $E(\varepsilon_{it}^2) = \sigma_{\varepsilon_i}^2 > 0$, the statistic may simply be obtained as the average of the KPSS statistics for each series (*Hadri 2*).When appropriately standardized, both statistics will be asymptotically standard normal.

Dealing With Dependence Between The Series:

1. Demeaning:

a. Obtain $\overline{q}_t = \sum_{i=1}^{N} q_{it}, \quad t = 1,\ldots,T$.
b. Calculate, for each *t*, $q_{it} - \overline{q}_t$.
c. Use these demeaned figures to calculate the LLC and IPS tests.

2. Multivariate Methods:

a. Treat the autoregressions in (2) as a SUR system. Estimate it using the two-step EGLS procedure.
b. Test the joint null hypothesis

$$H_0: \alpha_1 = \alpha_2 = \ldots = \alpha_N = 0$$

using the Wald statistic and call it MADF.
c. Test the individual hypotheses

$$H_{0i}: \alpha_i = 0, \; i = 1,\ldots,N$$

using the t-ratios obtained from EGLS estimation of the SUR system and call them SURADF.

3. Factor Analysis

3.1 Pesaran (2007)

a. Let q_{it} be generated by the following model:

(8) $$\Delta q_{it} = \alpha_{0i} + \beta_i q_{i,t-1} + u_{it}, \quad i = 1, \ldots, N \quad \text{where} \quad u_{it} = \eta_i f_t + \varepsilon_{it}$$

Combining these two expressions and making f_t observable by setting it equal to $\Delta \bar{q}_t - \alpha_0 - \beta \bar{q}_{t-1}$, we may express the individual equations we shall use in obtaining the test statistic as

(9) $$\Delta q_{it} = c_{i0} + c_i t + \beta_i q_{i,t-1} + \sum_{j=1}^{p} \gamma_{ij} \Delta q_{i,t-j} + \varphi_i \bar{q}_{t-1} + \sum_{j=0}^{p} \eta_{ij} \Delta \bar{q}_{t-j} + \varepsilon_{it}$$

b. The t-ratio β_i that we shall obtain from (9) will be the Cross-sectionally Adjusted ADF (CADF) test. Taking its average across cross-section units will yield *CIPS*, which may be used as a panel unit root test.

3.2 Bai ve Ng (2004)

a. Assume that the q_{it} are generated by

$$
\begin{aligned}
q_{it} &= \beta_{ir}' d_{tr} + \varphi_i' F_t + e_{it}, && t = 1,\ldots,T \\
F_{jt} &= \sum_{s=1}^{m_j} \alpha_{js} F_{j,t-s} + u_{jt}, && j = 1,\ldots,n \\
e_{it} &= \sum_{s=1}^{p_i} \rho_i e_{i,t-s} + \varepsilon_{it}, && i = 1,\ldots,N
\end{aligned}
\qquad (10)
$$

F_t = nx1 vector of common factors
e_{it} = the idiosyncratic component (factor specific to each series)

b. Estimates of F_t and the e_{it} ($\hat{F}_t$ and $\hat{e}_{it}$) are obtained and tests for unit roots in $\hat{F}_t$ and the $\hat{e}_{it}$ are performed separately so that the source of the presence or absence of a unit root in q_{it} may be determined. Since the $\hat{e}_{it}$'s are expected to be asymptotically independent, panel unit root procedures may be applied to these series.

The Data:

1. A panel of real exchange rates with Turkey's seventeen major trading partners, namely, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Japan, the Netherlands, Norway, Saudi Arabia, Spain, Sweden, Switzerland, the UK and the USA, was constructed. Thechoice of trading partners was dictated by (a) the share they had in Turkey's total trade, (b) data availability, and (c) the desire to benefit from the added heterogeneity that a larger panel may provide. It was found that these seventeen countries account, on the average, for 64.5% of Turkey's trade for the period 1989-2001. Important trading partners such as Russia (with an average share of 5%) and Iran (1.8%) had to be left out because price and/or exchange rate data were not available. On the other hand, relatively smaller trading partners, such as Denmark (0.52%), Finland (0.52%) and Greece (0.81%) were included to increase the heterogeneity in the panel.

