Umurzakov, Uktam; Mirzaev, Bakhodir; Salahodjaev, Raufhon et al.

Article

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Reference: Umurzakov, Uktam/Mirzaev, Bakhodir et. al. (2020). Energy consumption and economic growth : evidence from post-communist countries. In: International Journal of Energy Economics and Policy 10 (6), S. 59 - 65.
https://www.econjournals.com/index.php/ijeep/article/download/10003/5524.
doi:10.32479/ijeep.10003.

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2020, 10(6), 59-65.

Energy Consumption and Economic Growth: Evidence from Post-Communist Countries

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Received: 30 May 2020 **Accepted:** 01 September 2020 **DOI:** https://doi.org/10.32479/ijeep.10003

ABSTRACT

Current study aimed to explore the nexus between energy and economic growth in post-communist nations during 1995-2014. As an empirical model, the growth model is employed including economic complexity indicator as a measure of capabilities for exporting sophisticated products. We employ Pedroni's (1999) panel cointegration tests and Panel Dynamic OLS estimation to assess the long-term link between the variables. At 1% significance level, we confirm cointegration between energy consumption and economic growth. Panel Dynamic OLS results revealed that economic growth positively influences energy consumption in Post-Communist states. The Dumitrescu and Hurlin (2012) panel Granger causality test results discovered unidirectional causality running from economic growth to energy consumption. Economic growth causes energy consumption in post-communistic countries, confirming the conservation hypothesis.

Keywords: Energy, Growth, Post-Communist
JEL Classifications: C23, O47, Q40

1. INTRODUCTION

Related studies on the nexus between energy and growth is grounded on several different premises: the growth hypothesis, the conservation hypothesis, the feedback hypothesis, and the neutrality hypothesis. The growth hypothesis assumes that energy consumption is an instrumental determinant of economic growth complementary to other antecedents such as capital or labor. This implies that any measures leading to a decrease in energy consumption will have harmful effects on GDP growth. As a result, the direction of causality runs from energy consumption to economic growth. The conservation hypothesis suggests there is unidirectional causality from GDP growth to energy consumption (Gozgor et al., 2018). Therefore, any measures associated with reducing energy consumption will have no effect on economic output. The feedback hypothesis indicates existence of bi-directional causality between energy consumption and economic growth (Dagher and Yacoubian, 2012; Wesseh and Zoumara, 2012; Zhixin and Xin, 2011). Any policies aimed at reduction in energy consumption will have deteriorating implications for economic growth, which in turn will further decrease energy consumption. The neutrality hypothesis assumes that there is no causal link between energy consumption and economic growth. Consequently, understanding the effect of energy consumption on GDP growth is crucial for governments to adopt energy policies aimed at sustainable development.

Turning to the empirical evidence that investigates the link between energy and growth, the findings are, at best, mixed. A number studies document that energy use is a good determinant of economic growth (Chaudhry et al., 2012), while other studies find insignificant (Ozturk et al., 2010), bi-directional, or even negative effects (Narayan, 2016; Yildirim et al., 2014). Wang et al. (2011) explore the causal relationship between energy and economic growth in China for the period 1972-2006. The study applies the autoregressive distributed lag (ARDL) bounds testing approach. The study reports that both in the short- and long-term, economic growth is driven by rise in energy consumption and, "that restrictions on energy use may significantly hamper economic growth" (p. 4405). Esen and Bayrak (2017) revisit the energy-growth nexus for a sample of 75 net energy-importing countries for the period 1990 to 2012. The study, using cointegration tests, dynamic ordinary least squares (DOLS), and fully modified ordinary least squares (FMOLS) estimators, finds that overall energy consumption has pro-growth effects in energy-importing nations. Raza et al. (2016) investigates the effect of energy consumption, measured by electricity consumption, on economic growth in four South Asian countries for the years 1980-2010, namely Pakistan, India, Bangladesh, and Sri Lanka. Applying the random effects model, Pedroni cointegration technique, and Granger causality, the study finds that energy consumption has a unidirectional causal effect on GDP growth.

