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RESEARCH ARTICLE

The relationship between air pollution, fossil fuel energy consumption, and water resources in the panel of selected Asia-Pacific countries

Abdulkadir Abdulrashid Rafindadi · Zarinah Yusof · Khalid Zaman · Phouphet Kyophilavong · Ghulam Akhmat

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Abstract The objective of the study is to examine the relationship between air pollution, fossil fuel energy consumption, water resources, and natural resource rents in the panel of selected Asia-Pacific countries, over a period of 1975–2012. The study includes number of variables in the model for robust analysis. The results of cross-sectional analysis show that there is a significant relationship between air pollution, energy consumption, and water productivity in the individual countries of Asia-Pacific. However, the results of each country vary according to the time invariant shocks. For this purpose, the study employed the panel least square technique which includes the panel least square regression, panel fixed effect regression, and panel two-stage least square regression. In general, all the panel tests indicate that there is a significant and positive relationship between air pollution, energy consumption, and water resources in the region. The fossil fuel energy consumption has a major dominating impact on the changes in the air pollution in the region.

Keywords Air pollution · Energy consumption · Water resources · Natural resource rents · Asia-Pacific countries

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A. A. Rafindadi (✉) · Z. Yusof
Faculty of Economics and Administration, University of Malaya, Kuala Lumpur 50603, Malaysia
e-mail: aarafindadi@yahoo.com

K. Zaman
Department of Management Sciences, COMSATS Institute of Information Technology, Abbottabad, Pakistan
e-mail: khalidzaman@ciit.net.pk

P. Kyophilavong
Faculty of Economics and Business Management, National University of Laos (NUoL), PO Box 7322, Vientiane, Laos
e-mail: Phouphetkyophilavong@gmail.com

G. Akhmat (✉)
College of Public Administration, Huazhong University of Science and Technology (HUST), 1037, Luoyu Road, Wuhan, People's Republic of China
e-mail: ahmad_choudary@hotmail.com

Introduction

According to the UNEP (2012) report, Asia and the Pacific is the fastest emergent economic area in the world; however, untenable growth, population explosion, increased energy consumption, and the demise of natural resources are the biggest obstacle for the region's long-term sustainable development. The report of ADB (2014) concludes that the global requirement for the energy would be increased by one third from 2010 to 2035, while the People's Republic of China, India, and other developing Asian countries accounting for over 60 % of the global total. Exclusive of greater use of solar energy, geothermal, biofuel wind, etc., and enhanced energy effectiveness, the developing Asia's share in global energy-related carbon emissions will be increased from current 35 to 45 % by 2030. Another report of ADB (2013) shows that the there is a larger threat of water security in Asia and the Pacific regions which is mainly due to high population growth, massive rural-urban migration, increasing air and water pollution, water-related disasters, and climatic factors. There is no doubt that the Asia-Pacific countries have an important geographic importance worldwide. The number of studies has highlighted the importance of this region in terms of energy consumption, water resources, air pollution, and natural resources. This study takes an opportunity to explore the pollution-energy-water nexus in the context of Asia-Pacific countries.

Boudghene Stambouli et al. (2014) conclude that the photovoltaic (PV) energy is an important factor within a portfolio of energy sources in the next 10 to 20 years. Sahara Solar Breeder (SSB) project in the north African countries would be an enervative role in providing fresh and sustainable water/energy worldwide. Yüksel and Arman (2014) presented a comprehensive review of energy and environmental policies in Turkey. The results show that the Turkish citizens have migrated from eastern part of the country to western part of the country due to severe problems they faced in energy utilization and environmental pollution. Zarrineh and Abad (2014) examine the relationship between environmental, political, and socioeconomic impacts of drought in Lake Urmia Basin. The results show that the vital effect of Lake Urmia has been recognized as ecological and environmental consequences, i.e., several scarce species of flora and fauna are uncovered from the danger of extermination, and polluted air arising from the salt storms affect the daily life of people in the region. According to Akhmat et al. (2014a, p. 10),

> Emissions to the atmosphere cause a variety of negative impacts on climate and air quality. Pollution does not comprise a single chemical substance, but consists of a cocktail of many pollutants originating from a wide range of human activities and natural sources that can be controlled to different extents at different costs.

