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Is there a persistent inflation in OECD energy prices? Evidence from panel unit root tests

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Abstract

The aim of this paper is to investigate whether inflation persists in energy prices of OECD countries. The method of choice for this purpose appears naturally to be panel unit root tests. Using three unit root tests we investigate the unit root hypothesis for an energy price on an unbalanced panel of all 34 OECD countries for the period from the first quarter of 1979 to the first quarter of 2012. The main findings of this paper indicate that; inflation is not uniformly persistent for all OECD countries. However individual inspections support the fact that Belgium, Czech Republic, Estonia, France, Germany, Italy, Korea, Poland, Slovak Republic, Turkey and United Kingdom exhibit a persistent inflation in energy commodities. On the other hand empirical evidence also strongly supports the fact that inflation in the aggregated energy commodities in Austria, Canada, Finland, Luxemburg, Norway, Sweden and United States display no persistency.

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1. Introduction

This study explores whether persistence of inflation exists in the energy prices of OECD countries. Persistence of inflation can be described as the rate of convergence to the long-term average of the inflation trend following a monetary shock experienced in the economy. Another description is that price general level trend is static in case of a shock or deficiency experienced in the economy (Fuhrer, 2009). Inflation Persistence Network (IPT) Research Team consisting of the economists from the European Central Bank (ECB) have described the inflation persistence as follows: "the tendency of inflation converges slowly (or

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sluggishly) towards its long-run value following a shock which has led inflation away from its long-run value" (Altissimo, Ehrmann and Smets, 2006). From a different perspective, inflation persistence can be described as length of period elapsed during the process of returning to the balance level of inflation of the variations in inflation emerged due to an unexpected shock (Vladova and Pachedjiev, 2008).

The motivation behind this question arises from the fact that fluctuations in the energy prices have significant impact on economic activity. Davis and Haltiwanger, (2001), Brown and Yucel (2002), Jones et. al (2004), Lardic and Mignon (2008) and Doğrul and Soytas (2010) lay out the channels how oil prices effect on economy. Moreover Blanchard and Gali (2007), and Herrera and Pesavento (2009) incorporates financial markets into the mix. Another strand of energy price literature investigates the causality and co-movement of oil prices and real exchange rates. While Korhonen and Juurikkala (2007) and Habib and Kalamova (2007) Rickne (2009) approach to this subject from the point of oil exporting countries, Buetzer et al. analyzes cover 44 advanced and emerging countries that are both oil exporting and oil importing. On the other hand literature focuses on determination of the price in competitive markets for electricity (Cardella et al. 1997, Wolack and Patrick 2001). Consequently literature supports the fact that energy prices are an integral and substantial part of economic and financial activities.

In the event that the unexpected rises experienced in the energy prices have again shown a decreasing trend in the medium term, in other words, having a temporary characteristic, economic policy implementers will prefer not to develop policies against the shocks experienced in the energy prices. Hence, policy implementers will prefer to ignore these shocks (Cecchetti and Moesner, 2008). In other words, the fact that the policy implementers know the characteristics demonstrated by the energy prices, which have an important place in the dynamics of inflation, will improve the efficiency and credibility of the policies to be developed to fight against inflation. At this stage, persistence of inflation in the energy prices carries a reference feature to be taken into consideration by the policy implementers.

In this study whether inflation persistence exists in the energy prices of OECD countries is investigated. Panel unit root testing is the preferred econometric method in line with the objective of our study. Existence of unit root in the series indicates the effects of a shock in the series are lasting. This translates to persistency in case of inflation.

In our study we employed aggregated price levels in the form of Energy CPI to test the inflation persistency for 34 OECD countries with the time dimension encompassing observations between the first quarter of 1979 and the first quarter of 2012. Remainder of the paper is structured as follows: In the second section basic features of the panel unit root tests employed are illustrated. The third section reports the empirical results. Finally the study is concluded by the general interpretation of the empirical results and possible extensions of this study.