Shahbaz et al. (2018) assesses the link between growth and energy consumption for 10 energy-consuming countries using data from 1960 to 2015. The results, based on the Quantile-on-Quantile (QQ) approach, suggest that although energy consumption increases economic growth, the magnitude of this impact differs across countries depending on the relative importance of energy or technological development. In a similar vein, Apergis and Payne (2010) explore the link between energy consumption and GDP growth for 9 South American nations for the period 1980-2005. The authors apply a panel cointegration and error correction model to assess the causal relationship. The results suggest energy has a causal effect on economic development in both the short- and long-term.

Guo (2018) analyzes the nexus between economic growth and energy consumption in China. Using the time division of two periods, 1978-1992 and 1991-2016, the authors identify a strong dependence of the Chinese economy on energy consumption in favor of the growth hypothesis. These findings are proved by a co-integration test and error correction model. However, this relationship decreases year by year because China understands the unsustainability of relying only on energy input.

Apergis and Ozturk (2015) tested the Environmental Kuznets Curve (EKC) among 14 Asian countries. The EKC hypothesis states a concave graphical representation of the relationship between level of emissions and economic growth. According to the hypothesis, economic growth and emission levels increase at the same rate at the early stages and start to decline after an economy reaches a threshold level. Using the GMM model, the authors identified the unidirectional causal relationship between economic growth and emission level under the EKC hypothesis.

The conservation hypothesis is also proved by Yildirim et al. (2014) using a sample of ASEAN countries, including Indonesia, Malaysia, the Philippines, Singapore, and Thailand. An analysis of data from the period of 1971–2009 shows a unidirectional nexus from economic growth to energy consumption in the cases of Indonesia, Malaysia, the Philippines, and Thailand. According to the results, Singapore doesn't demonstrate any relationship between energy and economic performance, thereby supporting the neutrality hypothesis. Similarly, Huang et al. (2008) studied the nexus between economic growth and energy consumption using a sample of 82 countries between 1972 and 2002. These countries were divided into four categories, including low income, lower middle income, upper middle income, and high-income countries. According to their findings, low-income countries are under the neutrality hypothesis of connection between economic growth and energy consumption. Other groups of countries have unidirectional causality of energy-growth the nexus which is described by the conservation hypothesis. Authors apply a Generalized Method of Moments (GMM) to estimate the panel VAR model in each category of countries.

Al-mulali et al. (2013) explored the relationship between energy and economic growth for Latin American and Caribbean countries. The authors apply a canonical cointegrating regression (CCR) for the period 1980-2008. The results suggest that, "56% of the countries have a long run bi-directional positive relationship between energy consumption and economic growth, 6% of the countries have a long run bi-directional negative relationship between energy consumption and economic growth, 16% of the countries were found to have a positive one way long run relationship between energy consumption and economic growth, 16% of the countries have a long run positive relationship between economic growth and energy, and 6% of the countries have no relationship between energy consumption and economic growth" (p. 46).

Rezitis and Ahammad (2015) use panel data of nine South and Southeast Asian countries including Malaysia, Pakistan, Bangladesh, Brunei Darussalam, India, Indonesia, the Philippines, Sri Lanka, and Thailand. Authors identify bi-directional causality between economic growth and energy consumption in observed countries based on Granger causality test results. The cases of individual countries prove the results of panel analysis, which states that economies depend on energy consumption. The relationships between GDP growth and energy usage, which is found in the cases of Bangladesh, Brunei Darussalam, India, and Thailand, support the growth hypothesis. Malaysia and the Philippines show results in favor of the feedback hypothesis while Sri Lanka tends toward the conservation hypothesis. Support of the neutrality hypothesis is found in the cases of Indonesia and Pakistan.

Vidyarthi (2015) empirically investigates the link between energy consumption and economic growth for a panel of five South Asian economies, namely India, Pakistan, Bangladesh, Sri Lanka, and Nepal, over the period from 1971 to 2010. The study relies on Pedroni cointegration and the Granger causality test based on panel vector error correction to assess long-term evidence. The results suggest that in the long-term, there is bi-directional causality between energy consumption and GDP per capita, while in the short-term conservation policies may harm economic growth in these developing markets. Similarly, an analysis of the Indian economy is conducted by Ozturk and Uddin (2012) and studies the energy-growth carbon emission nexus using the Johansen–Juselius maximum likelihood procedure. The results prove the feedback hypothesis and identify strong causal relationships between energy consumption and carbon emissions in India.