2. The series are monthly and cover the period 1984.01-2001.06. The price index used in the construction of the series is the Consumer Price Index (1987=100). The exchange rates and the domestic CPI series were obtained from the Central Bank database. The foreign CPIs were downloaded from the International Financial Statistics database and their base years were shifted to 1987.

Figure 1
Plots of the Turkish Real Exchange Rate With Selected Trading Partners

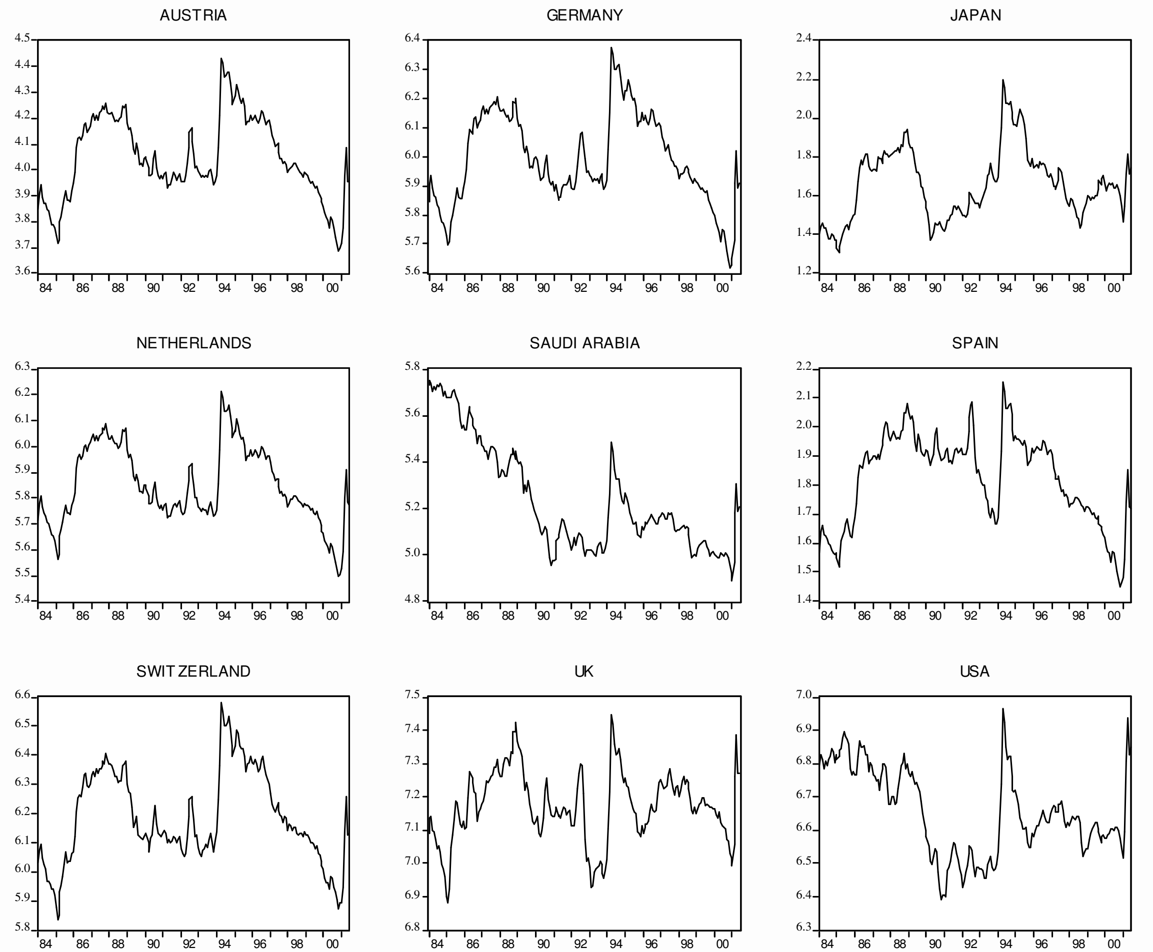


Table 1

ADF and KPSS Tests Results

	Intercept				**Intercept and Trend**			
	p	**ADF**	$\bar{k}$	**KPSS**	**p**	**ADF**	$\bar{k}$	**KPSS**
Austria	2	-2.155 (0.224)[1]	11	0.196	2	-2.189 (0.493)	11	0.191**
Belgium	1	-2.604 (0.094)*	11	0.227	1	-2.689 (0.243)	11	0.187**
Denmark	1	-2.675 (0.080)*	11	0.197	1	-2.714 (0.232)	11	0.183**
Finland	1	-2.094 (0.247)	11	0.874***	1	-2.876 (0.173)	11	0.178**
France	1	-2.534 (0.109)	11	0.306	1	-2.736 (0.224)	11	0.184**
Germany	1	-2.518 (0.113)	11	0.208	1	-2.579 (0.291)	11	0.178**
Greece	1	-2.946 (0.042)**	11	0.350*	1	-2.980 (0.140)	11	0.191**
Italy	1	-2.741 (0.069)*	11	0.637**	1	-3.282 (0.072)*	11	0.208**
Japan	1	-2.542 (0.107)	11	0.178	1	-2.541 (0.308)	11	0.114
Netherlands	1	-2.652 (0.084)*	11	0.220	2	-2.356 (0.402)	11	0.158**
Norway	1	-2.785 (0.062)*	11	0.607**	1	-3.196 (0.088)*	11	0.158**