2. Methodological Issues

In order to investigate whether inflation persistence exists in energy prices, this study uses panel unit root testing. For that purpose panel unit roots developed by Choi (2001), Demetrescu et al. (2006) and Constantini and Lupi (2013) are employed. What these three tests have in common is that they combine of p-values obtained from Augmented Dickey-Fuller (ADF) test of the individual time series. The method provides the researcher the advantage of being able to use unbalanced panel data so long as the missing value does not interrupt any individual series. In other words for these three tests it is permissible to use panels with missing values if only they are at the beginning or at the end of the individual series. Another advantage of combining individual p-values is it allows each time series to have different specification of nonstochastic and stochastic components. Finally they all test the null hypothesis of unit root against the alternative of at least one time series is stationary. This section explains these three tests in further detail.

2.1. Choi Test

Choi test, which is named after its developer Choi (2001), is a first generation test indicating it does not take into account that there may be cross-sectional dependence. Basically Choi (2001) takes the mean of probits obtained from each individual p-value of unit root tests of separate time series. Let p_i (i=1,…,N) be individual p-values, probits are defined as $t_i=\Phi^{-1}(p_i)$ where Φ^{-1} is the inverse of the standard normal cumulative distribution function. Choi test, then combines the probits obtained from individual p-values as follows

$$Z = \frac{1}{N}\sum_{i=1}^{N} t_i \rightarrow \mathrm{N}(0,1)\,. \tag{1}$$

It is also possible to use the individual p-values directly in following manner:

$$-2\sum_{i=1}^{N}\log(p_i) \rightarrow \chi^2_{2N}\,.$$

2.2. DHT Test

DHT test which is named after the initials of its developers Demetrescu, Hassler and Tarcolea (2006), is second generation test indicating it allows for cross-sectional dependence. DHT test also combines probits obtained from individual p-values of the ADF unit root tests. Demetrescu et al. (2006) states that the cross-sectional dependency emerges as a dependency in p-values, which in turn can be expressed as correlation among probits. Since probits are, by construction, standardized, correlation among individual probits can easily be calculated as covariances among them: Cov(t_i,t_j)=ρ for $i\neq j$ and i,j=1,…,N where N is the number of time series in the panel. Due to cross-sectional dependency represented as the correlation among probits it is no longer possible to use eq. 1 to combine them. However utilizing the modification proposed by Hartung (1999) the test statistic becomes

$$\hat{Z}_H = \frac{\sum_{i=1}^{N}\lambda_i t_i}{\sqrt{\sum_{i}^{N}\lambda_i^2 + \left[\left(\sum_{i=1}^{N}\lambda_i\right)^2 - \sum_{i=1}^{N}\lambda_i^2\right]\left[\hat{\rho}^* + \kappa\sqrt{\frac{2}{N+1}}\left(1-\hat{\rho}^*\right)\right]}}\,, \tag{2}$$

where λ_i are weights for i=1,…,N, $\hat{\rho}^*$ is a consistent estimator $\hat{\rho}^* = \max\left(\frac{-1}{N-1}, \hat{\rho}\right)$ with $\hat{\rho} = 1 - \frac{1}{N-1}\sum_{i=1}^{N}\left(t_i - \frac{1}{N}\sum_{i=1}^{N} t_i\right)$ and κ>0 is a parameter regulating in small samples the actual significance level. The $\hat{Z}_H$ statistic in eq. 2 has limiting standard normal distribution under the necessary and sufficient condition of a normal copula of the original test statistics. However Dickey-Fuller type tests do not satisfy this condition. Demetrescu et al. (2006) show in their simulations, for medium and high cross-correlation modification proposed in eq. 2 delivers good results even if the existence of deviance from normality in individual ADF tests has unfavourable effects on the DHT test statistics. They stress that results using Hartung's (1999) modification in such cases are superior to results when the cross-sectional dependence is ignored.

