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Triangular Relationship between Energy Consumption, Price Index and National Income in Asian Countries: A Pooled Mean Group Approach in Presence of Structural Breaks

Bilal Mehmood
Department of Economics, GC University, Lahore, Pakistan.
Email: dr.philos.bilal@gmail.com

Syed Hassan Raza
Department of Economics, Lahore Leads University, Lahore, Pakistan.
Email: hassanraza.economist@gmail.com

Mahwish Rana
Department of Economics, Lahore Leads University, Lahore, Pakistan.
Email: wish.rana@yahoo.com

Huma Sohaib
Department of Economics, Lahore Leads University, Lahore, Pakistan.
Email: humasohaib786@gmail.com

Muhammad Azhar Khan
Department of Economics, Lahore Leads University, Lahore, Pakistan.
Email: send2azhar@yahoo.com

ABSTRACT: Energy consumption is a key factor in economic activity. To ascertain its role in economic growth, this study empirically investigates its role for Asian countries. Price index is also included in analysis as factor of economic growth. We examine and quantify this long run relationship for a sample of selected Asian countries with data on relevant variables for a large time dimension (1970 to 2012). Econometric precision is brought by using pooled mean group (PMG) besides other Pedroni, Kao and Westerlund panel cointegration tests. PMG being heterogeneous panels estimation technique allows the slope and short run parameters to vary across the countries. Structural breaks are also incorporated to observe the impact of shocks that leave permanent effect on national income. Results show the presence of long run relationship between energy consumption and national income. The positive contribution of energy consumption is quantified using Fully Modified OLS and dynamic OLS as well. Policy recommendations are made on the basis of empirical analysis.

Keywords: Energy consumption; National income; Price index; Pedroni Cointegration; Kao Cointegration; Westerlund Test; Structural breaks
JEL Classifications: C23; E31; E39; Q43; P44

1. Introduction

Energy conservation became a relatively more important concern throughout the world after 1970's energy crisis and interest worthy issue for researchers to study the relationship between energy consumption and economic growth. As per International Agency Report (IEA, 2007) approximations, the world demand for energy is increasing with 1.8% annual rate and will increase half between 2005 and 2030. Asia with 60% of the world population recorded 3% growth in energy consumption for the year 2012 which is far above the world average. Overall, Asia shows higher energy consumption than that of the world average. Currently, energy concept is in fashion because enhanced global warming and the Kyoto Protocol which requires reducing the greenhouse emission relative to the amounts emitted in 1990. Hence, the Asian countries also require the suitable basis to formulate the energy policies with better economic growth.

Energy plays a key role in economic development and growth. Consequently, it is important to understand the relationship between energy consumption and economic growth in order to design effective policy. Over the past years, a large number of empirical studies analyzed the causality between energy consumption and economic growth because it has significance for economic policy. Most of the literature assesses the different outcomes of causality like unidirectional bi-directional causality. Unidirectional causality implies that reducing the energy consumption would lower the economic growth. Whereas, bi-directional causality implies higher energy consumption excites the economic growth. The absence of causality indicates the energy consumption does not affect the growth and vice versa.

The researchers incorporated different techniques to investigate the relationship between economic growth and energy consumption. Engle and Granger (1987) proposed a cointegration method to test the long run relationship between the variables and since then it is a widely used technique in economic literature. Some of the researchers (Adhikari and Chen, 2012) incorporated this technique to check the relationship economic growth and energy consumption. Preceding empirical investigation shows conflicting results due to time period and methods applied. Therefore, now we have several modern techniques to testify the cointegration.

This paper not only investigates the relationship of energy consumption and economic growth like previous conventional research, but it also includes the structural breaks which provide a strong basis to analyze the outcomes. To prove the validity of results, we have applied residual based cointegration approach, including Pedroni and Kaos, panel error correction approach which include Westerlund and dynamic heterogeneous panel cointegration approach which include pooled mean group estimation (PMG).

2. Literature Review

A comprehensive literature is available showing the efforts of enormous researchers integrating the econometric techniques to assess the relationship between energy consumption and economic growth (see Ozturk, 2010). It all started from single country model to multiple countries, simple framework to multiple frame including controlled variables and then time series analysis to more complex panel analysis.