S. Arabia	1	-2.446 (0.131)	11	1.289***	1	-2.450 (0.353)	11	0.326***
Spain	2	-2.335 (0.162)	11	0.370*	2	-2.507 (0.325)	11	0.307***
Sweden	1	-2.460 (0.127)	11	0.745***	1	-3.217 (0.084)*	11	0.251***
Switzerland	1	-2.492 (0.119)	11	0.169	1	-2.491 (0.332)	11	0.169**
UK	1	-4.302 (0.001)***	10	0.087	1	-4.302 (0.004)***	10	0.088
USA		-2.951(0.041)**	11	0.624**	1	-2.856 (0.179)	10	0.271***

<u>Notes</u>:

1. The figures in parentheses are p-values obtained using MacKinnon (1996).
2. The critical values for the KPSS tests have been obtained from Table 1 of Kwiatowski et al (1992).

	0.10	0.05	0.01
Intercept	0.347	0.463	0.739
Intercept and Trend	0.119	0.146	0.216

3. "*": significant at the 10% level. "**" : significant at the 5% level "***: significant at the 1% level.

Table 2		
LLC, IPS, Maddala-Wu, Choi and Hadri Test Results		
	Intercept	**Intercept and Trend**
LLC	-4.366 (0.000)***	-5.360 (0.000)***
IPS	-5.406 (0.000)***	-3.424 (0.000)***
P	9.726 (0.000)***	12.693 (0.000)***
P_m	7.239 (0.000)***	12.837 (0.000)***
Z	88.345 (0.000)***	60.446 (0.004)***
Hadri 1	6.590 (0.000)***	3.207 (0.001)***
Hadri 2	-5.672 (0.000)***	-3.535 (0.000)***

Notes:

1. The figures in parentheses are p-values. For LLC, IPS, Hadri 1 and 2, P_m and Z, they are based on the standard normal distribution, while, for P, it is based on the χ^2_{2N} distribution.
2. "***" : significant at the 1% level.

