MOVING TOWARDS GREEN ENVIRONMENT: THE ROLE OF RENEWABLE TRANSITION

Lim, Shiau Mooi

Faculty of Business & Finance, Universiti Tunku Abdul Rahman, Jalan Universiti, Kampar, Perak,

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ABSTRACT

Finding a viable solution to slow down the emissions thus becomes the top agenda in world development. In this respect, technological switching toward renewable energy seems to hold the promise to break the link between energy consumption and greenhouse gas emission that entails the global warming problem. Does renewable transition able to bring a cleaner environment? This study constructs a coherent framework of convergence using a dynamic panel model covering 102 countries in 1975-2015. The results of the study reveal a convergence of emission and this finding may contribute to policymakers on environmental protection for the global reduction of emissions.

Keywords: *Renewable energy, convergence, dynamic panel, GMM*

INTRODUCTION

The environment is not free, and the cost is incurred by using non-renewable resources such as natural gas and fossil fuel. Sustainability development for a nation is fundamentally a challenge of the country's tradeoff. However, the heavy dependence on electricity generation and industrial activities on fossil fuels is not without consequences. The production based on the use of fossil fuels has several environmental impacts on land, air and water (see, for instance, Kashif et al. [1] in China; Atsu et al. [2] in South Africa; Caglar et al. [3] in Brazil, Russian Federation, India, and China; Hossain [4] in newly industrialized countries; Munir et al. [5] in ASEAN-5 economies).

Today, there are 416.45 Parts Per Million (PPM) of carbon dioxide (CO_2) released into the atmosphere [6]. Even though there is a downward trend in greenhouse gas (GHG) after the efforts made in Paris climate summit in 2015, but the global carbon dioxide (CO_2) emissions are predicted to increase to 1500 PPM if fossil-fuel burning continues at a business-as-usual rate. The global surface temperature has risen about 2.0 degrees Celsius (35.6 degrees Fahrenheit) since the 20th century and is expected to rise to 3.5 degrees Celsius (38.3 degrees Fahrenheit) above pre-industrial levels by the end of this century. For comparison, an increase of one degree Celsius brings measurable effects on the planet, from Artic melting to sea-level rise.

Solving the global warming problem is regarded as the most important challenge facing humankind in the 21st century. To ameliorate this risk, countries are undertaking the policy of switching from non-renewable resources to renewable resources or renewable transition for sustainable energy security in future [7]. Renewable energy is the prospects and challenges for conversion technologies development in the future due to renewable resources helping to improve the environment and secure the future of the planet [8]. It is believed that renewable energy is cleaner as it does not emit as much GHG as fossil fuels. Having that said, no concrete empirical evidence on the effectiveness of renewable energy in reducing greenhouse gas emissions.

The findings are handful and often contradictory. On the one hand, Murshed et al. [9], for instance, found that renewable energy consumption significantly reduces carbon emissions and carbon footprint in the G7 countries. Several studies also concluded that renewable energy consumption does help in reducing carbon emissions, for instance, Saidi and Omri [10] for the case of OECD countries, Dong et al. [11] for the case of China, and Danis et al. [12] for the case of BRICS countries. On the other hand, Khezri et al. [13] came across disappointingly limited pollution-reducing impact of renewable energy in a sample of 29 Asia-Pacific countries.

The question is, does renewable transition able to bring a cleaner environment? Thus, the objective is to investigate the effect of the transition from non-renewable energy to renewable energy on greenhouse gases (GHG) emission. It is an issue that connects environmental problems, sustainable economic growth, and human well-being. Positive economic impacts for local communities can go hand-in-hand with environmental benefits by providing reliable energy sources for improving health and livelihoods. Hence, this study hypothesis that renewable transition from non-renewable energy to renewable energy can reduce greenhouse gas (GHG) emission that benefits the environment.