2.3. pCADF Test

Constantini and Lupi (2013) elaborate Choi and DHT unit root test by obtaining the p-values form Hansen's (1995) Covariate Augmented Dickey- Fuller (CADF) tests rather than standard ADF tests, hence the name pCADF. The reason behind using Hansen's (1995) CADF instead of standard ADF is to obtain most powerful test using the information embodied in the stationary covariates which are dependent to the variable of interest.Hansen (1995) begins with a standard ADF type data generating process (DGP):

$$y_t = d_t + s_t,$$
$$a(L)\Delta s_t = \delta s_{t-1} + v_t,$$

where d_t id a deterministic term, L is the lag operator and the lag polynomial is $a(L)=(1-a_1L-a_2L^2-\ldots-a_pL^p)$. Then v_t in the DGP is augmented by a covariate:

$$v_t = \boldsymbol{b}(L)'(\Delta \boldsymbol{x}_t - \boldsymbol{\mu}_x) + e_t,$$

where $\mathbf{b}(L)=(\boldsymbol{b}_{q2}L^{-q_2}+\ldots+\boldsymbol{b}_{q1}L^{q_1})$ is lag and lead polynomial with q_2 are leads and q_1 are lags, $\Delta\boldsymbol{x}_t$ is the stationary covariate and $\boldsymbol{\mu}_x$ is its expected value. The distribution of test statistic is determined by a standard Wiener process, standard normal distribution independent of the aforementioned Wiener process and ρ^2 which is the long-run squared correlation between v_t and e_t. The term ρ^2 is interpreted as the measure of relative contribution of $\Delta\boldsymbol{x}_t$, to v_t at the zero frequency. If $\Delta\boldsymbol{x}_t$ has no explicative power on the long-run movement of v_t, then $\rho^2\approx1$ and if $\Delta\boldsymbol{x}_t$ explains almost all of the long-run movement of v_t, then $\rho^2\approx0$.

The pCADF test, then, combines the p-values from the individual CADF tests directly, as in Choi test, or modifies them, as in DHT test for cross-sectionally dependent panels. When Hartung's (1999) modification is going to be applied depends on the when p-value of Paseran's (2004) cross-sectional dependency test. If p-value of Paseran's (2004) test is below certain level, which is generally taken to be 0.10, the modification is administered (Lupi, 2011).

Constantini and Lupi (2013) and Lupi (2011) propose three alternatives to be used as stationary covariates in the Hansen's CADF test. Firstly the first difference of the average of other series can be used as the stationary covariate. Second, the difference of the principal component of all individual series can be used. Finally, first difference of a stationary series can be chosen due to economic considerations. In the second case where pCADF test uses principle component among the individual series automatically takes cross-section dependency into account, thus the need for Hartung's (1999) modification ceases.

3. Empirical Results

This section employs the three unit root tests discussed in the antecedent section to investigate the persistency in energy price inflation. In order to procure inflation in energy prices CPI of energy commodities, which is collected from International Energy Agency (IEA), is used. Inflation is calculated as the per cent change same period previous year. Original data (CPI of aggregated energy commodities) covers the period from the first quarter of 1978 to the first quarter of 2012, the inflation data however loses four quarters due to the transformation and thus covers the period from the first quarter of 1979 to the first quarter of 2012.

The results of Choi and DHT tests are reported in Table 1. The results of pCADF tests are reported in Table 3. Table 2, Table 4 and Table 5 provides the individual p-values utilized in all three unit root tests. The reason for reporting individual p-values is that rejection of the null hypothesizes only states there is at least one time series in the whole panel that is stationary. Although this indicates the whole panel does not have a unit root, it is not very informative on the whole. Since individual p-values are obtained from standard ADF and Hansen's (1995) CDF, we consider p-values lower than 0.10 indicate there is no unit root in the separate individual time series.

