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Nexus Between the Energy Market, Industrialization, and Economic Growth in the Asia-Pacific Region

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This study investigates the nexus between the energy market and its determinants in eight countries from the Asia-Pacific region over 1994–2018. The results show energy demand, prices, economic growth and industrialization positively affect the energy supply. On the other hand, energy supply and growth and industrialization positively affect energy demand, and energy prices negatively affects energy demand. The study also suggests policy implications.

I. INTRODUCTION

The Asia-Pacific region encompasses a broad set of countries with diverse levels of economic growth and energy markets (Doi et al., 2010). There are 48 countries in the region, collectively covering 25% of the world's total land area. As far as the region's energy market is concerned, it is projected that the demand of energy will be 149 quadrillion British thermal units in 2040 (International Energy Agency, or IEA, 2020). According to Doi et al. (2010), the energy demand in the Asia-Pacific is anticipated to increase at an annual rate of 2.4% between 2005 and 2030, a faster rate than the global average growth rate of 1.5%. The growth in energy prices will continue to have the largest impact on future energy demand and supply trends (International Energy Agency, 2011). Population growth is a significant driver of imminent energy trends, with the world's population expected to increase by 26%, from 6.8 billion in 2009 to 8.6 billion in 2035 (International Energy Agency, 2011). The Asia-Pacific region's total population is 4.142 billion, accounting for almost 60% of the global population (IEA, 2021).

Some studies (Samuel et al., 2013; Zaharia et al., 2019) confirm that the determinants of the energy market are mixed, but the gross domestic product, energy prices, and industrialization are identified as influencing indicators in the region. However, the numerous studies documenting the pattern of the energy market (De Vita et al., 2006; Narayan, 2020; Prabheesh et al., 2020) are inconclusive. According to the Intergovernmental Panel on Climate Change, from 1880 to 2012, the average global temperature increased by 0.85°C. By the end of this century, this increase is expected to exceed 1.5°C, compared to 1850 to 1900. The primary cause behind this rise in temperature is CO₂ emissions, and the main causes behind increasing carbon emissions are the energy market, economic growth, and industrialization. However, the United Nations estab-

lished Sustainable Development Goals in 2015 to reduce the global temperature by 2°C by the end of this century.

This study contributes to the literature by examining the degree of association between the energy market and its determinants over 1994–2018 in the eight Asia-Pacific countries, namely, Australia, China, India, Indonesia, Japan, Malaysia, Thailand, and New Zealand. Although these countries signed the Kyoto and Paris Agreements and accepted the Sustainable Development Goals, they still source their energy from nonrenewable sources. Therefore, an examination of the nexus between the energy market and its determinants is warranted.

The remainder of the study is organized as follows. Section II discusses the data sources and methodology. Section III discusses the empirical findings, and Section IV concludes the study with policy implications.

II. DATA AND ECONOMETRIC TECHNIQUES

The annual data from 1994 to 2018 for the variables for energy supply (*lnES*), energy demand (*lnED*), energy price (*lnEP*), economic growth (*lnEG*), and industrialization (*lnINDS*) are gathered from the Global Energy Statistical Yearbook 2020, and data for economic growth and industrialization are sourced from the 2020 World Development Indicators. For energy supply and demand, we use the oil supply and oil demand as proxies, respectively. The gross domestic product per capita (in constant 2010 US dollars) represents economic growth, crude oil spot prices represent the energy price, and value-added industry (in constant 2010 US dollars) is the proxy for industrialization.

This study argues that these variables are the fundamental determinants of the energy market, following Samuel et al. (2013) and Zaharia et al. (2019). First, the energy supply and demand functions are defined as follows:

$$ES = f(ED, EP, EG, INDS) \quad (1)$$

$$ED = f(ES, EP, EG, INDS) \quad (2)$$

Table 1. Cross-Section dependence (LM) test results

	<i>lnES</i>	<i>lnED</i>	<i>lnEP</i>	<i>lnEG</i>	<i>lnINDS</i>
Breusch-Pagan LM	335.4***	614.8***	700.0***	641.3***	541.1***
P-values	0.00	0.00	0.00	0.00	0.00

This table shows the cross-section dependence (LM) test results. *** indicates that the null hypothesis rejection is significant at the 1% level.

Table 2. S-G unit root test results

Variables	CIPS		CADF	
	Level	First Difference	Level	First Difference
<i>lnES</i>	-2.53***	...	-2.48**	...
<i>lnED</i>	-2.34**	...	-2.41**	...
<i>lnEP</i>	2.61***	...	-2.57***	...
<i>lnEG</i>	-1.24	-3.28***	-1.43	-2.57***
<i>lnINDS</i>	-1.88	-3.91***	-1.88	-2.27**

This table shows S-G unit root test results. Pesaran's CIPS and CADF panel unit root tests are used in the presence of cross-section dependence. The symbols ***&** signify the 1% and 5% significance levels, respectively.