Kraft and Kraft (1978) were the first to study the relationship of US energy consumption and GNP with twenty eight years data set. Their investigation found a unidirectional causality running from GNP to energy consumption. Soytas and Sari (2003) measured the relationship between GDP and energy consumption with two different time series, one for ten emerging markets of the world and second for G7 countries. They used energy annual consumption and GDP per capita as variables and applied the Johansen cointegration test and vector error correction techniques. The results suggest causality runs from energy consumption to GDP in Turkey, France, Germany and Japan, and from GDP to energy consumption in Italy and Korea.

Imran and Siddiqui (2010) measured the relationship between energy consumption and economic growth in three SAARC countries with multi-frame work panel data. They incorporated real GDP, energy consumption, labor force and capital stock by using modern panel unit root technique, residual based panel cointegration and panel based error correction models. They found a unidirectional causality in long run running from energy consumption to economic growth, but in the short run they found no causality. Chontanawat (2010) used the panel data of 12 Asian countries to measure the causality between energy consumption and GDP. The analysis includes per capita final energy consumption and real GDP in accordance with purchasing power parity. He applied LLC test, IPS test, panel cointegration test and found bi-directional causality between energy and the economy.
Dobnik (2011) measured the relationship between real GDP and energy consumption with a data set of 23 OECD countries from 1971 to 2009. He incorporated the panel econometric techniques which include panel error correction model and Granger causality test with structural breaks. Research concludes bidirectional causality in short and long run between two variables.

Fowowe (2012) investigated the relationship between real GDP and energy consumption for 14 Sub Saharan African countries. The research includes Pedroni's unit root test with 34 years data on energy consumption and real GDP. Homogeneous causality found between GDP and energy consumption and vice versa. Amiri and Talbi (2012) used 27 years data set from 1980-2007 with heterogeneous econometric panel of six MENA countries. Pedroni cointegration test and pooled mean group test were used to find the cointegration. The research concluded in MENA countries energy intensity of GDP greatly depends on investment, urbanization rate and structure of economies.

Adhikari & Chen (2012) measured the long run relationship between energy consumption and economic growth for 80 developing countries from 1990 to 2009. The countries divided among three different classes which include higher income group, middle income group and lower income group. They applied panel unit root test, panel cointegration test and panel dynamic ordinary least square test. Results revealed long run cointegrated relationship in all the groups of country. Campo and Sarmiento (2013) estimated the elasticity of energy consumption and GDP in a long run relationship. They applied Pedroni and Westerlund's cointegration test to check the relationship and the slopes of long run relationship. They found the cointegration exists in both directions for energy consumption and GDP.

Dritsaki and Dritsaki (2014) scrutinize the relationship between energy consumption, economic growth and CO_2 emissions for developing countries. They apply panel cointegration technique and panel causality test to probe the relationship between energy consumption, economic growth and CO_2 emissions for Greece, Spain and Portugal for time period of 1960-2009. Fully modified OLS and Dynamic OLS were used to estimate the long run coefficient. Causality analysis used in this study indicates energy as a force for economic growth both in short and long run. Yildirim et al. (2014) reexamined the relationship between energy consumption per capita and real GDP per capita for economies of Indonesia, Malaysia, the Philippines, Singapore and Thailand. They took data from 1971 to 2009 and analyzed both panel data and time series causality tests. Conservation hypothesis proved true for Indonesia, Malaysia and the Philippines. Though a bi-directional relation was discovered for Thailand. For Singapore, the neutrality hypothesis was supported.

All of these studies overlook the possibility of heterogeneous intercepts, short-run dynamics and error variances across the countries. Moreover, possibility of structural breaks is also overseen in the existing literature. This paper subjects a sample of Asian countries to an econometrically rigorous framework of cointegration with the possibility of structural breaks, in order to contribute to literature. In addition a summary of related literature is listed as follows in Table 1.