Eggoh et al. (2011) assess the relationship between energy consumption and economic growth in a sample of 21 African economies over the period from 1970-2006 using cointegration techniques and OLS, DOLS, and PMG estimators. The study finds a bivariate causal relationship between energy consumption and economic growth for both net energy importing and exporting countries.

Similarly, Lee and Chang (2008) state that panel cointegration and panel-based error correction models prove the neutrality hypothesis in the short-term within a sample of 16 Asian countries. The results of long-term analysis show the unidirectional dependence of economic growth on energy consumption and prove the growth hypothesis. In contrast, the results of the Granger causality and panel cointegration test, conducted by Narayan and Smyth (2008) within the G7 countries, identify short- and long-term nexuses between economic growth and energy consumption supporting the growth hypothesis. The same trend is found by Ciarreta and Zarraga (2008) who conduct analysis of 12 European countries using panel causality and cointegration models. The research doesn't identify the connection between economic growth and electricity consumption in the short-term, which proves the neutrality hypothesis, but cointegration between observed variables is found in the long-term. According to their findings, there is evidence in favor of the growth hypothesis. The 1% increase in electricity consumption causes a 0.3% increase in GDP in the case of observed European countries.

In a similar vein, Ozturk et al. (2010) investigates the relationship between energy consumption and economic growth for a sample of 51 low- and middle-income countries from 1971 to 2005. The results suggest that, overall, there is a long-term effect of energy consumption on economic growth. However, when the authors disaggregate countries by income group, their results confirm the conservation hypothesis for low income countries and feedback hypothesis for middle income countries. Gorus et al. (2019) further investigates the link between energy consumption and economic growth for Middle East and North Africa (MENA) countries for the period 1975-2014. Their results suggest that, in the short-and intermediate-term, economic growth has a causal effect on energy usage, while in the long-term energy consumption has a positive impact on economic growth. Therefore, while energy conservation policies may be implemented in the short-term and intermediate-term, these policies are harmful for economic progress in the long-term. These findings agree with Ouedraogo (2013), who assesses the relationship between energy consumption and economic growth for the economic community of West African States (ECOWAS) over the period 1980-2008. The study relies on panel unit root, Granger causality, and panel cointegration techniques to explore the causal relationships. The results suggest that in the short-term, GDP growth has an effect on energy consumption, while energy consumption is causal to economic growth in the long-term.

According to Mahadevan and Asafu-Adjaye (2007), there is a unidirectional growth-energy nexus under the growth hypothesis among developing countries and a bidirectional relationship among developed countries under the feedback hypothesis. Authors use the panel error correction model with a sample of 20 countries which export and import energy. Similar results are found by Lee and Chang (2007), whose work estimates the VAR model by GMM technique using a sample of 22 developed and 18 developing countries. The results show bidirectional relationships between economic growth and energy consumption in developed countries under the feedback hypothesis. However, this growth-energy nexus is indicated as unidirectional in developing countries, in favor of the conservation hypothesis.

The feedback hypothesis is also proved by Bildirici and Kayıkçı (2012) based on the sample of Commonwealth Independent States (CIS) using data of the period from 1990 to 2009. The sample consists of 11 countries including Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Belarus, Russian Federation, Tajikistan, Ukraine, and Uzbekistan. These countries are divided by 3 groups with accordance to income. The authors use the Pedroni cointegration, Fully Modified Ordinary Least Squares (FMOLS), and Panel ARDL methods in their work. According to the results of cointegration tests, economic growth and electricity consumption are cointegrated in all 3 groups. The causality tests show bi-directional relationships between economic growth and electricity consumption. The results of FMOLS and ARDL show the negative impact of electricity usage on economic performance in the second group and a positive effect in the first group in favor of the growth hypothesis. This work is closely related to the current study, although it differs in terms of sample size and main independent variable.

To the best of our knowledge, this is the first study to assess the relationship between energy consumption and economic growth for a sample of post-communist countries. The results of our paper show that, overall there are unidirectional relationships between economic growth and energy consumption in favor of the conservation hypothesis in 26 countries for the period from 1995 to 2014.

The rest of this study is structured as follows: Section 2 discusses data and methods; Section 3 offers empirical results; Section 4 concludes the manuscript.

