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RESEARCH ARTICLE

Does trade openness affect CO_2 emissions: evidence from ten newly industrialized countries?

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Abstract This paper examines whether the hypothetical environmental Kuznet curve (EKC) exists or not and investigates how trade openness affects CO_2 emissions, together with real GDP and total primary energy consumption. The study sample comprises ten newly industrialized countries (NICs-10) from 1971 to 2013. The results support the existence of hypothetical EKC and indicate that trade openness negatively and significantly affects emissions, while real GDP and energy do positive effects of emissions. Moreover, the empirical results of short-run causalities indicate feedback hypothetical linkage of real GDP and trade, unidirectional linkages from energy to emissions, and from trade to energy. The error correction terms (ECTs) reveal in the long run, feedback linkages of emissions, real GDP, and trade openness, while energy Granger causes emissions, real GDP, and trade, respectively. The study recommendations are that our policymakers should encourage and expand the trade openness in these countries, not only to restrain CO_2 emissions but also to boost their growth.

Keywords Trade openness · Newly industrialized countries · Carbon dioxide emissions · Environmental Kuznet curve · Total energy · Real GDP

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Introduction

In the past couple of decades, the international trade has made tremendous contributions to the overall global economy, both in the developed and developing countries. According to the World Development Indicator (World Bank 2016), the share of international trade in the total global economy has more than doubled from 24.2% in 1960 to 58.3% in 2015. However, along with the development of trade openness, greenhouse gas (GHG) emissions, 73% of which is carbon dioxide (CO_2), have increasing rapidly. For reducing the GHG emissions and controlling global warming, the international community signed the Kyoto Protocol in 1997 under the United Nations Framework Convention on Climate Change (UNFCC), which was only limited to developed countries. As the successor of the Kyoto Protocol, the Paris Agreement of UNFCC was adopted by consensus with 195 countries (comprising more than 95% of global emissions) in 2015. This agreement is more extensive and efficient for all members, including the major developing and emitting countries, for example, India and China. Moreover, specific targets should be scheduled and goals met by signed countries (Taraska 2015). The main goal is to control warming to 2 °C, aiming for 1.5 °C above preindustrial levels. Figure 1 presents the trend of global trade and CO_2 emissions from 1971 to 2013. International trade, measured in constant 2010 US$, was about 43 trillion US$ in 2013, which is eight times more than that in

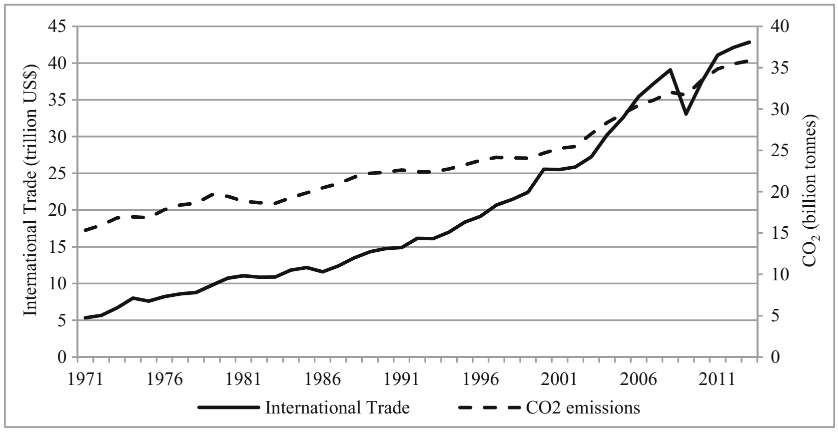

Fig. 1 The trends of international trade and CO_2 emissions, 1971–2013. Source from WB (2016)

1971. The total emissions in 2013 are nearly 36 billion tonnes, twofold more than that in 1971.

According to Waugh (2000), there were current ten newly industrialized countries (NICs-10), which are selected from developing countries, namely Brazil, China, Indonesia, India, Mexico, Malaysia, the Philippines, Thailand, Turkey, and South Africa. This classification is consistent with other political scientists and economists, such as Guillén (2003). The industrialization level of NICs is higher than that of other developing countries, but a little bit less than that of developed countries. The characteristics of the NICs are prosperity of market economy and trade openness, along with increasingly serious environmental pollution and huge energy consumption. The NICs perform a similar role in global value chains, all are outsourcing locations, and play very different roles in global production and in global value chains at the similar stage of development (Boddin 2016). Figure 2 presents the proportion of total NICs-10's CO_2 emissions, real GDP, total primary energy consumption, and international trade in global share. In 2013, the total CO_2 emissions in NICs-10 was about 15.2 billion metric tonnes, about 42.368% of total global emissions, which is twofold more than that in 1975 (12.429%). While the ratio of total primary energy consumption was about 40.181% in 2013, triple that in 1975. Moreover, the rates of real GDP and international trade were occupied at 23.050 and 19.364% in 2013, respectively.