Table 1. Summary for Selected Empirical Literature

Study	Technique	Countries	Causality Findings
Yu and Choi (1985)	Granger causality test	UK, USA, Philippines, Korea and Poland	Energy → Growth
Ebohon (1996)	Granger causality test	Nigeria and Tanzania	Energy → GDP
Glasure and Lee (1998)	Bivariate VECM	Korea and Singapore	Energy ↔ Growth
Asafu-Adjaye (2000)	Granger causality test and Cointegration	Philippines	Energy → Growth
Fatai et al. (2004)	Granger causality test	New Zealand	No Causality
Jumbe (2004)	Cointegration and ECM	Malawi	Energy → GDP
Narayan and Smyth (2008)	Multivariate panel VECM	G7 countries	Energy → Growth
Ozturk et al. (2010)	Panel causality	51 countries	Energy ← Growth

Source: Authors' Compilation

3. Data and Methodology

Data of national income, energy use (kg of oil equivalent per capita) and consumer price index (2005 = 100) from 1970 to 2012 is used. The data are obtained from world development indicators WDI (2014). The countries include Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, Hong Kong, India, Indonesia, Iran, Japan, Jordon, Kazakhstan, Korea, Kuwait, Kyrgyz Republic, Lebanon, Malaysia, Maldives, Oman, Pakistan, Philippines and Saudi Arabia. All the variables are in the logarithmic form for linearization. The countries and time period is taken according to the availability of data for selected Asian countries.

Model to be estimated is as follows:

$$Y_{i,t} = \alpha_i + \beta_i E_{i,t} + \gamma_i P_{i,t} + \varepsilon_{i,t} \quad \text{.....(1)}$$

Y = Gross domestic income (constant 2000 US$)
E = Energy use (kg of oil equivalent per capita)
P = Consumer price index (2005 = 100)

$$\varepsilon_{i,t} = \rho_i \varepsilon_{i,t-1} + \omega_{it} \quad \text{(1.1)}$$

$\varepsilon_{i,t}$ is the disturbance from the panel regression and ρ_i shows the autoregressive vector of residuals in the ith cross countries.

The model parameter α_i allows for the possibility of the country specific fixed-effects and the coefficient of β_i allows for the variation across individual countries.

4. Empirical Analysis

Our panel dataset has time dimension of 43 years which is composes a substantial length of time series and therefore, existence of unit roots in variables cannot be ruled out. To confirm the presence of time series variables contain unit root, we employ three different yet popular tests.

4.1 Panel Unit Root Tests

Levin et al. (2002) (LL), Im et al. (2003) (IPS) and Maddala and Wu (1999) (MW) tests. The LL tests are based on homogeneity of the autoregressive parameter, while the IPS tests are based on heterogeneity of autoregressive parameters. Thus, no pooling regressions are associated with IPS tests. MW tests, on the other hand, are based on Fisher type unit root tests that are not restricted to the sample sizes for different samples (Maddala and Wu, 1999).

We use three different tests to confirm our results. Maddala and Wu (1999) argue that "other conservative tests (applicable in the case of correlated tests) based on Bonferroni bounds have also been found to be inferior to the Fisher test." Results from all these tests are given in table 2. The selection of the appropriate lag length was made using the Schwarz Bayesian Information Criterion. Results from all unit root tests suggest that Y, E and P are non-stationary at level and stationary at 1st difference.

Table 2. Unit Root Tests

	Y	**ΔY**	**E**	**ΔE**	**P**	**ΔP**
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic
Levin, Lin & Chu	-1.472*	-4.285***	-3.291***	-2.314**	7.6612	-12.398***
Im, Pesaran and Shin W-stat	10.678	16.302	1.4094	-2.748***	-0.522	-4.120***
Maddala & Wu-ADF-Fisher χ^2	76.919***	126.469***	46.445	86.446***	9.791	186.113***
Maddala & Wu-PP-Fisher χ^2	7.154	140.680***	11.569	412.903***	4.627	160.373***

Source: Authors' estimation

Δ denotes first difference. Both variables are taken in natural logarithms. All tests take non-stationarity as null. **Note:** Table shows the individual statistics and p-values with the lag length selection of one. Intercept is included in all terms with or without first differences. Probabilities of fisher type test are using asymptotic χ^2 distributions while other type of tests assumes asymptotic normality.