The findings are interesting for at least two reasons. From the viewpoint of emission reduction, when convergence, which implies a single stable steady state is found, small-scale policy interventions are likely to be sufficient to help accelerate the countries' transition. Putting in the context of the existing literature that finds CO_2 emissions converging within groups, this finding of emission convergence provides a sense of relief, as de-carbonization effort

*Corresponding author.
E-mail address : limsm@utar.edu.my

can be hastened when countries with high fossil fuel consumption are moving toward the consumption of renewable energy.

LITERATURE

The concept of convergence was origin from income convergence [14]. Later, there has been a growing number of environmental convergence related studies that were inspired by the conventional economic convergence studies (for example, see Solow [14], Barro & Sala-i Martin [15]), such as environmental pollution (Camarero et al. [16], Brännlund et al. [17], Solarin & Tiwari [18], Paynes & Apergis [19], Erdogan & Okumus [20], Song et al. [21]).

Why do countries converge in terms of environmental values? The answer to this question is the environmental catch-up hypothesis by Brock and Taylor [22]. This hypothesis refers to the convergence of environmental quality between the rich (developed) and the poor (developing) countries at a certain point in time, which can explain through the Environmental Kuznets Curve (EKC) (for instance, see Yang et al. [23], Dogan & Seker [11], Kais & Sami [24], Ajmi et al. [25], Pata & Caglar [26], Ho & Ho [27], Ike et al. [28]). EKC has shown the behavior and relationship between environmental degradation and income per capita as an economy develops from a primarily rural agricultural society to an industrialized urban economy [29],[30]. Kuznets [29] hypothesized that as an economy hits a peak in per capita income, market forces increase and then decrease the overall environmental quality of the society.

According to EKC, rises in per capita income will get emissions per capita closer to each other. This EKC hypothesis exactly implies the convergence concept. Although economic growth will tend to increase environmental degradation, in the long run those rich countries sure will tend to clean up their environment [30]. Likewise, if the convergence of per capita carbon emissions were found in developed countries, it would tend to encourage those developing countries to accept a cap on their created emissions [31]. Fast-growing countries typically increase the per capita carbon emissions as compared to slow-growing countries that tend to decrease the per capita carbon emissions (Stern et al. [32], Erdogan & Acaravci [20], Payne [33], Lee et al. [34], Khan et al. [35]). Thus, countries are bearing the consequences ranging from greenhouse gas emissions to deforestation.

Can renewable transition bring about emission reduction? According to Marrero [36], to achieve a 20% reduction in emissions, a reduction of 20% in energy consumption would not be sufficient enough. Renewable energy is the best alternative for reducing pollution and increasing the countries' energy security by reducing their dependency on fossil fuels [37]. For instance, Gulden and Mehmet [38] and Lopez-Menendez et al. [39], which focused on the European Union, uncovered the pollution-reducing effect of a shift in energy consumption mix towards renewable energy technologies. However, the findings are contradictory.

On the one hand, increases in renewable resources decrease the level of emissions. According to Ike et al. [40], renewable energy consumption and energy prices has a negative impact on CO_2 emissions in G-7 countries. Among other studies that focused on the panel of G-7 countries included Cetia et al. [41], Xu et al. [42], and Cai et al. [43]. Their findings also support the effect of renewable energy consumption on CO_2 emissions. In contrast, Wang [44] highlighted that renewable energy consumption simultaneously reduced the carbon emissions and sustained the economic growth of Henan Province. Similar findings by Saidi and Omri [10] in 15 major renewable energy-consuming countries and Huang et al. [45] in 48 major energy-consuming countries. In addition, Boluk amd Mert [46] discovered that renewable energy managed to improve the environmental problems but also towards the sustainability of Turkey's electricity production.