2. DATA AND EMPIRICAL MODEL

To the best of our knowledge, previous studies exploring the nexus between energy and economic growth are based on traditional growth models (Yuan et al., 2008; Apergis and Payne, 2010a; Shahbaz and Dube, 2012; Maji and Sulaiman, 2019). This model can be represented as:

$$Y=f(K, L) \quad (1)$$

Dividing the equation by labor (L), we obtain the following:

$$Y/L=f(K/L,1) \quad (2)$$

where K/L is productivity measure, L is labor.

In many empirical studies, gross fixed capital formation is used as a measure of capital (Yuan et al., 2008; Apergis and Payne, 2010; Inglesi-Lotz, 2016; Maji and Sulaiman, 2019). However, for several post-communistic countries, the data on gross fixed capital formation is not available. Gozgor et al. (2018) stated that Economic Complexity Indicator (ECI) provides a good measure for productivity and economic structure. After replacing K/L and incorporating energy consumption, the model can be depicted as:

$$Y/L=f\,(ECI,\ EC) \tag{3}$$

where ECI is an economic complexity indicator and EC is energy consumption.

Equation (3) considers the relationship between energy consumption, ECI, and economic growth, shedding light on the nexus between consumption of conventional energy and economic growth employing secondary data on post-communistic countries during 1990 and 2018, available from the World Bank's World Development Indicators. After balancing the data, our sample includes 26 post-communist countries – Armenia, Azerbaijan, Bulgaria, Bosnia and Herzegovina, Belarus, Czech Republic, Estonia, Georgia, Croatia, Hungary, Kazakhstan, Kyrgyz Republic, Lithuania, Latvia, Moldova, Poland, Romania, Russian Federation, Serbia, Slovak Republic, Slovenia, Montenegro, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan between 1995and 2015. Furthermore, we transformed the model (3) into the logarithmic form, obtaining the following model:

$$\ln Y = \alpha + \beta_1 \ln EC + \beta_2 ECI + \varepsilon \tag{4}$$

where Y denotes real GDP per capita (constant 2010 US$).

Energy consumption is measured as energy use (kg of oil equivalent) and ECI is an economic complexity index computed using Standard International Trade Classification. The summary statistics and variables description is depicted in Table 1.

3. METHODS AND RESULTS

Following Yuan et al. (2008), we employ Pedroni's (1999) panel cointegration tests and Panel Dynamic OLS estimation and Dumitrescu and Hurlin's (2012) panel Granger causality test. Before estimating panel DOLS and causality, we report the correlation matrix and unit root test results (Tables 2 and 3).

According to Table 2, there are no worrisome correlation coefficients which may cause multicollinearity.

Table 1: Descriptive statistics

Variables	*ln* Y	*ln* EC	ECI
Indicator	GDP per capita (constant 2010 US$)	Energy use (kg of oil eauivalent)	Economic complexity indicator (SITC)
Source	WDI	WDI	Atlas MIT
Mean	8.451	7.569	0.419
Std. dev	1.034	0.689	0.749
Min	5.905	5.647	−1.591
Max	10.144	8.550	1.787
N. of observations	480	480	480

Following Apergis and Payne (2010b), Inglesi-Lotz (2016), and Maji and Sulaiman (2019), we run the panel unit root test proposed by Im et al. (2003). The specification of the test is depicted below:

$$y_{it} = \rho_i y_{i(t-1)} + \sigma_i x_{it} + \varepsilon_{it} \tag{5}$$

where xit represents the combination of all the explanatory variables in the model; ρi denotes the autoregressive elasticities, ϵit is the residual term, i=1,…N for each country and t=1,…T is the time period.