Giljum et al. (2014) evaluates global patterns of material extraction and trade and energy consumption between the year 1980 and 2009. The results show some promising facts, i.e., global material extraction increases by more than 90 % over the past 30 years and is reaching almost 70 billion tonnes today. The trade factors in physical terms have increased by a factor of 2.5 billion tonnes over the past 30 years, and in 2009, 9.3 billion tonnes of raw materials and products were traded around the globe. Akhmat et al. (2014b) examine the relationship between energy consumption and climatic factors in the world's largest regions, over a period of 1975–2011. The results show that both the variables, i.e., energy and climatic factors, have a long-run and causal relationship between them; however, the causality analysis was mixed in region by region. Ponce de Leon Barido and Marshall (2014) examine the relationship between carbon dioxide emissions and urbanization in the panel of 80 countries for the period 1983–2005. The results show that the 1 % increase in urbanization correlates with a 0.95 % increase in emissions in a region.

Ashnani et al. (2014) examine the available renewable energies and nonrenewable energies in a country, i.e., Malaysia s status quo in energy and biodiesel market. The results conclude that by developing biodiesel production in the Malaysia, the country would flourish all over the world. Calbick and Gunton (2014) examine the differences in greenhouse gas emissions among high-income OECD countries. The results indicate that the energy prices and environmental governance enlighten two thirds of the divergences in per capita greenhouse gas emissions. Shao et al. (2014) examine the carbon emission from industrial energy consumption in Tianjin, China. The results suggested low-carbon development of industries in Tianjin. According to Akenji (2014, p. 13),

> An axiom that has shaped policy approaches to sustainable consumption has been that if more consumers understand the environmental consequences of their consumption patterns, through their market choices they would inevitably put pressure on retailers and manufacturers to move towards sustainable production.

The above discussion confirms the strong relationship between energy, water, and air pollution. In the subsequent section, an analysis has been carried out to explore the panel relationship between energy-water-pollution nexus in the selected Asia-Pacific countries. The study is divided into the following sections: after "Introduction" which is presented above, "Data source and methodological framework" shows the data and methodology. The results are discussed in "Results" section. "Conclusion" section concludes the study.

Data source and methodological framework

The data for fossil fuel energy consumption, GDP per unit use of energy, water resources, natural rents, and carbon dioxide emissions are taken from World Development Indicators published by World Bank (2013), over a period of 1975–2012. These variables have been selected because of the vital importance in the Asia-Pacific region. The units of measurement for the fossil fuel energy consumption is in percent of total energy consumption; GDP per unit use of energy measured by PPP $ per kilogram of oil equivalent; water resources measured by constant 2005 US$ GDP per cubic meter of total freshwater withdrawal; natural resource rents as percentage of GDP, and finally, carbon dioxide emission measured in kiloton.

This study used the model specifications of Akhmat et al. (2014a) to examine the significance of each country's carbon dioxide emissions on the efficiency of energy resources, water productivity, and natural resource rents in the selected Asia-Pacific countries, i.e.,

$$\Delta \ln(CO_2) = \beta_0 + \beta_1 \ln(\mathrm{FOSSIL}) + \beta_2 \ln(\mathrm{GDPERG}) + \beta_3 \ln(\mathrm{HPRO}) + \beta_4 \ln(\mathrm{NRENTS}) + \mu_t \quad (1)$$

where CO_2 represents carbon dioxide emissions; FOSSIL represents fossil fuel energy consumption; GDPERG

represents GDP per unit use of energy; HPRO represents water productivity; NRENTS represents natural resource rents, and μ represents error term.