On the other hand, some studies came across a disappointedly limited pollution-reducing impact of renewable energy. An increase in renewable energy consumption increase the emissions (For instance, Van der Ploeg & Withagen [47], Grafton et al. [48], Van der Ploeg & Withagen [49], Li & Haneklais [50]). Those studies found that implementing carbon tax to phase out fossil fuels for the adoption of renewable energy intends to fasten the extraction of fossil fuels by the fossil fuels owners. Because fossil fuels are non-renewable resources, their prices reflect the cost of production and their scarcity. Thus, owners of fossil fuels enjoy scarcity rents and maximize their profits by deciding when to extract their non-renewable resources. The over-extraction of fossil fuels will increase the current emissions level. If a future tightening of climate policy threatens to decrease future scarcity rents, the fossil fuel owners will decide to extract less in the future and extract more today instead to maximize profits. Additionally, Karaaslan and Çamkaya [51] emphasized that a 1% increase in renewable energy consumption results in a 0.126% increase in CO_2 in the short term for the case of Turkey, while Li and Haneklais [50] reveal that an increase of 1% in renewable energy consumption increase the CO_2 emissions by 0.288% in the long term for the case of China.

There has been a growing concern by both developed and developing countries on the environmental impact of carbon emissions and ecological footprint with respect to climate change and the humanity use of the ecosystem. Convergence implies that countries are not following the paths in pollution controls as there are moving towards a common environmental performance [50],[52],[53],[54]. In a nutshell, the aforementioned studies seem to find evidence of convergence for developed or industrialized countries, yet divergence or mixed evidence at the global level. The ignorance of the carbon emission and ecological footprint on the environment will potentially result in unintended and undesirable impacts on our future. Hence, actions should be taken by policymakers on environmental quality.

METHODOLOGY

Data and Sample

This study lays out an empirical model that sheds the light on the convergence of emissions across a sample of 102 countries in the world. Subject to data availability, the panel data was in an unbalanced structure, covering the time span from the year 1975 to 2015. With sufficient length of time dimension data covering the major event, namely the Paris agreement in the year 2015 that raise concern on the climate change, it enables us to uncover the changing trend of the transition from conventional energy to renewable energy. The list of economies is reported in Table 2. Meanwhile, Table 2 explains the variables used in gauging the carbon emission convergence, such as renewable energy, non-renewable energy, Gross Domestic Product (GDP), population and

Table 1 Country list: 1975 to 2015

Algeria	Albania	Angola	Benin
Argentina	Austria	Bangladesh	Egypt, Arab Rep.
Australia	Belgium	Bolivia	Ethiopia
Brazil	Bulgaria	Cameroon	Haiti
Brunei	Chile	Congo, Rep.	Jordan
Canada	China	Cote d'Ivoire	Korea, Dem. People's Rep.
Colombia	Cyprus	El Salvador	Morocco
Costa Rica	Czech Republic	Ghana	Mozambique
Cuba	Denmark	Guatemala	Nepal
Dominican Republic	Finland	Honduras	Senegal
Ecuador	France	India	Syrian Arab Republic
Gabon	Germany	Indonesia	Tanzania
Hong Kong	Greece	Kenya	Togo
Iran, Islamic Rep.	Hungary	Myanmar	Tunisia
Iraq	Iceland	Nicaragua	Yemen, Rep.
Jamaica	Ireland	Nigeria	Zimbabwe
Japan	Israel	Pakistan	
Korea, Rep	Italy	Philippines	
Lebanon	Kuwait	Sri Lanka	
Libya	Luxembourg	Sudan	
Mexico	Malaysia	Zambia	
New Zealand	Malta		
Panama	Netherlands		
Paraguay	Norway		
Peru	Poland		
Singapore	Portugal		
United State	Saudi Arab		
Venezuela, RB	Slovak Republic		
	Spain		
	Sweden		
	Switzerland		
	Thailand		
	Trinidad & Tobago		
	Turkey		
	United Kingdom		
	Uruguay		

Table 2 Data Description and Source

Variable	Description and Sources
Carbon dioxide (CO_2)	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring. It is measured as metric tons per capita. *Source*: World Bank
Renewable Energy Consumption	Renewable energy consumption which is measured as the share of renewable energy per capita in total final energy consumption. *Source*: World Bank
Non-renewable energy (Fossil Fuel Energy Consumption	Fossil fuel comprises coal, oil, petroleum, and natural gas products. It is measured as the share of fossil fuel energy consumption in percentage of total. *Source*: World Bank
GDP Per Capita	GDP per capita is gross domestic product divided by midyear population. It is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. Data are in current 2017 U.S. dollars. *Source*: World Bank
population	Population which is measured the total population ages of 15- 64. *Source*: World Bank
Trade openness	Trade openness is the ratio of exports plus imports as the share of GDP. *Source*: World Bank

trade openness. Data for this study is obtained from World Bank Database.