Table 3				
ADF, LLC, IPS, P, P_m and Z Test Results for Demeaned Data				
	Intercept		**Intercept and Trend**	
LLC	-2.214 (0.013)**		-0.602 (0.273)	
IPS	-1.787 (0.047)**		0.699 (0.758)	
P	41.564 (0.175)		24.248 (0.892)	
P_m	0.917 (0.180)		-1.183 (0.882)	
Z	-1.748 (0.040)**		0.870 (0.808)	
	p	**ADF**	**p**	**ADF**
Austria	7	-2.240 (0193)	1	-1.115 (0.923)
Belgium	3	-2.126 (0.235)	3	-1.804 (0.699)
Denmark	1	-2.578 (0.099)*	1	-2.187 (0.494)
Finland	12	-1.782 (0.389)	12	-3.087 (0.112)
France	3	-1.952 (0.308)	3	-1.912 (0.645)
Germany	1	-1.714 (0.423)	1	-1.574 (0.800)
Greece	12	-0.931 (0.777)	12	-1.931 (0.634)
Italy	4	-1.481 (0.542)	4	-2.130 (0.526)
Japan	1	-2.180 (0.215)	1	-2.632 (0.267)
Netherlands	1	-2.221 (0.200)	1	-2.151 (0.514)
Norway	1	-2.405 (0.142)	1	-3.172 (0.093)*
S. Arabia	1	-2.656 (0.084)*	1	-1.429 (0.850)
Spain	1	-1.821 (0.369)	1	-1.594 (0.793)
Sweden	1	-1.005 (0.752)	1	-2.193 (0.490)
Switzerland	3	-2.140 (0.229)	3	-2.238 (0.466)
UK	1	-1.482 (0.541)	1	-2.204 (0.484)
USA	1	-1.435 (0.565)	4	-1.091 (0.928)

Notes:

1. The figures in parentheses are p-values. The ones associated with the ADF test are obtained using MacKinnon (1996). For LLC, IPS, P_m and Z, they are based on the standard normal distribution, while, for P, it is based on the χ^2_{2N} distribution.
2. "*" : significant at the 10% level. "**" : significant at the 5% level.

Table 4

MADF and SURADF Test Results

	MADF	***Critical Values***		
		0.10	*0.05*	*0.01*
Intercept	80.029*	*76.179*	*81.215*	*91.555*
Intercept and Trend	98.578	*121.102*	*127.226*	*139.417*

	Intercept					**Intercept and Trend**				
	p	**SURADF**	*0.10*	*0.05*	*0.01*	**p**	**SURADF**	*0.10*	*0.05*	*0.01*
Austria	2	-5.987	*-0.340*	*-6.742*	*-7.401*	2	-7.229	*-8.336*	*-8.669*	*-9.243*
Belgium	1	-7.066**	*-6.661*	*-7.044*	*-7.657*	1	-8.275	*-8.767*	*-9.066*	*-9.642*
Denmark	1	-6.335	*-6.549*	*-6.930*	*-7.555*	1	-7.664	*-8.604*	*-8.933*	*-9.560*
Finland	1	-3.727	*-5.782*	*-6.188*	*-6.915*	1	-5.666	*-7.419*	*-7.831*	*-8.559*
France	1	-6.811*	*-6.620*	*-6.976*	*-7.566*	1	-8.122	*-8.671*	*-9.001*	*-9.610*
Germany	1	-6.631*	*-6.554*	*-6.907*	*-7.566*	1	-7.790	*-8.588*	*-8.900*	*-9.484*
Greece	1	-2.582	*-5.168*	*-5.597*	*-6.378*	1	-3.551	*-6.508*	*-6.949*	*-7.713*
Italy	1	4.352	*-5.595*	*-6.013*	*-6.763*	1	-5.830	*-7.144*	*-7.534*	*-8.282*
Japan	1	-3.736	*-4.149*	*-4.575*	*-5.275*	1	-4.288	*-5.137*	*-5.551*	*-6.250*
Netherlands	1	-6.738*	*-6.491*	*-6.856*	*-7.502*	2	-7.423	*-8.443*	*-8.757*	*-9.353*
Norway	1	-4.654	*-6.164*	*-6.548*	*-7.303*	1	-5.851	*-7.966*	*-8.335*	*-9.069*
S. Arabia	1	-3.929	*-4.448*	*-4.822*	*-5.477*	1	-3.566	*-5.503*	*-5.856*	*-6.534*
Spain	2	-4.244	*-5.906*	*-6.319*	*-7.019*	2	-5.745	*-7.617*	*-7.994*	*-8.714*
Sweden	1	-2.757	*-5.399*	*-5.822*	*-6.588*	1	-4.449	*-6.873*	*-7.295*	*-8.036*
Switzerland	1	-5.656	*-5.685*	*-6.088*	*-6.834*	1	-6.847	*-7.298*	*-7.692*	*-8.368*
UK	1	-4.361	*-5.043*	*-5.505*	*-6.242*	1	-5.417	*-6.505*	*-6.742*	*-7.473*
USA	1	-3.456	*-4.592*	*-4.956*	*-5.676*	1	-3.377	*-5.731*	*-6.112*	*-6.838*