In cross-sectional analysis, the study used one-to-one relationship with each independent variable with the dependent variable, i.e., carbon dioxide emissions. Moreover, the study used the panel least square regression technique to pool the Asia-Pacific countries rather than individual countries and examine the relationship between the variables. This study takes an incentive to further incorporate the time invariant shocks of Asia-Pacific countries and employed panel fixed effect regression technique. In most of the previous studies, i.e., Khan et al. (2013) and Zaman et al. (2011) do not used simultaneous equation technique that might be the problem of endogeneity in their models. For the safest side, this study further employed panel two-stage least square regression technique to encounter the problem of simultaneity in the model.

Results

Table 1 reports the estimates of the carbon dioxide emissions with the air pollution, fossil fuel energy consumption, GDP per unit use of energy, and the natural resource rents and provides the summary and diagnostic statistics.

The results show that there is a significant and positive relationship between carbon emissions and fossil fuel energy consumption in China, Japan, Malaysia, Singapore, Philippines, and Brunei; however, the magnitude is different across countries. As there is around one-to-one corresponding relationship between carbon emissions and fossil fuel energy in Japan, while the rest of the countries have a less elastic relationship between the variables. According to Sundblad et al. (2014, p. 13),

> Mitigating the global climate change requires actions at different levels including that lay people change their consumption patterns, which cause emissions of greenhouse gases.

In addition, the GDP per unit use of energy has a significant and positive relationship with the carbon dioxide emission in Japan (i.e., 0.251 %), South Korea (i.e., 0.669 %), Indonesia (i.e., 1.028 %), Malaysia (i.e., 1.528 %), and Singapore (i.e., 0.258 %), respectively. While if there is 1 % increase in GDP per unit use of energy, carbon emissions decrease by 0.128 percentage point in New Zealand. The results indicate that Asia-Pacific countries move violently to pull off economic growth without a tandem witnessing an increase in carbon dioxide emissions. However, there is a still an open debate on the method of "low carbon and green growth" (Hwang and Yoo 2014).

Subsequently, the results related with water productivity and carbon emissions have varied in nature, as in the case of Japan, Australia, South Korea, Indonesia, Malaysia, Philippines, and Brunei which have a significant and positive relationship between the variables; however, there are three countries, i.e., South Korea, Malaysian, and Brunei, which have a more elastic relationship between the variables. Finally, except Singapore, all countries have a significant and positive association between the natural resource rents and carbon emissions, while Australia does not show significant correlation between the variables. Singapore has a negative relationship between the natural resource rents and carbon emissions.

Table 1 The impact of carbon dioxide emissions on the energy consumption and water resources

Coefficient estimates					Diagnostic statistics				
Country	ΔFOSSIL	ΔGDPERG	ΔHPRO	ΔNRENTS		FOSSIL	GDPERG	HPRO	NRENTS
China	0.568**	0.048	-0.008	0.225***	R^2	0.589	0.121	0.120	0.569
Japan	1.021*	0.251***	0.589**	1.728*	R^2	0.901	0.325	0.668	0.899
Australia	−0.012	0.189	0.639*	0.059	R^2	0.425	0.236	0.801	0.128
South Korea	0.102	0.669**	1.259*	0.669**	R^2	0.235	0.701	0.998	0.825
Indonesia	−0.004	1.028*	0.445**	0.728*	R^2	0.198	0.989	0.689	0.912
Malaysia	0.858*	1.528*	1.639*	1.289*	R^2	0.997	0.990	0.990	0.945
Singapore	0.715*	0.325**	−0.362**	−0.526**	R^2	0.980	0.512	0.458	0.774
Philippines	0.025***	0.201***	0.258**	1.029*	R^2	0.201	0.499	0.991	0.993
New Zealand	−0.089	−0.128***	−0.025	0.585**	R^2	0.228	0.501	0.218	0.825
Brunei	0.625**	0.085	1.895*	0.245***	R^2	0.819	0.213	0.993	0.659

Dependent variable: $\Delta\ln(CO_2)$. Robust standard errors are used to calculate the standard errors. All the variables are in the natural logarithm; therefore, the results are presented in the form of elasticities. The independent variables also with the Δ (difference) operator with natural logarithm due to the series of non-stationary at level, but at first difference, it would become stationary

*p=0.01; **p=0.05; ***p=0.10 (significant, respectively)

The results infer that the integrating carbon services into the execution of accessible environmental directives could offer increased security of coastal habitats (Sutton-Grier et al. 2014). Table 2 shows the panel least square test for the Asia-Pacific region.