Model Estimation

In this study, firstly, we estimated the convergence of carbon emission. The concept of convergence seeks to regress the growing proportion of carbon emission on its initial level. A negative, which is significantly different from zero, means β-convergence is confirmed. The β-convergence suggests that countries with small initial levels of carbon emission released have higher growth levels than countries with high carbon emission levels initially. All countries converge to the same inverse adoption level as the other important country differences are controlled for in assessing the per capita growth rates between the countries.

There are two types of β-convergence, unconditional (absolute) β-convergence and conditional β-convergence. The unconditional β-convergence relates to converging to a common stable state, and the model is stated as:

$$\text{In}\left(\frac{GHG_{it}}{GHG_{it-\tau}}\right) = \alpha + \beta \text{In} GHG_{it-\tau} + \mu_c + \xi_t + \varepsilon_{it} \quad (1)$$

where GHG_{it} denotes as the carbon emission released of country $i(i = 1, 2, \ldots, 102)$ at time $t(t = 1975, 1980, \ldots, 2015)$, $\text{In}GHG_{it-\tau}$ denotes as the natural logarithm of lagged carbon emission in, τ is the length of the interval (5-year average), in which to reduce the business cycles as well as the possibility of autocorrelation problems, β denotes as the coefficient of convergence, μ_c denotes as the variable that captures the unobserved country effects, ξ_t measures time-specific effects, and ε_{it} denotes as the error term.

If the hypothesis of $\beta < 0$ is holds in Equation 1, it is referred to as unconditional (absolute) conditional β-convergence. It means that the countries with relatively low levels grow faster in terms of carbon emission, hence, tend to catch up with those countries that started at a higher initial level of carbon emission.

Rearranging the terms in Equation 1, this study obtains:

$$GHG_{it} = \alpha + \beta \text{In} GHG_{it-\tau} + \mu_c + \xi_t + \varepsilon_{it} \quad (2)$$

where GHG_{it} denotes as $\text{In}\left(\frac{GHG_{it}}{GHG_{it-\tau}}\right)$

However, if the Equation 1 does not hold true; apart from $\beta < 0$, it is referred to conditional β-convergence, which means that the growth paths differ and do not converge to the same carbon emission level. The conditional β-convergence occurs when the developing countries with a lower initial carbon emission level tend to grow faster than the ones from developed countries when other important countries' differences are controlled.

The conditional β-convergence allows various subgroups of countries to converge to specific levels that are based on country-specific conditions. The model is stated as:

$$\text{In}\left(\frac{GHG_{it}}{GHG_{it-\tau}}\right) = \alpha + \beta \text{In} GHG_{it-\tau} + \gamma X_{it} + \mu_c + \xi_t + \varepsilon_{it} \quad (3)$$

where X_{it} denotes as the conditional variables, γ denotes as the coefficient of control variables, the μ_c denotes as the variable that captures the unobserved country effects, and ξ_t measures time-specific effects. Therefore, this study controls the Gross Domestic Product (GDP) per capita, trade openness and population for the conditional convergence estimation. This study assumes that the rate of convergence depends on these factors.

According to Vallés-Giménez and Zárate-Marco [55], the environmental issues should be considered from a dynamic perspective; for instance, the carbon emission in one year depends on the previous year's emission. In addition, the dynamic panel data model reflects the dynamic lag effects in response to the lag dependent variables. The emission is a dynamic process as it considers the time lag effect, which the early development status of the carbon emission can affect the future development.