Further, we transform these equations into logarithmic form as follows, respectively:

$$\ln ES = \alpha_t + \beta_1 \ln ED_t + \beta_2 \ln EP_t + \beta_3 \ln EG_t + \beta_4 \ln INDSt + \varepsilon_t \quad (3)$$

$$\ln ED = \alpha_t + \beta_1 \ln ES_t + \beta_2 \ln EP_t + \beta_3 \ln EG_t + \beta_4 \ln INDSt + \varepsilon_t \quad (4)$$

where *lnES* is the natural logarithm of energy supply; *lnED*, *lnEP*, *lnEG*, and *lnINDS* represent the energy demand, energy price, economic growth, and industrialization, and ε_t is the error term. The cross-correlation (Lagrange multiplier) test formulated by Breusch and Pagan (1980) is applied to check cross-sectional dependence. The cross-section Im–Pesaran–Shin and cross-section augmented Dickey–Fuller second-generation unit root tests, put forth by Pesaran (2007), are applied. Moreover, Westerlund's (2007) panel cointegration technique is more appropriate than other techniques to tackle cross-sectional dependency. Finally, the panel autoregressive distributed lag (ARDL) model of Pesaran et al. (2001) is used to analyze the degree of association between the variables.

The ARDL model is used because the variables are integrated with a mixture of I(0) and I(1), and none of the variables is I(2). The robustness of the panel ARDL model is also checked through the panel-corrected standard error method (i.e., the panel-specific autocorrelation of the AR(1) process). Further, this study analyzes the causal relations between the variables through the Dumitrescu–Hurlin (2012) Granger non-causality approach.

III. EMPIRICAL FINDINGS AND DISCUSSION

The result of the CD test confirms cross-sectional dependence in the series, as shown in [Table 1](#).

The second-generation unit root test results show a mixture of I(0) and I(1), as shown in [Table 2](#), which require the use of the panel ARDL model.

The Westerlund cointegration technique confirms the long-run association between the series, as shown in [Table 3](#).

Consequently, we apply the panel ARDL model, and the results are depicted in [Table 4](#). The results of Model I show that energy demand and energy price in the long run positively affect the energy supply, with coefficient values of 0.90 and 0.02, respectively, significant at the 1% level. This implies that a 1% increase in energy demand increases the energy supply by 90%, and a 1% increase in energy price increases the energy supply by 2%. Similarly, economic growth and industrialization positively affect the energy supply, with coefficient values of 0.64 and 0.59, respectively, significant at the 1% level. This implies that a 1% increase in economic growth increases the energy supply by 64%. A one unit increase in industrialization increases the energy supply by 59%. In the short run, the energy demand negatively affects the energy supply; however, the energy price and industrialization positively affect the energy supply. Hence, we reject the null hypothesis of there being no positive association between the energy supply and the energy demand, price, growth, and industrialization. The error correction term value of -0.31, significant at the 5% level, denotes the speed with which the energy supply and explanatory variables adjust in the long-run equilibrium.

The results of Model II show that, in the long run, energy supply, economic growth, and industrialization positively affect the energy demand, with elasticities 1.15, 0.98 and 0.92, respectively. This implies that a change of 1% in energy supply, economic growth, and industrialization affects the energy demand by 1.15%, 0.98%, and 0.92%, respectively. These results align with previous studies (De Vita et al., 2006; Khan & Ahmad, 2008; Kumar, 2011; Kumarasinghe & Gunathilake, 2009). On the other hand, the energy price negatively affects energy demand. The elasticity is -0.06, which implies that a change of 1% in energy price decreases the energy demand by 6% in the long run. This

Table 3. Westerlund panel cointegration test results

Westerlund test			
Model-I $\ln ES = \ln ED + \ln EP + \Delta \ln EG + \Delta \ln INDS$			
Test	Value	Z-Value	p-Value
G-t	-2.60	-1.72	0.04
G-a	-8.31	-0.62	0.73
P-t	-8.23	-2.89	0.00
P-a	-6.21	-0.04	0.48
Model-II $\ln ED = \ln ES + \ln EP + \Delta \ln EG + \Delta \ln INDS$			
Test	Value	Z-Value	p-Value
G-t	-2.78	-2.11	0.09
G-a	-1.19	3.45	1.00
P-t	-2.29	1.80	0.16
P-a	-0.91	2.01	0.97

This table shows the Westerlund panel cointegration test results.