Table 1. Results of Choi and DHT panel unit root tests

Test		Test statistic	p-value
Choi	None	-12.87288	0.0000
	Drift	-11.82666	0.0000
	Trend	-9.08202	0.0000
DHT	None	-9.94929	0.0000
	Drift	-5.25004	0.0000
	Trend	-7.01939	0.0000

Table 2. Individual p-values utilized in Choi and DHT panel unit root tests

Countries	None		Drift		Trend	
	p-value	lag	p-value	lag	p-value	lag
Australia	0.0029	5	0.0005	4	0.0042	4
Austria	0.0012	5	0.0049	5	0.0287	5
Belgium	0.0057	4	0.0178	5	0.1616	4
Canada	0.0056	5	0.0092	5	0.0346	5
Chile	0.0308	4	0.0236	4	0.0018	3
Czech Republic	0.1045	4	0.1078	4	0.6715	4
Denmark	0.0000	4	0.0001	4	0.0052	4
Estonia	0.4380	4	0.0626	5	0.1574	5
Finland	0.0035	4	0.0034	4	0.0256	4
France	0.0055	4	0.0274	4	0.1730	4
Germany	0.0092	4	0.0340	4	0.1156	4
Greece	0.0175	4	0.0371	4	0.1867	4
Hungary	0.0997	4	0.1450	4	0.1929	5
Iceland	0.3970	5	0.3174	5	0.0759	5
Ireland	0.0018	4	0.0123	4	0.1440	4
Israel	0.0402	5	0.2285	5	0.2413	5
Italy	0.0445	4	0.0484	5	0.2510	5
Japan	0.0000	4	0.0001	4	0.0009	4
Korea	0.0762	4	0.0705	4	0.2119	4
Luxembourg	0.0023	4	0.0191	4	0.0828	4
Mexico	0.0503	4	0.0883	4	0.0000	3
Netherlands	0.0020	4	0.0097	4	0.0478	4
New Zealand	0.0036	4	0.0008	4	0.0057	4
Norway	0.0080	5	0.0002	4	0.0003	4
Poland	0.1240	0	0.0964	0	0.4030	0
Portugal	0.1441	5	0.0478	5	0.0835	5
Slovak Republic	0.1308	4	0.1282	4	0.1096	4
Slovenia	0.1945	4	0.1242	4	0.2468	4
Spain	0.0066	4	0.0114	5	0.0824	5
Sweden	0.0066	4	0.0064	4	0.0245	4
Switzerland	0.0002	4	0.0033	4	0.0135	4
Turkey	0.0788	4	0.6602	4	0.7476	4
United Kingdom	0.0080	5	0.0182	5	0.1194	5
United States	0.0000	5	0.0002	5	0.0015	5

The results of Choi and DHT tests reported in table 1 show that the null hypothesis of all series are non-stationary is rejected in favor of at least one of the series is stationary. In other words, individual time series composing the panel are not uniformly non-stationary. For sixteen countries (Belgium, Czech Republic, Estonia, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Republic of Korea, Poland, Slovak Republic, Slovenia, Turkey and United Kingdom) hypothesis of series has unit root in case of deterministic constant and trend cannot be rejected. Of these sixteen countries Czech Republic, Hungary, Israel, Slovak Republic, Slovenia and Turkey also have unit root in the case of only constant. Iceland, on the other hand, does not have unit root in case constant and trend but has unit root only constant case is considered

Table 3 reports the finding of pCADF test in detail. The table is composed of two types of pCADF tests depending on how the covariates in the individual CADF tests are determined. If the covariates are principle component among all the time series then test is named pCADF.PC where PC is the abbreviation for principle component. If the covariates are the first difference of the average of other series then the test is named pCADF.DY where D is the first difference and Y indicating all the series in the panel except itself.