To estimate absolute convergence in the emissions across 102 countries, this study adopted the System Generalized Method of Moments (GMM) estimator proposed by Arellano and Bover [56] and Blundell and Bond [57] to overcome the problems of dynamic panel bias and potential endogeneity of regressors. The system GMM estimator addresses endogeneity by simultaneously solving level and difference equations with the utilization of instruments in first differences for the level equation and the use of instruments in levels for the first difference equations. Lags of endogenous variables are used as instruments. The instruments utilized in the first differenced estimator comprise information about the endogenous variables in the first differences and the lagged first differences are informative instruments for the endogenous variables in levels. This will result in capturing the variations between countries' characteristics and controlling for individual heterogeneity.

Equation 4 is a dynamic panel model with a lagged dependent variable, therefore, the least-squares fixed-effect dummy variable and within-group estimators are not consistent [62]. Hence, to study the convergence of carbon emission, the dynamic panel model was extended and expressed as:

$$\Delta GHG_{it} = \alpha + \beta \Delta GHG_{it-\tau} + \Delta\xi_t + \Delta\varepsilon_{it} \quad (4)$$

where $\Delta GHG_{it} = GHG_{it} - GHG$, $\Delta\xi_t = \xi_t - \xi_{t-\tau}$, and $\Delta\varepsilon_{it} = \varepsilon_{it} - \varepsilon_{it-\tau}$. In Equation 5, the OLS estimate of is biased since the lagged dependent variable ($\Delta GHG_{i,t}$) is correlated with the differenced error term .

Besides that, to observe the conditional convergence process of the emission, the model is expressed as:

$$\Delta GHG_{it} = \alpha \Delta GHG_{it-\tau} + \varphi \Delta X_{it} + \Delta\xi_t + \Delta\varepsilon_{it} \quad (5)$$

where $\Delta GHG_{it} = GHG_{it} - GHG$, $\Delta\xi_t = \xi_t - \xi_{t-1}$, and $\Delta\varepsilon_{it} = \varepsilon_{it} - \varepsilon_{it-1}$.

To fill the gap of the renewable transition on carbon emission, this study intends to examine the impact of the renewable transition on the convergence of carbon emission. The model can be expressed as:

$$\Delta GHG_{it} = \alpha_0 + \beta_1 GHG_{it-5} + \beta_2 RE_{it} + \beta_2 NRE_{it} + \Sigma\eta_i X_{it} + \beta_4\theta_t + \Delta\varepsilon_{it} \quad (6)$$

In this Equation 6, *RE* is the renewable energy consumption, *NRE* is the fossil fuel consumption; *X* is the control variables for per capita GDP, population, and trade openness; is time-specific effect; θ_t is the random error term; i stands for regions; t means time.

This study expects that the sign of the *RE* coefficient should be negative ($\beta_2 < 0$) while *NRE* coefficient should be positive ($\beta_3 > 0$). Note that if the is $\beta_1 < 0$, this implies that the convergence of carbon emission across the countries persists over time. Hence, this indicates that the less usage of renewable energy, the more the carbon emissions are released that might cause damage to the environment. The first control factor is the logarithm of real GDP per capita (LGDPC), which is included as a measure of economic development. The second factor is trade openness, which refers to the level of trade openness in each country, while the third factor is population which refers to the population in each country.

Result Analysis

In this study, the focus is on the conditional -convergence hypothesis, which in principle, is the analog to the conditional -convergence in income in the economic growth literature [63],[17]. If the result is a statistically significant negative value on the , it indicates the existence of convergence, while a significant positive value indicates divergence. The parametric estimates for the carbon emission model are reported in Table 3.