Notes: The critical values were generated using Monte Carlo methods based on 10,000 replications, as was done by Breuer et al (2001). The authors are grateful to Myles Wallace for providing them with the necessary RATS code.

Table 5

The CADF and CIPS Test Results

	Intercept		**Intercept and Trend**	
	p	**CADF**	**p**	**CADF**
Austria	2	-2.010	2	-1.675
Belgium	1	-2.545	1	-2.233
Denmark	1	-2.984*	1	-3.431*
Finland	1	-1.404	1	-2.155
France	1	-2.376	1	-1.990
Germany	1	-2.165	1	-2.371
Greece	1	-0.847	1	-2.322
Italy	1	-1.612	1	-2.165
Japan	1	-2.105	1	-2.435
Netherlands	1	-2.556	2	-2.931
Norway	1	-2.653	1	-3.131
S. Arabia	1	-2.946*	1	-1.979
Spain	2	-2.066	2	-1.854
Sweden	1	-1.046	1	-2.035
Switzerland	1	-1.983	1	-2.402
UK	1	-1.985	1	-2.585
USA	1	-2.357	1	-1.931
CIPS		-2.096		-2.331

Table 6

The ADF Test on the Common Factor and the Idiosyncratic Components

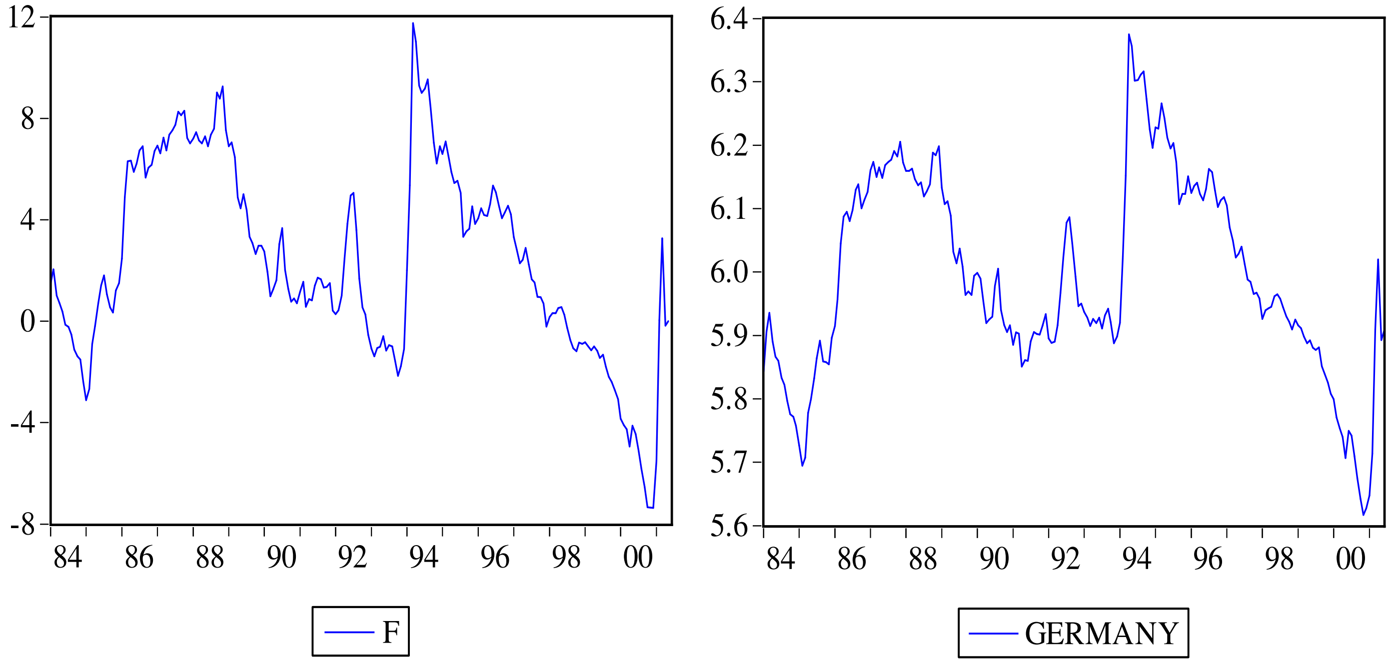
	Intercept				Intercept and Trend			
	p	**ADF**	$\frac{Var(\Delta\hat{e})}{Var(\Delta q)}$	$\frac{\sigma(\varphi'\hat{F})}{\sigma(\hat{e})}$	**p**	**ADF**	$\frac{Var(\Delta\hat{e})}{Var(\Delta q)}$	$\frac{\sigma(\varphi'\hat{F})}{\sigma(\hat{e})}$