The purposes of the present paper are to examine how trade affects carbon dioxide emissions and to investigate whether the hypothetical environmental Kuznet curve (EKC) exists or not in a sample of NICs-10 covering the time series of 1971–2013. Compared with previous papers, such as Sharif Hossain (2011), the present paper examines the EKC hypothesis in panel by using panel ordinary least squares (OLS), dynamic OLS (DOLS), and fully modified OLS (FMOLS) long-run estimates (Pedroni 2001, 2004) to quantize the impacts of independent variables (real GDP, total primary energy consumption, and trade openness) on the dependent variable, namely emissions. In addition, we use the newest and a longer time series data to analyze the linkage of the selected variables from 1971 to 2013, which would be more reliable and efficient. Other contributions are as follows.

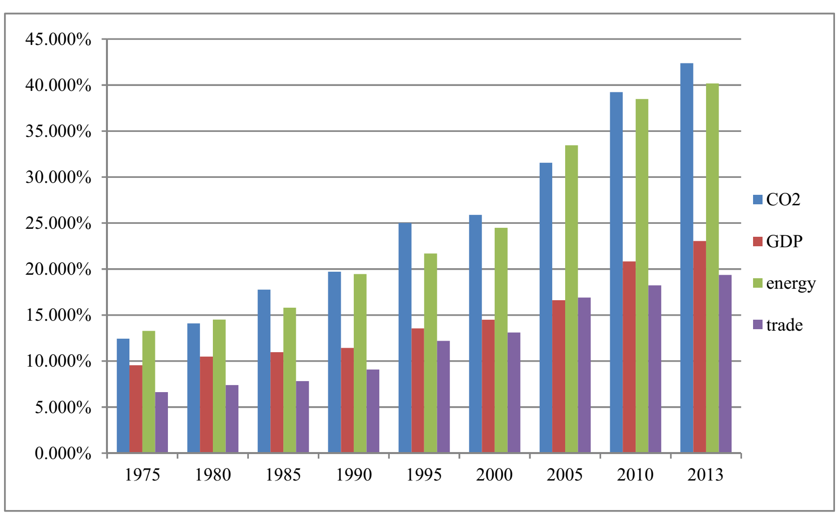

Fig. 2 The proportion of the total share in NICs-10 of global total

To the best of our knowledge, this paper is the first to analyze the NICs-10 by employing panel time series data. According to Hsiao (2007), compared with cross-sectional data, panel data have not only more degrees of freedom but also much more accurate predictions. Second, this paper uses both Pedroni (1999, 2004) and Johansen Fisher panel co-integration test (Maddala and Wu 1999), which can get more measurable results. Lastly, it employs the panel vector error-correction model (VECM) to affirm the directional causalities between the selected time series data.

The remainder of the paper is structured as follows: The "Literature review" section provides a brief reviews of the literature. The "Model, data, and descriptive statistics" section explains the model, data, and descriptive statistics. The "Empirical results and discussions" section introduces the econometric methodology, empirical results, and discussions. Finally, the "Conclusions and implications" section presents the conclusions and implications.

Literature review

The pioneer study of the relationship between environmental degradation and trade openness is Grossman and Krueger (1991), who analyzed the environmental influence of the North American Free Trade Agreement (NAFTA), which was a breakthrough in exploring the linkage of environmental quality and economic openness. Moreover, Grossman and Krueger (1991) proposed the EKC hypothesis based on Kuznets (1955). Since then, numerous studies have examined the nexus of emissions and international trade, as well as the EKC hypothesis. Table 1 summarizes the studies about the linkages of international trade and CO_2 emissions, together with the EKC hypothesis in recent years. These empirical papers can be separated into two categories.

The first category comprises cross-sectional studies (see Table 1). For instance, using the latest data from 1960 to 2009 in South Africa, Kohler (2013) uses the technologies of ARDL bounds test and VECM causality to explore the linkages of commercial energy use, emissions, real income, and trade liberalization. The empirical results of ARDL indicate the existences of the EKC hypothesis and co-integration between emissions, energy use, trade liberalization, and real income. Moreover, bidirectional Granger causal relationships exist between energy use and emissions, between trade liberalization and real income, as well as between trade liberalization and energy. Kohler concludes that trade does not contribute to the emissions in the long term. Applying the same methodology, Shahbaz et al. (2013) explore their relationships between output, energy, trade, and carbon dioxide emissions in Indonesia from 1975Q1 to 2011Q4. The empirical results reveal feedback causal linkages of energy use and emissions, and the output and emissions. The policy implication is that trade liberalization positively affects the environmental improvement.