Table 3 shows the estimation results for the convergence of emissions across 102 countries. From the estimated lghg, we can infer the "implied β" since $\beta = (\alpha - 1))/\tau$. To be coherent with the β-convergence hypothesis, convergence requires $\beta < 0$, which is possible given the fact that the estimated lghg is less than one. System GMM estimators of the implied β for all models (Model 1-Model 8) are less than 0 and statistically significant at a 1% level. Hence, the result is favourable to carbon emission convergence across the sampled countries. This result implies that those countries with a low emissions levels tend to have a high rate relative to those

Table 3 System GMM estimates from a panel of 5-years span data

Variables/ statistic	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	-0.1629*** (0.0468)	-0.3802*** (0.1390)	-0.3323*** (0.0900)	-0.1579** (0.0654)	-0.4392*** (0.1072)	-0.3605*** (0.0582)	-0.3074** (0.1373)	-0.3274*** (0.0850)
Implied	-0.2325*** (0.0093)	-0.2760*** (0.0278)	-0.2664*** (0.0180)	-0.2315*** (0.0130)	-0.2878*** (0.0214)	-0.2721*** (0.0170)	-0.2614*** (0.0274)	-0.2654*** (0.0170)
re	-0.0641* (0.0354)	0.2683* (0.1551)	0.7652* (0.0440)	-0.0336 (0.0440)	-0.0356 (0.0272)	-0.0044 (0.0233)	0.1951* (0.1173)	-0.0380 (0.0275)
nre	-	0.0184** (0.0079)	0.0109*** (0.0037)	0.0015 (0.0044)	0.0002 (0.0023)	0.0033** (0.0017)	0.0182** (0.0071)	-0.0005 (0.0019)
openess	-	-	-	0.0003 (0.0013)	-	0.0008 (0.0011)	-	0.0003 (0.0010)
lgdpc	-	-	-	-	0.2193*** (0.0779)	0.1217*** (0.0441)	-0.7127 (0.7972)	0.5345* (0.2747)
lgdpc2	-	-	-	-	-	-	0.0371 (0.0445)	-0.0214 (0.0144)
lpop	-	-	0.1609*** (0.0537)	-	0.4221*** (0.1142)	0.3452*** (0.0826)	-	0.3441*** (0.0957)
constant	2.5202*** (0.6682)	0.6350 (1.4260)	-0.2083 (0.9589)	2.0529*** (0.4489)	-3.4163** (1.4110)	-2.7401*** (0.8539)	3.8399 (3.4795)	-4.427*** (1.6196)
m1	-4.04***	-3.74***	-4.06***	-3.73***	-3.57***	-3.62***	-3.42***	-3.69***
m2	0.15	0.97	0.89	1.07	1.57	1.62	0.78	1.63
Sargan	57.81	25.71	95.00	66.79	80.02	88.42	39.29	75.74
Diff-in-Sargan	7.56	5.64	2.88	6.06	4.10	2.44	4.58	2.14
Observations	752	749	749	689	698	677	698	677

Notes: denotes the lag of contribution of greenhouse gas emission (kt of CO_2 equivalent)), re denotes as renewable energy consumption (kt of oil equivalent), nre denotes as non-renewable energy (fossil fuel energy consumption in % of total), lgdp demotes as the log of GDP per capita (current US$), lgdpc2 is the square of GDP per capita (to measure the EKC hypothesis), lpop denotes as the population ages 15-64 in total. Time dummies are included in all regressions. The implied is the convergence parameter, wherein convergence occurs if the implied is significantly less than 1. The superscripts ***, ** and * denote the significance at 1%, 5% and 10% level, respectively. m1 and m2 refer to the first and second order autocorrelation in the first difference residual, where one should expect the presence of first-order autocorrelation (m1) but not second-order autocorrelation (m2) for the validity of the moment conditions. Sar.Han and Dif.Sar, respectively, denote the Sargan-Hansen test as well as Difference in Sargan-Hansen test on testing the validity of the instrumental variables.

with a low rate of emissions. Hence, the policymakers around the world should consider the long run emission targets.

The Sargan test is used to test the instrumental variables' validity. In particular, the results of the Sargan-Hansen test for all models are statistically insignificant, implying that the instrumental variables used are valid. The Arellano-Bond test detects first-order autocorrelation (m1) in the error terms but finds no evidence for second-order autocorrelation (m2). Hence, this study would have expected if the system estimator was correctly specified. Meanwhile, the difference Sargan-Hansen test result suggests that additional instruments in the level equations compared to the difference GMM are valid, pointing to the fact that the estimates of system GMM are more reasonable than that of the difference GMM. The System GMM estimations of the implied for all models are all in statistically significant negative value.