Table 2 shows the statistics and p values of panel unit root test. The results suggest that Y, E and P have a unit root rending them are non-stationary. After first differencing the variables and repeating the test variables series become stationary as common intercept panel unit root test reject the null of non-stationary at 1% level of significance and individual intercept panel unit root tests are significant at 5% level of significance. Most of the tests infer that all three variables are first difference stationary with order of integration one, I(1).

4.2 Cointegration Analysis

After investigating stationarity of the Y, E and P, we employ three generations of panel cointegration approaches:

I. Residual Based Panel Cointegration
II. Error Correction Based Panel Cointegration
III. Dynamic Heterogeneous Panel Cointegration

I. Residual Based Panel Cointegration Approaches

Under this generation of panel cointegration two approaches have been employed, namely; Pedroni's cointegration and Kao's cointegration tests.

a. Pedroni's Cointegration Tests

Pedroni (2004) highlights that the cointegration vector may have heterogeneity across cross sections i.e. in countries so on the basis of this he developed two types of tests. The first type is based on the with-in dimensional panel approach including four statistics: panel ѵ-statistics, panel ρ-statistics, panel PP-statistic and panel ADF-statistic. These statistics pool the autoregressive coefficients of the residuals for unit root testing. While the second type is the between dimensional approach (group test) which include three statistics: panel ρ-statistics, panel PP-statistic and group ADF-statistic. These statistics are the simple average of separately estimated coefficient for every group.

The seven statistics are:

Panel ѵ-Statistics

$$Z_{\upsilon} = \left(\sum_{i=1}^{N}\sum_{i=1}^{T}\hat{L}_{11i}^{-2}\,\hat{\varepsilon}_{it-1}^{2}\right)^{-1} \tag{2}$$

Panel ρ-Statistics

$$Z_{\upsilon} = \left(\sum_{i=1}^{N}\sum_{i=1}^{T}\hat{L}_{11i}^{-2}\,\hat{\varepsilon}_{it-1}^{2}\right)^{-1}\sum_{i=1}^{N}\sum_{i=1}^{T}\hat{L}_{11i}^{-2}\left(\hat{\varepsilon}_{it-1}^{2}\Delta\varepsilon_{it} - \hat{\lambda}_{i}\right) \tag{3}$$

Panel PP-Statistics

$$Z_{\upsilon} = \left(\hat{\sigma}\sum_{i=1}^{N}\sum_{i=1}^{T}\hat{L}_{11i}^{-2}\,\hat{\varepsilon}_{it-1}^{2}\right)^{-1/2}\sum_{i=1}^{N}\sum_{i=1}^{T}\hat{L}_{11i}^{-2}\left(\hat{\varepsilon}_{it-1}^{2}\Delta\varepsilon_{it} - \hat{\lambda}_{i}\right) \tag{4}$$

Panel ADF Statistics

$$Z_{t*} = \left(\hat{s}\;{*}^{2}\sum_{i=1}^{N}\sum_{i=1}^{T}\hat{L}_{11i}^{-2}\,\hat{\varepsilon}_{it-1}^{*2}\right)^{-1/2}\sum_{i=1}^{N}\sum_{i=1}^{T}\hat{L}_{11i}^{-2}\,\hat{\varepsilon}_{it-1}^{*2}\Delta\varepsilon^{*}{}_{it} \tag{5}$$

Group ρ Statistics

$$\mathrm{Z}_{\rho} = \sum_{i=1}^{N}\left(\sum_{i=1}^{T}\hat{\varepsilon}_{it-1}^{*2}\right)^{-1}\sum_{i=1}^{T}\left(\hat{\varepsilon}_{it-1}^{2}\Delta\varepsilon_{it} - \hat{\lambda}_{i}\right) \tag{6}$$

Group pp Statistics

$$\tilde{Z}_{\rho} = \sum_{i=1}^{N}\left(\hat{\sigma}^{\,2}\sum_{i=1}^{T}\hat{\varepsilon}_{it-1}^{2}\right)^{-1/2}\sum_{i=1}^{T}\left(\hat{\varepsilon}_{it-1}^{2}\Delta\hat{\varepsilon}_{it} - \hat{\lambda}_{i}\right) \tag{7}$$