Table 3. Results of pCADF panel unit root tests

Test		Test Statistic	p-value	Average ρ^2
pCADF.PC	None	-1.79333868	0.0365	0.17565211
	Drift	-7.55556000	0.0000	0.18119930
	Trend	-5.99827900	0.0000	0.16922820
pCADF.DY	None	-4.21321000	0.0000	0.21407870
	Drift	-7.20062300	0.0000	0.22181220
	Trend	6.43318000	0.0000	0.21175300

The results of pCADF tests also support the fact that the series composing the panel does not hove unit root all together. For any deterministic term in the unit root test the hypothesis of all series being non-stationary is rejected in favor of there is at least one series that is stationary. Moreover in addition to the p-values table 3 also reports the average ρ^2 which is considered as an indicator of failure of the covariate. Since the values of average ρ^2 are relatively low for both pCADF.PC and pCADF.DY the covariates in the tests are not meaningless. It is also noticeable that the average ρ^2 values are lower in pCADF.PC, declaring principle component in this case to be a better covariate.

For detailed inspection table 4 and 5 presents the individual CADF test results utilized in pCADF.PC and pCADF.DY tests respectively. In both tests null hypothesis of unit root cannot be rejected for Belgium, Czech Republic, Denmark, Estonia, France, Germany, Iceland, Italy, Japan, Netherlands, Poland, Portugal, Slovak Republic and United Kingdom under any type of deterministic term. Additionally Korea's series is also non-stationary for any type of deterministic term when the covariate is principle component. Switzerland is also non-stationary in the same test but only when the deterministic term in the models are a constant or a constant with a trend. Furthermore Turkey is non-stationary as well, even if only for the case of deterministic trend when the covariates are selected to be the principle component.

When we compare the list of non-stationary countries in table 3 with the non-stationary countries in table 2 under the case of constant and trend as deterministic terms, we observe Belgium, Czech Republic, Estonia, France, Germany, Italy, Korea, Poland, Slovak Republic, Turkey and United Kingdom are common in both. On the other hand Austria, Canada, Finland, Luxemburg, Norway, Sweden and United States commonly reject the null of unit root in all three individual unit root tests when the deterministic terms are a constant or a constant with a trend.