$\hat{F}$	2	-2.586 (0.098)*			1	-3.120		
Austria	6	-0.690 (0.417)	0.0487	2.7276	4	-0.855	0.0492	3.2939
Belgium	3	-0.558 (0.474)	0.0349	3.5934	3	-1.063	0.0353	4.0873
Denmark	1	-0.068 (0.659)	0.0382	3.3436	2	-0.983	0.0385	4.3638
Finland	12	-1.587 (0.106)	0.0896	1.3235	12	-2.153	0.0903	1.8220
France	3	-0.998 (0.285)	0.0353	4.4832	3	-1.026	0.0356	4.6489
Germany	1	-1.326 (0.171)	0.0428	3.1708	1	-1.458	0.0432	3.3930
Greece	12	-0.702 (0.412)	0.1473	1.5698	12	-1.121	0.1475	2.0198
Italy	3	-1.604 (0.102)	0.1024	2.0945	3	-1.569	0.1029	2.3565
Japan	1	-0.874 (0.336)	0.3584	1.0044	8	-2.905**	0.3572	0.7126
Netherlands	1	-1.955 (0.049)**	0.0456	4.2159	1	-2.034	0.0460	4.4383
Norway	5	-0.760 (0.386)	0.0584	3.4677	1	-2.118	0.0586	4.8370
S. Arabia	1	0.244 (0.756)	0.3762	0.5071	1	-0.616	0.3754	0.7126
Spain	1	-0.473 (0.510)	0.0756	1.8935	1	-0.836	0.0765	1.9313
Sweden	1	-1.054 (0.263)	0.1264	1.7591	1	-1.252	0.1266	2.3136
Switzerland	3	-1.584 (0.107)	0.1064	2.2580	3	-2.128	0.1065	2.6512
UK	1	-1.425 (0.144)	0.1668	1.4842	1	-1.296	0.1671	1.7602
USA	1	-0.809 (0.364)	0.3486	0.8392	1	-0.796	0.3480	0.8683