The second category is based on panel analysis technologies (see Table 1). For the purpose of exploring the nexus of carbon dioxide emissions, energy use, output, and trade with a sample of nine emerging countries from 1971 to 2007, Sharif Hossain (2011) employs methodologies of GMM and panel VECM Granger causality. His findings suggest no long-run causalities among the selected time series data and mixed unidirectional short-run causalities. Moreover, the panel estimation from GMM only suggests that foreign trade plays a key role in emissions with a negative sign in the long run. And another study finds no long-run linkages of selected variables in panel. Using panel FMOLS and DOLS, and VECM methodologies, Jebli et al. (2016) examine the causality of emissions, real income, renewable and non-renewable energy, and foreign trade with 25 OECD countries from 1980 to 2010. The total feedback hypothetical long-run and mixed short-run causalities are found among the analyzed time series data. In addition, long-run estimates suggest that international trade, together with renewable energy, does negative influence on emissions in selected OECD countries and that the EKC hypothesis exists. Using a similar methodology in the ten selected CEECs, Destek et al. (2016)'s findings support the EKC hypothesis and reveal that an increase of 1% energy increases emissions by 1.09–1.16%, while an increase of 1% trade decreases emissions by 0.069–0.097%. Moreover, the long-run feedback causal linkage is found between emissions and trade, but only unidirectional short-run linkage is found from trade to CO_2 emissions.

Model, data, and descriptive statistics

Model

The omitted variable bias has been discussed for several decades in the nexus of economic growth and pollution. Ang (2007), Lean and Smyth (2010), and Ahmad et al. (2016) add an important factor energy use into the equation, in order to reduce omitted variable bias. Furthermore, Halicioglu (2009), Jalil and Mahmud (2009), Ahmed et al. (2016), and Shahbaz et al. (2017) introduce trade in discussion to cut down the impact of omitted variable bias. Therefore, we would follow these

Table 1 Summary of recent studies on the linkage of trade and emissions, together with EKC hypothesis

Authors	Country/region	Data	Methods	Long-run linkage of trade and emissions	EKC hypothesis
Cross-sectional studies					
Halicioglu (2009)	Turkey	1960–2005	ARDL bounds test; VECM Granger causality	Trade→CO_2	Support
Saboori et al. (2012)	Indonesia	1971–2007	ARDL bounds test;	Trade→CO_2	Not support
Kohler (2013)	South Africa	1960–2009	ARDL bounds test; VECM Granger causality	Trade↔CO_2	Not support
Shahbaz et al. (2013)	Indonesia	1975Q1-2011Q4	ARDL bounds test; VECM Granger causality	Trade↔CO_2	Not examined
Boutabba (2014)	India	1971–2008	ARDL bounds test; VECM Granger causality	Trade→CO_2	Support
Ben Jebli and Ben Youssef (2015)	Tunisia	1980–2009	ARDL bounds test; VECM Granger causality	Trade→CO_2	Not support
Farhani and Ozturk (2015)	USA	1971–2012	ARDL bounds test; VECM Granger causality	Trade→CO_2	Not support
Panel analysis					
Sharif Hossain (2011)	Nine emerging countries	1971–2007	GMM, VECM Granger causality	No causality	Not examined
Mehrara (2013)	BRICS	1960–1996	Hausman test; pooled least squares	Trade→CO_2	Support
Akin (2014)	85 Countries	1990–2011	DOLS, FMOLS; VECM Granger causality	Trade→CO_2	Not examined
Kasman and Duman (2015)	15 new EU member and candidate countries	1992–2010	FMOLS; VECM Granger causality	Trade↔CO_2	Support
Ibrahim and Rizvi (2015)	Eight Southeast and East Asian countries	1971–2009	OLS	Trade→CO_2	Support
Al-Mulali and Ozturk (2015)	14 MENA countries	1996–2012	FMOLS; VECM Granger causality	Trade↔CO_2	Not examined
Jebli et al. (2016)	25 OECD countries	1980–2010	DOLS, FMOLS; VECM Granger causality	Trade↔CO_2	Support
Ahmed et al. (2016)	BRICS	1970–2013	FMOLS; VECM Granger causality	Trade→CO_2	Not examined
Destek et al. (2016)	Ten CEEC countries	1991–2011	DOLS, FMOLS; VECM Granger causality	Trade↔CO_2	Support
Dogan and Seker (2016)	23 Top renewable energy countries	1985–2011	DOLS, FMOLS	Trade→CO_2	Support

EKC environmental Kuznets curve, *MENA Middle East and North Africa*, *OECD* Organization for Economic Cooperation and Development, *CEEC* Central and Eastern European Countries, *ARDL* autoregressive distributed lag, *VECM* vector error correction model, *OLS* ordinary least square, *DOLS* dynamic ordinary least square, *FMOLS* fully modified ordinary least square, *GMM* generalized method of moments

papers' methodologies in this study. CO_2 emissions (CO) can be described as the following multivariate equation of real GDP (GDP), the square of real GDP (GDP^2), energy consumption (EN), and trade openness (TRA).