Group ADF Statistics

$$\widetilde{Z}_{*\rho} = \sum_{i=1}^{N}\left(\sum_{i=1}^{T}\widehat{S}_{\iota}^{\,2}\hat{\varepsilon}_{it-1}^{*2}\right)^{-1/2}\sum_{i=1}^{T}\left(\hat{\varepsilon}_{it-1}^{*2}\Delta\hat{\varepsilon}^{*}{}_{it}\right) \tag{8}$$

Critical values are presented by Pedroni (1999) and each of these tests is able to accommodate the individual specific short run dynamics, specific slope coefficients, deterministic trends and as well as individual specific fixed effects. For an application of Pedroni (1999, 2004), see Mehmood & Siddiqui (2013).

b. Kao's Cointegration Tests

Kao is an Engle-Granger based cointegration test that follows the same basic approach as the Pedroni tests, but specifies cross-section specific intercepts and homogeneous coefficients on the first-stage regressors. Under the null of no cointegration, Kao estimates the augmented version ADF test statistic. The asymptotic distributions of this test converge to a standard normal distribution N(0,1) as T → ∞ and N → ∞. Kao's panel tests have higher (lower) power than Pedroni's tests when a small-T (high-T) number of observations are included in a homogeneous panel. Results of both the residual based cointegration tests are tabulated as follows:

Table 3 shows that Pedroni panel cointegration tests applied and five out of seven statistics with maximum 10% level of significance confirm the presence of long run cointegration between Y, E and P. While rest of two statistics (panel and group rho statistics) are statistically insignificant. Thus, existence of co-integration between national income, energy consumption and price index cannot be ruled out.

II. Panel Error Correction Cointegration Approach

Table 4 is to further confirm that either there exist the short run dynamics or not. Since both series are of integrated of order one so we can further investigate with the panel cointegration test using the first difference variables, four panel co integration tests introduced by Westerlund (2007) used and applied on the whole panel. This test preference is all because it uses the large degree of heterogeneity and also use to check the cross sectional dependence as well.

Table 4 shows that three out of four statistics; group mean and panel statistics can reject the null hypothesis of no cointegration at 10% in group mean stat and at 5% level of significance in panel statistics. Westerlund (2007) shed light on the possibility of presence of long run steady state relationship between the panel variables. The robust p-values point toward the presence of long run relationship between Y, E and P and also confirm the presence of short run dynamics by rejecting the null hypothesis of no panel error correction or no panel cointegration. So the results confirm the presence of significant error correction term and this is supported by the Granger representation theorem (Granger, 1987) which implies that the error correction term would be significant if, significant cointegration exists.

Table 3. Results of Residual Based Cointegration

Pedroni's Tests

H_o: No Cointegration between National Income and Energy consumption

	Test Type	Statistic	Inference
Within Dimension	Panel v statistic	-3.9620	No Cointegration
	Panel ρ statistic	-2.1962^{**}	*Cointegration*
	Panel PP statistic	-2.6708^{***}	*Cointegration*
	Panel ADF statistic	0.0176	No Cointegration
Between Dimension	Group ρ statistic	-4.7434^{***}	*Cointegration*
	Group PP statistic	-5.6462^{***}	*Cointegration*
	Group ADF statistic	3.2118	No Cointegration

Note: Test type is Pedroni Engle Granger test with individual intercept and deterministic trend. Bandwidth selection and Newey-West automatic selection.

Kao's Test

H_o: No Cointegration between National Income and Energy Consumption

ADF	**-4.7850^{***}**	*Cointegration*

Note: Test type is Kao Engle Granger test with individual intercept (by default). Bandwidth selection and Newey-West automatic selection.

Source: Authors' estimation

Table 4. Cointegration Results

H_o: No Cointegration

Type	Statistic	Value	z-value	p-value	Robust p-value	Inference
Group Mean	G_t	-1.464	2.909	0.998	0.320	No Cointegration
	G_α	-8.528	0.447	0.672	0.000	*Cointegration*
Panel	P_t	-2.408	5.449	1.000	0.020	*Cointegration*
	P_α	-2.888	2.497	0.994	0.010	*Cointegration*

Source: Authors' estimation

Note: Optimal lag length was chosen according to Akaike and Schwartz criteria. We allow for constant trend with 1 lag value and Bart let-kernel window set to 1. Bootstrapped p values which are for obtaining robust p-values set to 200. G_t, G_a is group mean statistics to test the null of no cointegration in the whole panel against the alternative of existence of co integration in some countries. P_t, P_a are the panel statistics check the null of no cointegration against the alternative of cointegration in the whole panel.