Table 4. Individual p-values utilized in pCADF.PC test

Countries	None					Drift					Trend				
	ρ^2	p-value	lag	lag (q1)	lag (q2)	ρ^2	p-value	lag	lag (q1)	lag (q2)	ρ^2	p-value	lag	lag (q1)	lag (q2)
Australia	0.0000	0.6451	3	0	0	0.0001	0.0546	1	0	0	0.0000	0.0832	1	0	0
Austria	0.0650	0.1164	4	5	0	0.0433	0.0252	4	5	0	0.0423	0.0349	4	5	0
Belgium	0.1981	0.3478	4	0	0	0.1928	0.4319	4	0	0	0.1925	0.4725	4	0	0
Canada	0.0093	0.0097	5	5	0	0.0092	0.0049	5	5	0	0.0066	0.0055	5	5	0
Chile	0.0024	0.1086	0	1	0	0.0100	0.0190	0	3	0	0.0092	0.0222	0	3	0
Czech Republic	0.6082	0.6494	4	4	0	0.7056	0.7785	4	4	0	0.9978	0.4574	4	0	0
Denmark	0.1666	0.2753	4	0	0	0.1609	0.1739	4	0	0	0.1613	0.1916	4	0	0
Estonia	0.2449	0.5101	4	4	0	0.2362	0.4053	4	4	0	0.2031	0.4213	4	4	0
Finland	0.1037	0.0155	1	0	0	0.0059	0.0000	0	0	0	0.0065	0.0002	0	0	0
France	0.1978	0.3092	4	4	0	0.2368	0.1834	4	4	0	0.2359	0.2670	4	4	0
Germany	0.0130	0.4109	4	5	0	0.0166	0.7214	4	5	0	0.0190	0.7784	4	5	0
Greece	0.0224	0.3933	5	4	0	0.0178	0.0802	5	4	0	0.0322	0.0160	5	4	0
Hungary	0.3623	0.4468	5	5	0	0.3169	0.0943	5	5	0	0.3017	0.0698	5	5	0
Iceland	0.2701	0.4202	5	4	0	0.2647	0.3127	5	4	0	0.2465	0.1885	5	4	0
Ireland	0.1062	0.4146	4	4	0	0.0333	0.0133	5	4	0	0.0214	0.0193	5	4	0
Israel	0.1456	0.1759	4	4	0	0.0481	0.0087	5	4	0	0.0109	0.0001	4	5	0
Italy	0.4756	0.8618	5	5	0	0.4505	0.8040	5	5	0	0.4328	0.9020	5	5	0
Japan	0.1519	0.4134	4	1	0	0.1530	0.5597	4	1	0	0.1557	0.6553	4	1	0
Korea	0.0639	0.2247	5	5	0	0.0609	0.1595	4	5	0	0.0589	0.1695	4	5	0
Luxembourg	0.0021	0.1518	4	4	0	0.0418	0.0186	3	3	0	0.0424	0.0289	3	3	0
Mexico	0.5407	0.3053	4	1	0	0.7941	0.2053	4	1	0	0.4844	0.0000	2	4	0
Netherlands	0.2678	0.1672	4	5	0	0.2760	0.2765	4	5	0	0.2771	0.5321	4	5	0
New Zealand	0.1272	0.3095	4	4	0	0.0246	0.0448	5	5	0	0.0022	0.0819	5	5	0
Norway	0.2456	0.0015	3	0	0	0.4585	0.0006	3	0	0	0.4548	0.0029	3	0	0
Poland	0.2192	0.5955	4	4	0	0.2409	0.3879	3	4	0	0.2249	0.4552	4	4	0
Portugal	0.0672	0.3103	3	3	0	0.0503	0.1617	3	3	0	0.0664	0.1708	3	3	0
Slovak Republic	0.6215	0.1729	4	4	0	0.6654	0.3507	4	4	0	0.4687	0.1498	4	5	0
Slovenia	0.0222	0.0034	0	0	0	0.0440	0.0004	0	0	0	0.0512	0.0004	0	0	0
Spain	0.1468	0.1062	5	5	0	0.1369	0.0233	5	5	0	0.1446	0.0335	5	5	0
Sweden	0.0652	0.0699	3	0	0	0.0512	0.0144	3	0	0	0.0328	0.0098	3	0	0
Switzerland	0.0162	0.0689	4	4	0	0.0162	0.1488	4	4	0	0.0151	0.1875	4	4	0
Turkey	0.1689	0.0200	5	2	0	0.1753	0.0251	5	2	0	0.1746	0.1038	5	2	0
United Kingdom	0.0874	0.5093	5	4	0	0.0587	0.2790	5	4	0	0.0373	0.7831	5	4	0
United States	0.1672	0.0245	4	5	0	0.1643	0.0333	4	5	0	0.1429	0.0301	5	5	0