Table 2: Correlation matrix

Variables	*ln* Y	*ln* EC	ECI
ln Y	1		
ln EC	0.764	1	
ECI	0.646	0.420	1

Table 3: Panel unit root test results

Variable	Form	Method	Statistic	P-value	Conclusion
ln GDP per capita	Level	LLC	−2.546	0.005	Stationary
		Breitung	10.25	1.000	Non stationary
		IPS	3.52	0.999	Non stationary
		Fisher-ADF	23.50	0.999	Non stationary
		Fisher-PP	74.27	0.009	Non stationary
	1st difference	LLC	−4.57	0.000	Stationary
		Breitung	−3.63	0.000	Stationary
		IPS	−7.43	0.000	Stationary
		Fisher-ADF	151.68	0.000	Stationary
		Fisher-PP	303.16	0.000	Stationary
ln Energy	Level	LLC	−1.63	0.052	Stationary
		Breitung	0.1291	0.551	Non stationary
		IPS	0.1344	0.554	Non stationary
		Fisher-ADF	55.563	0.211	Non stationary
		Fisher-PP	63.303	0.068	Stationary
	1st difference	LLC	−8.454	0.000	Stationary
		Breitung	−8.411	0.000	Stationary
		IPS	−9.844	0.000	Stationary
		Fisher-ADF	190.124	0.000	Stationary
		Fisher-PP	357.411	0.000	Stationary
ECI	Level	LLC	−2.160	0.015	Stationary
		Breitung	−0.7	0.242	Non stationary
		IPS	−1.937	0.026	Stationary
		Fisher-ADF	50.026	0.393	Non stationary
		Fisher-PP	92.536	0.000	Stationary
	1st difference	LLC	−5.988	0.000	Stationary
		Breitung	−8.826	0.000	Stationary
		IPS	−12.485	0.000	Stationary
		Fisher-ADF	220.120	0.000	Stationary
		Fisher-PP	773.547	0.000	Stationary

$$\epsilon_{it} = \sum_{j=1}^{n=1} \theta_{ij} \epsilon_{it-1} + \varepsilon_{it} \quad (6)$$

The IPS test is based on heterogeneity of the autoregressive parameter (Maddala and Wu, 1999). It allows for different orders of serial correlation (Inglesi-Lotz, 2016) and follows the normal averaging Dickey Fuller (ADF) (Apergis and Payne, 2010b):

If eq. 6 is substituted into eq. 5:

$$y_{it} = \rho_i y_{i(t-1)} + \sigma_i x_{it} + \sum_{j=1}^{n=1} \theta_{ij} \epsilon_{it-1} + \varepsilon_{it} \quad (7)$$

where ρ_i shows the number of lags in the ADF regression.

IPS tests the null hypothesis of non-stationarity in every individual panel series over the alternative of no unit-root in at least one panel. For the robustness check, we additionally run panel unit root tests proposed by Levin et al. (2002) and Breitung and Das (2005), as well as the Fisher-type test. In general, the null hypotheses of the tests claim non-stationarity, while alternative assume that some or at least one panel is stationary. Results of the panel data unit root test are reported in Table 3. In the level form, GDP per capita does not contain unit-root only under the LLC test. Both energy consumption and ECI are stationary under LLC and Fisher PP-type tests. As some test statistics report non-stationarity, we reject the null hypothesis and take the first difference of the variables to re-test the model for unit-root. As a result, all variables are stationary at the 1% significance level. Stationarity enables further estimation of the model.

Furthermore, we conduct the Pedroni and Kao (1999) cointegration tests reported in Table 4. Pedroni panel cointegration is a one-tailed test that tests the presence of a long-term relationship using seven test statistics. The test statistics can be divided into two categories: group statistics that average the results of the individual country, and test statistics and panel statistics that pool the statistics along the within-dimension (Neal, 2014). The null hypothesis assumes no cointegration and it can be rejected when the majority of test statistics reject it.

According to Table 4, 6 out of 7 test statistics reject the null hypothesis, revealing a long-term relationship between energy consumption and economic growth. Kao tests for panel cointegration support the results of Pedroni as well at a 1% significance level. Since cointegration between the variables is confirmed, we estimate the model using the Pedroni Panel Dynamic OLS (DOLS). Panel DOLS is an extension of time series DOLS, estimating the cointegrating vector that exhibits a cointegrating relationship between variables (Neal, 2014). To verify the consistency of results, we employ time series cointegrated regression estimators (DOLS and FMOLS) adapted to panel data by Khodzhimatov (2018), as well as an OLS estimator.

Table 5 describes the results of panel cointegrated regressions. Our results revealed a positive and significant impact of energy consumption on economic growth. The results of the robustness check from panel DOLS, FMOLS, and OLS yield the same positive and significant coefficients of energy consumption. Such results are in line with the findings of Rezitis and Ahammad (2015) and Gozgor et al. (2018).