III. Dynamic Heterogeneous Panel Cointegration Approaches

There exists long-run cointegration between Y, E and P as found by Pedroni (2004) tests and Westerlund (2007) tests. These panel cointegration approaches identifies the existence of long run relationship between variables, however, do not provide the magnitude of this relationship. We employ two recently developed econometric technique generation, i.e. MG and PMG to identify the appropriate sign and the size of the slope coefficient in the long run equation. Under this generation of panel cointegration two approaches have been employed, namely; Mean group (MG) and pooled mean group (PMG) estimators. These are explained as follows:

a. Mean Group (MG) Estimator

Pesaran and Smith (1995) provided mean group estimator of dynamic panels for large number of time observations and large number of groups. In this method separate equations are estimated for each group and examined the distribution of coefficients of these equations across groups. It provides parameter estimates by taking means of coefficients calculated by separate equations for each group. It is one extreme of estimation because it just makes use of averaging in its estimation procedure. It does not consider any possibility of same parameters across groups.

b. Pooled Mean Group (PMG) Estimator

Pesaran and Smith (1997) suggested pooled mean group (PMG) estimator of dynamic panels for large number of time observations and large number of groups. Pesaran, Shin and Smith (1997, 1999) added further in PMG estimator and extended it. Pooled mean group estimator considers both averaging and pooling in its estimation procedure, so it is consider as an intermediate estimator. PMG estimator allows variation in the intercepts, short-run dynamics and error variances across the groups, but it does not allow long-run dynamics to differ across the groups. In addition to PMG and MG, Dynamic Fixed Effects (DFE) is also used to estimate the cointegrating vector. DFE specification controls the country specific effects, estimated through least square dummy variable (LSDV) or generalized method of moment (GMM). Dynamic fixed effect relies on pooling of cross-sections. Like the PMG estimator, DFE estimator also restricts the coefficient of cointegrating vector to be equal across all panels. Adopting from Pesaran, Shin and Smith (1997, 1999), PMG estimable model has an adjustment coefficient φ_i that is known as the error-correction term. In fact this error-correction term φ_i tells about how much adjustment occur in each period.

With long time series, the chance of having infrequent shocks that leave a permanent effect on a variable is high. Such a happening is known as structural break. Since time dimension in our sample is long as 43 years, we expect multiple structural breaks in each country data. Bai-Perron (2003) suggest test for detection of multiple structural breaks in a cointegration relationship. We employ the same to incorporate the effect of structural breaks in our estimations. Following is the list of structural breaks as per Bai-Perron (2003) test in Table 5:

Table 5. Structural Breaks

Country	No. of Structural Breaks	Location of Structural Breaks			
Bangladesh	3	1978	1984	2007	-
Bhutan	1	1986	-	-	-
Brunei Darussalam	3	1991	2001	2007	-
Cambodia	1	2000	-	-	-
China	2	1980	2007	-	-
Hong Kong	1	1979	-	-	-
India	2	1977	2007	-	-
Indonesia	2	1979	2007	-	-
Iran	2	1980	2007	-	-
Japan	2	1981	2007	-	-
Jordon	1	2001	-	-	-
Kazakhstan	3	1994	2000	2007	-
Korea	1	2007	-	-	-
Kuwait	2	1976	1995	-	-
Kyrgyz Republic	3	1992	1999	2007	-
Lebanon	3	1992	1999	2007	-
Malaysia	2	1976	2007	-	-
Maldives	2	1992	2006	-	-
Oman	1	2007	-	-	-
Pakistan	3	1976	1998	2007	-
Philippines	4	1977	1987	1999	2007
Saudi Arabia	1	2007	-	-	-

Source: Authors' estimations

After incorporating these structural dummies (D_1, D_2, D_3 and D_4) in our cointegration framework as dummy variables, following estimates were found. In addition to it, cointegration results are obtained in the absence of these dummies for comparison purpose.