Concerning the conditioning variable in Model 1, the renewable energy consumption indicates a negative effect on the convergence of emission. The estimated parameter for renewable energy consumption is negative and statistically significant at the 10% level. This shows the importance of renewable energy consumption in emissions dynamics; more importantly, it indicates the potential for emissions reduction from the policies planned for the country.

However, renewable energy consumption only turned to a positive effect on the convergence of emissions when non-renewable energy was used in the economy. This is in line with the findings by Van der Ploeg and Withagen [47], Grafton et al. [48], Van der Ploeg and Withagen [49], Roy and Schaffartzik [59], and Mohsin et al. [60], an increase in the renewable energy consumption tends to increase the carbon emissions due to fastening the used of fossil fuel. The reason is that the renewable energy in the data contains combustible renewable and waste, which are not clean resources [61].

Meanwhile, the clean energy source that is a perfect substitute unambiguously caused future renewable energy supply to increase in response to higher present renewable output, hence, inducing fossil fuel owners to extract more rapidly. Thus, subsidizing present fossil fuels to renewable energy (e.g., solar and wind) caused the green paradox due to the loss of higher extraction. Now, future extraction cost is lower given that renewable resources will be phased in earlier and more oil is left *in situ* [59].

In addition, the significance levels of GDP per capita and population are all above 1% except in Model 8 which the significance level of GDP per capita is above 10%. These findings suggest that GDP per capita and population impact the convergence of emissions across the countries. The findings are in line with Wang and Zhang [8], Matsuki and Pan [62] and Zhang and Hao [63]. This shows the importance of growth in GDP in emissions dynamics, and more importantly, it indicates the potential for reducing per capita emissions from policies that can decouple growth in GDP from emissions. Meanwhile, population density in those countries needs to be controlled to reduce the CO_2 emissions. However, the trade openness does not affect the convergence of emissions across 102 countries. This means that the convergence of emissions is more influenced by economic development in those countries.

With regard to global climate change, the trend toward lower-carbon intensity is needed across countries. This requires alternative and renewable energy sources as the country embarks on moving to a new climate economy. Renewable energy is widely perceived as synergy with many aspects of sustainable development. It is non-exhaustible and deemed to be less polluting. However, massive technological switching from non-renewable energy to renewable energy can be very polluting. The lower cost of renewable attracts the resource owners to keep more fossil fuels *in situ* and reinforces the faster transition from fossil fuels to renewable. Hence, taking into consideration the environmental impact of renewable energy investment can overstate the benefit of renewable energy consumption in emissions reductions.

CONCLUSION

In this study, we estimated the convergence of emissions across 102 countries from 1975- 2015. Due to the limitation of the estimation of the dynamic panel data model by using the traditional estimation, it has become standard practice nowadays to use the Generalized Method of Moments (GMM) (see Arellano and Bover [60], Blundell and Bond [61]). The dynamic panel GMM estimator can be used to control the dynamic nature while accounting for the endogeneity problem in the study.

The study results reveal a convergence of emissions across 102 countries around the world; however, the factors that influenced the convergence of emissions are varied. These findings may contribute to policymakers on environmental protection, especially when drafting the international agreements for the global reduction of emissions of greenhouse gases. The evidence of the convergence of emissions does not mean that the policymakers can become gratified in the continuing efforts to combat emissions, especially in the renewable transition.

According to the different factors that influence the convergence of emissions across countries, the policymakers may narrow the gap in carbon emissions among countries through the reduction of the use of non-renewable energy. The countries with a high proportion of renewable energy consumption should be decoupling from the traditional energy for a high-carbon economy to the green energy use for a low-carbon economy to optimize the energy structure. There is a limitation in this study. Due to the availability of data, the panel dataset of the 102 countries only covered the period from 1975 to 2015. In future, studies can explore with a long observation period.

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