Table 5. Individual p-values utilized in pCADF.DY test

Countries	None					Drift					Trend				
	ρ^2	p-value	lag	lag (q1)	lag (q2)	ρ^2	p-value	lag	lag (q1)	lag (q2)	ρ^2	p-value	lag	lag (q1)	lag (q2)
Australia	0.0019	0.6458	5	4	0	0.0019	0.6521	5	4	0	0.0017	0.6931	5	4	0
Austria	0.1684	0.2361	4	4	0	0.0629	0.0227	5	4	0	0.0608	0.0331	5	4	0
Belgium	0.2460	0.3263	4	0	0	0.2375	0.3391	4	0	0	0.2370	0.3982	4	0	0
Canada	0.0251	0.0208	4	5	0	0.0181	0.0050	4	5	0	0.0134	0.0054	4	5	0
Chile	0.0074	0.1078	0	1	0	0.0002	0.0509	0	2	0	0.0094	0.0247	0	3	0
Czech Republic	0.6680	0.6560	4	4	0	0.9881	0.4518	4	0	0	1.0000	0.4198	4	0	0
Denmark	0.1993	0.3275	4	0	0	0.1944	0.1508	4	0	0	0.1945	0.1788	4	0	0
Estonia	0.3157	0.5466	4	4	0	0.2996	0.3506	4	4	0	0.2634	0.3981	4	4	0
Finland	0.0782	0.1337	0	2	0	0.0129	0.0000	0	0	0	0.0142	0.0001	0	0	0
France	0.2995	0.4954	4	4	0	0.3556	0.2661	4	4	0	0.3547	0.4037	4	4	0
Germany	0.0313	0.5083	5	4	0	0.0294	0.5607	5	4	0	0.0313	0.6292	5	4	0
Greece	0.0432	0.3833	4	5	0	0.0339	0.0091	4	4	0	0.0267	0.0008	4	4	0
Hungary	0.4048	0.4552	5	5	0	0.3591	0.0824	5	5	0	0.3475	0.0599	5	5	0
Iceland	0.3284	0.4742	5	4	0	0.3187	0.3258	5	4	0	0.3021	0.1967	5	4	0
Ireland	0.1791	0.5294	4	4	0	0.0673	0.0148	5	4	0	0.0514	0.0232	5	4	0
Israel	0.0967	0.1225	4	5	0	0.0607	0.0026	4	5	0	0.0179	0.0001	4	5	0
Italy	0.5300	0.8206	5	5	0	0.4904	0.7222	5	5	0	0.4768	0.8501	5	5	0
Japan	0.1857	0.3727	4	1	0	0.1859	0.5104	4	1	0	0.1885	0.6219	4	1	0
Korea	0.1326	0.2855	5	5	0	0.0541	0.0140	2	5	0	0.0536	0.0159	2	5	0
Luxembourg	0.1023	0.2043	4	4	0	0.0622	0.0316	5	4	0	0.0621	0.0485	5	4	0
Mexico	0.5710	0.3179	4	1	0	0.9273	0.0003	1	0	0	0.9852	0.0003	2	0	0
Netherlands	0.3861	0.2212	4	4	0	0.4039	0.3104	4	4	0	0.4040	0.5949	4	4	0
New Zealand	0.1723	0.3394	4	4	0	0.0570	0.0412	5	5	0	0.0156	0.0701	5	5	0
Norway	0.2560	0.0016	3	0	0	0.4686	0.0005	3	0	0	0.4626	0.0026	3	0	0
Poland	0.2630	0.6516	4	4	0	0.2811	0.3710	3	4	0	0.2656	0.4508	4	4	0
Portugal	0.0945	0.3728	3	3	0	0.0709	0.1725	3	3	0	0.0896	0.1942	3	3	0
Slovak Republic	0.6348	0.1978	4	4	0	0.6743	0.3700	4	4	0	0.4874	0.1783	4	5	0
Slovenia	0.0824	0.0056	0	0	0	0.1121	0.0003	0	0	0	0.1213	0.0005	0	0	0
Spain	0.2577	0.1397	5	5	0	0.2397	0.0135	5	5	0	0.2403	0.0182	5	5	0
Sweden	0.0552	0.0955	3	0	0	0.0359	0.0227	3	0	0	0.0185	0.0148	3	0	0
Switzerland	0.0178	0.0049	2	0	0	0.0296	0.0000	1	0	0	0.0288	0.0001	1	0	0
Turkey	0.1687	0.0214	5	2	0	0.1702	0.0224	5	2	0	0.1694	0.0951	5	2	0
United Kingdom	0.1204	0.5532	5	4	0	0.0743	0.2309	5	4	0	0.0498	0.7379	5	4	0
United States	0.1550	0.0103	0	5	0	0.1636	0.0066	0	5	0	0.1547	0.0087	0	5	0

4. Conclusion

In this paper, our aim is to examine whether inflation is persistent in energy commodities for OECD countries. For this purpose we use panel unit root tests, namely Choi, DHT and pCADF tests. Panel unit root tests are preferred due to significant improvements in statistical power compared to unit root tests of individual time series. The powers of panel tests, as well as time series tests, are further improved by the use of covariates as in pCADF test. The panel unit root test results provide strong evidence against a unit root in inflation rates of energy commodities.