Results in the table 6 reveal the comparison of panel cointegration estimation using MG, DFE and PMG, with and without structural breaks. Introducing structural breaks has improved statistical inference. With the exception of MG, DFE and PMG show positive long run relationship between energy consumption and macroeconomic performance. The coefficient of energy consumption has increased in magnitude after the inclusion of structural dummies. The error correction term (φ_i) is negative and less than 1 in absolute sense. φ_i is statistically significant for both MG and DFE at 1%

while for PMG at 5%. In particular, the error correction term has become statistically significant after incorporating structural breaks.

Table 6. Cointegration Results

	MG (without Structural Breaks)	**MG (with Structural Breaks)**	**DFE (without Structural Breaks)**	**DFE (with Structural Breaks)**	**PMG (without Structural Breaks)**	**PMG (with Structural Breaks)**
	Long Run Parameters					
E	-3.3507 (0.621)	0.8656 (0.020)	-0.1278 (0.584)	-0.5643 (0.567)	0.5930 (0.000)	0.8673 (0.000)
P	2.9737 (0.199)	5.4320 (0.298)	0.1441 (0.072)	0.5962 (0.167)	0.5922 (0.000)	0.1124 (0.000)
D_1	-	-0.1248 (0.207)	-	-0.0468 (0.058)	-	-0.0523 (0.168)
D_2	-	-0.0063 (0.800)	-	-0.0297 (0.350)	-	-0.0063 (0.809)
D_3	-	-0.01822 (0.376)	-	-0.0685 (0.205)	-	-0.0159 (0.532)
D_4	-	0.0045 (0.317)	-	0.0566 (0.162)	-	0.0048 (0.317)
		Average Convergence Parameter				
Error Correction Term (φ_i)	-0.0313 (0.603)	-0.1711 (0.024)	-0.0558 (0.000)	-0.0405 (0.085)	-0.0080 (0.849)	-0.1513 (0.002)
	Short Run Parameters					
ΔE	0.2370 (0.000)	0.1095 (0.031)	0.3947 (0.000)	0.3873 (0.000)	0.3245 (0.000)	0.1978 (0.000)
ΔP	0.4609 (0.002)	0.4312 (0.002)	0.2699 (0.000)	0.2573 (0.074)	0.5871 (0.000)	0.5147 (0.000)
Intercept	-0.1806 (0.880)	2.1124 (0.215)	1.3567 (0.000)	1.0740 (0.009)	0.1024 (0.896)	2.5775 (0.003)
Note: In parenthesis, p-values of parameters are given.						

4.3 Hausman Test

Hausman test is used to decide the appropriate estimator between Mean Group and Pooled Mean Group. Null hypothesis of test is PMG estimator is efficient and consistent but MG estimator is inefficient against the alternative hypothesis that is PMG estimator is inefficient and inconsistent but MG estimator is consistent. It allows to decide between MG and DFE. Since it is already found that cointegration results using MG, DFE and PMG without structural breaks are unable to reveal cointegration. Therefore, we apply Hausman test on MG, DFE and PMG cointegration estimates with structural breaks in order decide the most efficient estimator among them. Table 7 depicts the same. These results are supported by the Granger representation theorem (Engle & Granger, 1987) which implies that the error correction term would be significant if, significant cointegration exists.

Table 7. Hausman Test for Selection Between:

MG and DFE	**MG and PMG**
H_0: DFE estimator is efficient and consistent, but MG is not efficient.	**H_0:** PMG estimator is efficient and consistent, but MG is not efficient.
$\mathbf{p-value} = 0.986 \nless 0.05$	$\mathbf{p-value} = 0.522 \nless 0.05$
Since **H_0** is not rejected, DFE estimator is efficient and consistent than MG estimator.	Since **H_0** is not rejected, PMG estimator is efficient and consistent than MG estimator.
Overall Decision: Both DFE and PMG estimators are found to be more efficient and consistent than MG estimator in both Hausman tests, respectively. While PMG estimator dominates the DFE estimator because it permits heterogeneity in short run coefficients. Hence PMG estimates should be relied upon, among the three estimators.	
Source: Authors' estimation	

4.4 Panel Causality Test

Table 8 shows the pairwise panel granger causality among national income, energy consumption and price index. Interestingly, there is bi-causal relationship among all variables. It is in lines with expectations since all three macroeconomic variables have the tendency to cause each other. In next step, we compare the slope coefficients of energy consumption and price index using different estimators.