Table 7

KPSS and Hadri Test Results as Applied to the $\hat{e}_{it}^{0}$ and $\hat{e}_{it}^{1}$

	Intercept		Intercept and Trend	
	$\bar{k}$	KPSS	$\bar{k}$	KPSS
Austria	11	0.858***	12	0.198***
Belgium	11	0.589**	11	0.201***
Denmark	11	0.936***	12	0.167**
Finland	11	1.174***	14	0.125**
France	11	0.227	11	0.168**
Germany	11	0.552**	14	0.148**
Greece	11	1.537***	18	0.140**
Italy	11	0.629**	23	0.157*
Japan	11	0.669**	14	0.063
Netherlands	11	0.404*	12	0.100*
Norway	11	1.349***	12	0.119*
S. Arabia	11	1.027***	37	0.159**
Spain	11	0.372*	32	0.153**
Sweden	11	0.935***	11	0.230***
Switzerland	11	0.916***	11	0.120*
UK	11	0.602**	14	0.175**
USA	11	0.427*	14	0.290***
Hadri 1	19.338 (0.000)***			
Hadri 2	16.867 (0.000)***			

Figure 2
Plot of the Common Factor (F) and the DM-Based Real Exchange Rate



Conclusions:

1. The application of the individual ADF and KPSS tests to these 17 series indicated that there was some weak support of the PPP hypothesis for the period in question when the intercept only case is considered. When a trend term is added, it is difficult to claim any support for PPP.

2. On the other hand, when first generation panel unit root tests were applied support for the PPP hypothesis was given by the all the tests with a unit root null while both Hadri tests rejected the stationarity of the series. This result was obtained irrespective of whether a trend term was included or not.

3. When the data was demeaned, LLC, IPS and Z still supported the PPP hypothesis in the intercept-only case, but at a lower level of significance while none of the panel unit root tests rejected the null when a trend term was added. The support for PPP from individual ADF tests were further reduced.

4. There was some weak support from the MADF test for the intercept-only case and only four significant outcomes for the SURADF tests, but there was no support for PPP from these tests when a trend term was added.

5. The results obtained from the CADF and CIPS tests were not any different from the demeaning and multivariate testing solutions for the cross-sectional dependence problem.

6. In decomposing the series into their common factors and idiosyncratic components, we found that, in both cases, a single common factor was sufficient to account for the common component of the series. We found that this common component was I(0) for the intercept-only case but I(1) for the intercept + trend case. The common component also dominated the variance of each q_i, implying that it was the factor contributing to the rejection of the null when the univariate and the majority of the panel tests were directly applied to the q_{it} in the intercept only case and the non-rejection in the intercept + trend case. In fact, when the univariate ADF and KPSS tests were applied to the idiosyncratic components in the latter case, only one series was found to be I(0).

7. In sum, the support we obtained for the absolute version of the PPP hypothesis from applying the first generation panel procedures directly to the q_{it} appear to be due to ignoring the dependence between the series. The procedures where this dependence is accounted for either give very weak support to the PPP hypothesis (intercept-only case) or strongly favour the presence of a unit root in the series. A, rather informal, explanation for this outcome may be obtained by comparing the plots of the series for Germany, our largest trading partner, and the common component, $\hat{F}_t$. We note that the series are almost the same. Thus, it is not surprising to find that testing for a unit root in a panel of Turkish RERs when the majority of the series are from continental Europe and they resemble the German series does not provide any evidence supporting the PPP hypothesis. This strong co-movement in the series is, apparently, not sufficiently offset by cross-sectional heterogeneity, so that the null of a unit root is not rejected when the dependence between the series is taken into account, particularly when a trend terms in included.