Once the causal relationship is established, we proceed to identify the direction of causality by using the panel Granger non-causality test for heterogeneous panel data models proposed by Dumitrescu and Hurlin (2012). The benchmark model is presented below, where $x_{i,t}$ and $y_{i,t}$ are observations of two stationary variables for individual i in period t.

$$y_{i,t} = \alpha_i + \sum_{k=1}^{K} \gamma_{ik} y_{i,t-k} + \sum_{k=1}^{K} \beta_{ik} x_{i,t-k} + \varepsilon_{i,t} \quad (8)$$

The test is based on the individual Wald statistics of Granger non-causality averaged across the cross-section units. The null hypothesis claims no causal relationship between the variables. The testing procedure of the null is based on *z-bar* and *z bar tilde*. For a small number of observations (N) and time period (T), Lopez and Weber (2017) suggest testing the null hypothesis based on *z bar tilde statistics*. Dumitrescu and Hurlin (2012) provide no guidance for lag order selection. However, it is recommended to select the number of lags based on an information criterion (AIC/BIC/HQIC) (Chang et al., 2013; Lopez and Weber, 2017).

Table 6 reports the results of the Dumotrescu and Hurlin's panel Granger causality test results. We first test whether economic growth does not Granger-cause energy consumption. At the 1% significance level, we reject the null hypothesis as *z-bar tilde*

Table 4: Pedroni and Kao panel cointegration tests results

Test statistics	Statistics	P-value
V-stat	0.43	0.332
Panel rho-stat	−3.32	0.000***
Panel PP-stat	−7.54	0.000***
Panel ADF-stat	−7.54	0.004***
Group rho stat	−1.31	0.095*
Group PP stat	−8.91	0.000***
Group ADF stat	−2.22	0.013**
Kao	−7.99	0.000***

***, ** and * indicate significance at 1%, 5% and 10% levels, respectively

Table 5: Impact of renewable energy on economic growth

Variables	Pedroni DOLS	DOLS	FMOLS	OLS
ln energy	1.599***	0.66***	0.37***	0.349***
	111	17.86	19.57	5.31
ECI	0.0323***	0.02	0.06***	−0.006
	40.06	1.39	6.86	0.77

***, ** and * indicate significance at 1%, 5% and 10% levels, respectively. While figures in parentheses are t-statistic

Table 6: DH granger non-causality test results

Economic growth does not granger-cause energy consumption	
W-bar	2.694
Z-bar	5.869*** (0.000)
Z-bar tilde	4.099*** (0.000)
Optimal number of lags (AIC)	4
Lags tested	1-4
Energy consumption does not granger-cause economic growth	
W-bar	1.175
Z-bar	0.608 (0.544)
Z-bar tilde	0.057 (0.954)
Optimal number of lags (AIC)	4
Lags tested	1-4

***, ** and * indicate significance at 1%, 5% and 10% levels, respectively. While figures in parentheses are P-values statistics are higher than critical values. Furthermore, we check for the presence of bidirectional causality. Due to the large probability value of *z-bar tilde* statistics (0.9543), we fail to reject the null hypothesis. Our estimates revealed unidirectional causality running from economic growth to energy consumption. In other words, economic growth causes energy consumption in post-communistic countries, confirming conservation hypothesis and supporting previous findings (Dehnavi and Haghnejad, 2012; Azlina and Mustapha, 2012; Damette and Seghir, 2013).

4. CONCLUSION

The causal link between energy consumption and economic growth is explored for a group of post-communist countries covering the period 1995 and 2014 and utilizing the Pedroni cointegration and panel Granger causality test. Our findings confirm the cointegration between energy consumption and economic growth. Panel Dynamic OLS results revealed a positive and significant impact of energy consumption on economic growth. The Dumitrescu and Hurlin's (2012) panel Granger causality test results discovered unidirectional causality running from economic growth to energy consumption. Economic growth causes energy consumption in post-communistic countries, confirming the conservation hypothesis.

This implies that environmental policy actions directed at decreasing energy consumption will not impact growth prospects and development of PSC. Moreover, our findings also imply that the policymakers in PSC can promote energy efficient measures which will not harm economic growth, but reduce the risks of environmental degradation in this region.

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