Table 8. Granger Causality Test Results

Causality	F-Statistic	p-value	Remarks
Energy Consumption → National Income	20.929	0.000	Causality Exists
National Income → Energy Consumption	35.819	0.000	Causality Exists
Price Index → National Income	4.462	0.012	Causality Exists
National Income → Price Index	18.714	0.000	Causality Exists
Price Index → Energy Consumption	4.116	0.017	Causality Exists
Energy Consumption → Price Index	34.706	0.000	Causality Exists

Source: Authors' estimation

4.5 Estimation of Long-Run Cointegrating Vector

For comparison purposes, the long run cointegrating vector is done using Pooled OLS (POLS), Fully Modified OLS (FMOLS), Dynamic OLS (DOLS), Dynamic Fixed Effects (DFE) and Pooled Mean Group (PMG) estimators. Finally, the estimates of long run cointegrating vector are tabulated in Table 9.

Table 9. Estimation of Long-Run Cointegrating Vector

Dependent variable is Y and independent variables are E and P

Technique	Variable	Coefficient ($\hat{\beta}$)	Standard Error	Statistics	p-value	Inference
POLS	**E**	0.7875	0.0551	14.30	0.000	Positive & significant
	P	-0.0196	0.0375	-0.52	0.602	Negative & insignificant
DFE	**E**	-0.5643	0.9861	-0.57	0.567	Negative & insignificant
	P	0.5962	0.4311	1.38	0.167	Positive & insignificant
FMOLS	**E**	0.7509	0.0511	14.71	0.000	Positive & significant
	P	0.2167	0.0247	8.77	0.000	Positive & significant
DOLS	**E**	0.7658	0.0549	13.94	0.000	Positive & significant
	P	0.1647	0.0206	8.00	0.000	Positive & significant
PMG	**E**	0.8673	0.0266	32.55	0.000	Positive & significant
	P	0.1124	0.0277	4.06	0.000	Positive & significant

Note: FMOLS and DOLS estimates are found with Bartlett Kernel and Newey-West fixed bandwidth.

Source: Authors' estimation

For energy consumption 'E' slope coefficients ($\hat{\beta}$) are positive and statistically significant at 1% level of significance for all techniques expect for DFE in which it has a negative sign. For price index 'P' slope coefficients ($\hat{\beta}$) are positive and statistically significant at 1% level of significance for all techniques expect for POLS and DFE. Firstly, it is safe to infer that energy consumption and price index have positive and statistically significant contribution in national income since most of the estimation techniques reveal this. Secondly, this finding is further validated with the positive and statistically significant coefficients in PMG. Since PMG is statistically most rigorous and sophisticated estimation technique, it affirms the long run relationship between the energy consumption, price index and national income.

5. Conclusion

In this paper, we examine the association between economic growth and energy consumption comprising of the data of 22 Asian countries from 1970 to 2012 using the Pedroni's cointegration test, Kao cointegration, Westerlund cointegration and Pooled mean group estimator. This paper is adds to the existing literature by using ameliorated and flexible techniques of panel cointegration and contributes to the existing works like that of Dritsaki and Dritsaki (2014). The results demonstrate a positive relationship between energy consumption, price index and national income.

Our empirical findings advocate that energy is an indispensable factor for economic growth in Asian countries. Two way mutual causality between national income, energy consumption and price index (inflation) validates the synergy between national income, energy consumption and inflation for the case of Asian countries. This infers both of the factors are integral part of economic development. Resultantly, it provides a link to policy makers for better and effective environmental, energy and economic growth policies. The Asian countries should invest more on renewable energy resources and should concentrate more on achieving long term energy goals. Such policies will boost the available energy infrastructure which will lead to transition towards development for developing countries in Asia.

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