The results of pooled least square show that fossil fuel energy consumption has a positive relationship with carbon dioxide emission in the panel of selected Asia-Pacific countries; if there is 1 % increase in the fossil fuel energy consumption, carbon dioxide emissions increase by 0.404 percentage points which indicate less elastic relationship between the variables. The results imply that reducing carbon price instability by changing carbon permits to taxes would speed up the espousal of carbon abatement technologies in the region. Similarly, GDP per unit use of energy and water productivity both have a significant and positive association with the carbon dioxide emission in the region; however, the magnitude of water productivity (i.e., 0.537 %) is somehow greater than the GDP per unit use of energy (i.e., 0.152 %). According to Moore and Hunt (2012, p. 865),

> Concerns over global climate change have spurred interest in accounting for carbon emissions from human activities. Most of this effort has focused on emissions from vehicles and energy use within buildings. However, relatively little is known about how the urban landscape, and particularly storm water management, contributes to the carbon footprint of urban areas.

Table 3 shows the results of panel fixed effect model. The results incorporated the country-related specific shocks through panel fixed effect regression method.

Table 2 Panel least square regression test

Variable	Coefficient	Std. error	t-Statistic	Prob.
C	−10.711	0.463	−23.126	0.000
Ln(FOSSIL)	0.404	0.022	17.955	0.000
Ln(GDPERG)	0.152	0.051	2.978	0.004
Ln(HPRO)	0.537	0.214	2.511	0.015
Ln(NRENTS)	−0.125	0.089	−1.405	0.166
R^2	0.929026	Mean dependent variable		−1.346858
Adjusted R^2	0.922574	S.D. dependent variable		0.586584
S.E. of regression	0.163220	Akaike info criterion		−0.690982
Sum squared residual	1.172196	Schwarz criterion		−0.497939
Log likelihood	21.92907	Hannan-Quinn criteria		−0.617742
F-statistic	143.9867	Durbin-Watson statistics		1.822960
Prob (F-statistic)	0.000000			

Method: pooled least squares. Sample: 1990–2012. Dependent variable: $\ln(CO_2)$. All variables have a natural logarithm form, so there results are in the elasticities

Table 3 Pooled fixed effect regression test

Variable	Coefficient	Std. error	t-Statistic	Prob.
C	5.153	3.353	1.536	0.137
Ln(FOSSIL)	0.467	0.147	3.180	0.004
Ln(GDPERG)	0.158	0.083	1.911	0.068
Ln(HPRO)	0.108	0.187	0.577	0.569
Ln(NRENTS)	1.072	0.307	3.487	0.001
Effects specification				
Cross-section fixed (dummy variables)				
Period fixed (dummy variables)				
R^2	0.992	Mean dependent variable		−1.346
Adjusted R^2	0.985	S.D. dependent variable		0.586
S.E. of regression	0.071	Akaike info criterion		−2.144
Sum squared residual	0.121	Schwarz criterion		−1.179
Log likelihood	77.531	Hannan-Quinn criteria		−1.778
F-statistic	135.328	Durbin-Watson statistics		1.804
Prob (F-statistic)	0.000			

Dependent variable: $\Delta\ln(CO_2)$. All variables have a natural logarithm form, so there results are in the elasticities

The results show that the fossil fuel energy consumption and the GDP per unit use of energy consumption has a significant and positive relationship with the carbon dioxide emission in the region; however, there is around one-to-one corresponding relationship between natural resource rents and carbon emissions in the Asia-Pacific countries. This results has been contrary to the panel least square method, where natural resource has no relationship with the carbon emissions; however, after incorporating the country-specific shocks, these results have shown unitary elastic relationship. The results related with the water productivity and carbon emissions have been evaporated from the model and indicate the insignificant relationship between them. The value of adjusted R^2 shows the goodness of fit of the model, while F-statistics show that the model is stable at 1 % significant level. The value of Durbin-Watson indicates that there is no an autocorrelation problem in the model; however, for the sake of endogeneity tests, the study further confirms the relationship between the variables by using two-stage least square regression method (see Table 4).