We investigate further by reporting and comparing the results of the individual unit root tests used in these panel tests. The benchmark for this study is that, using the individual tests utilized in Choi, DHT and pCADF, there appears to be no unit root in inflation of aggregated energy commodities in Austria, Canada, Finland, Luxemburg, Norway, Sweden and United States. On the other hand, the persistency of inflation is strongly supported in case of Belgium, Czech Republic, Estonia, France, Germany, Italy, Korea, Poland, Slovak Republic, Turkey and United Kingdom.

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Appendix A. R Codes

The codes for the empirical part of this paper are written in R and are given below.

```
# setwd("c:\\...\\Energy_Prices_UR"); dir()
CPI <- read.csv("CPI.csv", header=T); CPI <- ts(CPI, start=c(1978,1),freq=4)
                                            #####
yoy.inf <- function(series){
  y <- rep(NA,length(series))
  for(i in 5:length(series))y[i] <- ((series[i] - series[i-4])/series[i-1])*100
  return(y)
}
                                            #####
epi <- c() # epi: energy price inflation
for (i in 1:dim(CPI)[2])
  epi <- c(epi,yoy.inf(CPI[,i]))
epi <- matrix(epi, nrow=137); colnames(epi) <- colnames(CPI)
epi <- epi[5:dim(epi)[1],] # first five obs. are lost due to Y-O-Y inf. calculation
                                            #####
# install.packages("punitroots", repos="http://R-Forge.R-project.org")
library(punitroots)
# Use "print()" instead of "summary()" if individual p-valuea are not needed
                                            #####
choi.none <- pCADFtest(Y=epi, type = "none", max.lag.y = 5, criterion = "AIC",
                  crosscorr = 0)
choi.drift <- pCADFtest(Y=epi, type = "drift", max.lag.y = 5, criterion = "AIC",
                  crosscorr = 0)
choi.trend <- pCADFtest(Y=epi, type = "trend", max.lag.y = 5, criterion = "AIC",
                  crosscorr = 0)
summary(choi.none); summary(choi.drift); summary(choi.trend)
                                            #####
DHT.none <- pCADFtest(Y=epi, type = "none", max.lag.y = 5, criterion = "AIC",
                       crosscorr = 1)
DHT.drift <- pCADFtest(Y=epi, type = "drift", max.lag.y = 5, criterion = "AIC",
                        crosscorr = 1)
DHT.trend <- pCADFtest(Y=epi, type = "trend", max.lag.y = 5, criterion = "AIC",
                        crosscorr = 1)
summary(DHT.none); summary(DHT.drift);summary(DHT.trend)
                                            #####
pCADF.none.PC <- pCADFtest(Y=epi, covariates = "PC", max.lag.y = 5, max.lag.X = 5,
                           type="none", criterion = "AIC")
pCADF.drift.PC <- pCADFtest(Y=epi, covariates = "PC", max.lag.y = 5, max.lag.X = 5,
                           type="drift", criterion = "AIC")
pCADF.trend.PC <- pCADFtest(Y=epi, covariates = "PC", max.lag.y = 5, max.lag.X = 5,
                           type="trend", criterion = "AIC")
summary(pCADF.none.PC); summary(pCADF.drift.PC);summary(pCADF.trend.PC)
                                            #####
pCADF.none.DY <- pCADFtest(Y=epi, covariates = "DY", max.lag.y = 5, max.lag.X = 5,
                           type="none", criterion = "AIC", crosscorr = 1)
pCADF.drift.DY <- pCADFtest(Y=epi, covariates = "DY", max.lag.y = 5, max.lag.X = 5,
                            type="drift", criterion = "AIC", crosscorr = 1)
pCADF.trend.DY <- pCADFtest(Y=epi, covariates = "DY", max.lag.y = 5, max.lag.X = 5,
                            type="trend", criterion = "AIC", crosscorr = 1)
summary(pCADF.none.DY); summary(pCADF.drift.DY); summary(pCADF.trend.DY)
```