Table 4. Panel ARDL and PCSE results

Model-I: $\ln ES = f(\ln ED, \ln EP, \ln EG, \ln INDS)$				Model-II: $\ln ED = f(\ln ES, \ln EP, \ln EG, \ln INDS)$			
$\ln ES$	Coefficient	t-stat	Prob.*	$\ln ED$	Coefficient	t-stat.	Prob.*
Long Run Equation				Long Run Equation			
$\ln ED$	0.90***	19.10	0.00	$\ln ES$	1.15***	12.38	0.00
$\ln EP$	0.02***	2.79	0.00	$\ln EP$	-0.06***	-3.11	0.00
$\ln EG$	0.64***	4.59	0.00	$\ln EG$	0.98***	2.88	0.00
$\ln INDS$	0.59***	4.80	0.00	$\ln INDS$	0.92***	3.01	0.00
Short Run Equation				Short Run Equation			
ECM (-1)	-0.31**	-2.27	0.02	ECM (-1)	-0.15**	-2.26	0.02
$\Delta \ln ED$	-0.30*	-1.82	0.07	$\Delta \ln ES$	0.19*	1.66	0.09
$\Delta \ln EP$	0.04**	2.60	0.01	$\Delta \ln EP$	0.01	0.93	0.35
$\Delta \ln EG$	0.37	0.85	0.39	$\Delta \ln EG$	0.16	0.48	0.63
$\Delta \ln INDS$	0.47**	2.11	0.03	$\Delta \ln INDS$	0.25	1.32	0.18
Constant	-3.08**	-2.41	0.01	Constant	2.28**	2.27	0.02
Panel Corrected Standard Error							
$\ln ES$	Coefficients	Z-test	P-values	$\ln ED$	Coefficients	Z-test	P-values
$\ln ED$	0.76***	8.40	0.00	$\ln ES$	0.43***	9.59	0.00
$\ln EP$	0.01**	2.97	0.01	$\ln EP$	-0.07**	-2.65	0.02
$\ln EG$	0.10***	4.04	0.00	$\ln EG$	0.12***	7.50	0.00
$\ln INDS$	0.20**	2.54	0.01	$\ln INDS$	0.49***	13.25	0.00
Cons.	-3.46**	-2.17	0.03	Cons.	-9.83***	-13.71	0.00
R-Squared	0.98	Wald Statistics	14731.10***	R-Squared	0.98	Wald Statistics	8257.41***

This table shows the panel ARDL and PCSE results. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

finding is similar to the results of Khalid and Khalid (2010) and consistent with the theory that an increase in prices will negatively affect the demand. However, only the energy supply affects the energy demand in the short run; the other variables affect the energy demand non-significantly. The error correction term, indicating the speed of adjustment, has a value of -0.15, significant at the 5% level. Additionally, the robustness of the panel ARDL method

is checked through the panel-corrected standard error method. The results are reported in the second panel of [Table 4](#), supporting the results of the panel ARDL models.

Furthermore, the results of the Granger non-causality approach are depicted in [Table 5](#), which shows the bidirectional relations between energy supply and energy demand, economic growth and energy supply, industrialization and energy supply, and energy demand and industrialization.

Table 5. Results of causality approach

Variables	<i>lnES</i>	<i>lnED</i>	<i>lnEP</i>	<i>lnEG</i>	<i>lnINDS</i>
<i>lnES</i>	---	4.30***	2.21	7.16***	5.68***
<i>lnED</i>	5.78***	---	2.18	2.99	3.82*
<i>lnEP</i>	2.99	2.56	---	1.23	1.43
<i>lnEG</i>	5.47***	8.17***	3.50	---	3.70
<i>lnINDS</i>	5.22***	6.01***	3.20	3.19	---

This table shows the causality results. *** and * denotes significance at the 1% and 10% levels, respectively.

However, unidirectional causality from economic growth to energy demand is revealed. Hence, these causalities support our choice of variables for this study.

IV. CONCLUDING REMARKS AND POLICY SUGGESTIONS

The findings of the study indicate a positive connection between the energy supply and the energy demand, price, growth, and industrialization. On the other hand, energy supply, growth, and industrialization positively affect the energy demand, and energy price negatively affects the energy demand. Based on these findings, we recommend that the growing energy demand should meet requirements to ensure minimum damage to the environment. According to a report of the Asian Development Bank (2013), coal is the main source of energy in Asia-Pacific countries, where the share of coal in the primary energy supply rose from 40.5% in 1994 to 48.7% in 2009 and, in the same period, the percentage of oil decreased from 33.9% to 26%. Coal is made up of carbon and emits CO₂ when it burns, which degrades the environmental quality. A transformed economy (from a living economy and animal power and human cap-

ital to non-living economy with machinery) requires more energy to survive (Mujtaba et al., 2021; Mujtaba & Jena, 2021). Therefore, it is suggested that policymakers frame policies that help diversify energy sources from nonrenewable to renewable sources. The rise in energy prices negatively affects the energy demand; therefore, increases in energy prices can also be used to overcome the demand for nonrenewable energy.

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Declaration of Interest

The authors declare that they have no conflict of interest.



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