The results of panel two-stage least square regression incorporate the problem of endogeneity in the model. The results are consistent with the results of the pooled least square regression model, where natural resource rents have an insignificant relationship with the carbon dioxide emission, while all other variables, i.e., fossil fuel energy consumption, GDP per unit use of energy, and water productivity have a significant and positive relationship with carbon emission in the region. However, in this analysis, water productivity has a higher magnitude as compared to the fossil fuel energy consumption and GDP per unit use of energy, which indicates the

Table 4 Pooled two-stage least square regression results

Variable	Coefficient	Std. error	t-Statistic	Prob.
C	−10.755	0.567	−18.951	0.000
Ln(FOSSIL)	0.416	0.029	14.172	0.000
Ln(GDPERG)	0.200	0.071	2.821	0.008
Ln(HPRO)	0.618	0.321	1.920	0.065
Ln(NRENTS)	−0.198	0.139	−1.424	0.165
R^2	0.940	Mean dependent variable		−1.289
Adjusted R^2	0.931	S.D. dependent variable		0.600
S.E. of regression	0.156	Sum squared residual		0.665
F-statistic	112.675	Durbin-Watson statistics		1.361
Prob (F-statistic)	0.000	Second-stage SSR		0.631
Instrument rank	5.000			

Dependent variable: $\ln(CO_2)$. All variables have a natural logarithm form, so there results are in the elasticities. Instrumental variables are the lag values of the independent variables

strong relationship with air pollution and water reservoirs in the Asia-Pacific countries.

Conclusion

This study focused on the triangulation between energy consumption, water productivity, and air pollution in the panel of selected Asia-Pacific countries, over a period of 1975–2012. The study used cross-sectional time series technique and panel least square regression (i.e., panel fixed effect and panel two-stage least square regression) for 10 selected Asia-Pacific countries, i.e., China, Japan, Australia, South Korea, Indonesia, Malaysia, Singapore, Philippines, New Zealand, and Brunei. The following conclusions were drawn from this exercise:

- Fossil fuel energy consumption has a significant and positive relationship with carbon dioxide emission in China, Japan, Malaysia, Singapore, Philippines, and Brunie.
- There is one-to-one corresponding relationship between the fossil fuel energy consumption and carbon dioxide emission in Japan.
- GDP per unit use of energy has a significant and positive relationship with carbon emissions in Japan, South Korea, Indonesia, Malaysia, Singapore, and Philippines.
- There is one-to-one corresponding relationship between GDP per unit use of energy and carbon emissions in Indonesia, while there is a more elastic relationship in the case of Malaysia.
- Water productivity and natural resource rents have a significant and positive relationship with carbon emissions in the Asia-Pacific countries.
- The results of panel least square regression indicate that there is a significant and positive impact of fossil fuel energy consumption, GDP per unit use of energy, and water productivity on carbon dioxide emissions in the region.
- The results of panel fixed effect regression indicate that there is a positive impact of fossil fuel energy consumption, GDP per unit use of energy, and natural resource rents on carbon dioxide emissions in the region. However, the magnitude of fossil fuel energy consumption has a higher magnitude on the change in carbon emissions as compared to the water resources and natural resource rents.
- For the possible problem of endogeneity in the model, the study used panel two-stage least square regression model.
- The results of panel two-stage least square regression indicate that fossil fuel energy consumption, GDP per unit use of energy, and natural resource rents have a positive impact on carbon dioxide emissions.

These results infer that fossil fuel energy consumption has a dominating role to change carbon dioxide emissions in the Asia-Pacific region. The results confirm the strong relationship between air pollution, water productivity, and natural resource rents in the region.

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