$$\mathrm{CO}_{it}=f\left(\mathrm{GDP}_{it},\mathrm{GDP}_{it}^2,\mathrm{EN}_{it},\mathrm{TRA}_{it}\right) \quad (1)$$

Taking the natural logarithms of Eq. (1), the function can be written as follows:

$$\mathrm{co}_{it}=\alpha_i+\theta_i t+\beta_{1i}\mathrm{gdp}_{it}+\beta_{2i}\mathrm{gdp}_{it}^2+\beta_{3i}\mathrm{en}_{it}+\beta_{4i}\mathrm{tra}_{it}+\varepsilon_{it} \quad (2)$$

where i = 1,2,3,…10 stands for the selected ten countries. t is the time period of 1971–2013. ε is the stochastic error term. α and θ are the trend and individual fixed country effects, respectively. β is the long-run elasticities of CO_2 emissions in regard of real GDP, the square of real GDP, total primary energy, and trade openness, respectively. The inverted U-shaped hypothetical EKC suggests the sign of β_1 to be positive, while the sign of β_2 to be negative. The sign of β_3 is respected to be positive for more energy usage causing bigger economic activity and more carbon dioxide emissions, while the sign of β_4 relies on developmental level of analytical country. Generally, in developed countries, the index is expected to be negative because developed countries close the high-polluting industries or transfer them to the developing countries, as well as import pollution-free products from other countries to protect local environment (Grossman and Krueger 1995; Halicioglu 2009).

Data and descriptive statistics

The NICs-10 contain Brazil (BRA), China (CHN), Indonesia (IDN), India (IND), Mexico (MEX), Malaysia (MYS), the Philippines (PHL), Thailand (THA), Turkey (TUR), and South Africa (ZAF). The data of CO_2 emissions, real GDP, the square of real GDP, and trade openness are from World Development Indicators (World Bank 2016). The data of total primary energy consumption is gathered from the British Petroleum Statistical Review of World Energy (BP 2016). CO_2 emissions, measured as million metric tonnes, are mainly from the combustion of fossil fuels (coal, oil, and gas) and the other relevant emission sources. The real GDP is measured in constant 2010 US$, which eliminates the influence of inflation. Total primary energy consumption, is measured as the million tonnes of oil equivalents (Mtoe) and comprises fossil fuels, nuclear energy, and renewable energy (hydro, solar, wind, biomass, and others). Trade openness, measured in constant 2010 US$, is the total of exports and imports of goods and services.

Average growth rates of the mentioned variables for each country from 1971 to 2013 are presented in Table 2. In the specific period, Thailand had fastest growth in average emission at 6.891%, followed by Malaysia at 6.899% and Indonesia at 6.653%. The slowest was South Africa at 2.591%. For economic growth rate, the leader of NICs-10 was China at 9.155% per year, followed by Malaysia at 6.373% and Indonesia at 5.957%. For the growth rate of primary energy consumption, Indonesia and Thailand were the first and second fastest countries, at 7.602 and 7.402%, compared to the world average growth of 0.864% in these years. China and India, which are the two biggest developing countries, had international trade per year of 16.083 and 10.888%, respectively, followed by Thailand and Turkey. In general, almost every selected index of each country was higher, compared with that of world annual average. The correlation matrix of growth rates is shown in Table 3. They are all significant at the 1% level. The growth rates' correlation between selected variables shows that all variables were positively correlated with each other. The emission was more correlated with total primary energy consumption than with other variables, but less correlated with trade openness than with others.

Empirical results and discussions

Panel stationary tests

We would employ five panel unit root tests to explore the stationary of five selected time series data. These five tests were separated into two sets. One is the common unit root process, including Levin-Lin-Chu (LLC) (Levin et al. 2002) and the Breitung (2000), and another set is individual unit root process, including the Im-Pesaran-Shin (IPS) W (Im et al. 2003), the Fisher augmented Dickey-Fuller (ADF) (Dickey and Fuller 1979), and the Fisher Phillips-Perron (PP) tests (Phillips and Perron 1988). For both of these two sets, the null hypothesis means a unit root of unstationary, while the alternative hypothesis suggests no unit root of stationarity.

All the selected variables of the panel stationary tests are shown in Table 4. The founding indicates that all four time series data had a unit root in the level, but all the statistics were stationary in the 1st difference at a 1% significance level. Thus, the alternative hypothesis of no unit root was accepted in I(1).

Co-integration test and long-run estimates

Employed by Pedroni (1999, 2004), the aim of this step is to examine whether there is evidence of co-integration of the four selected variables in the long run. The statistics of Pedroni residual co-integration tests, based on residual-based strategy of Engle and Granger (1987), are comprised of two groups, named within-dimension and between-dimension

Table 2 The average growth rates of mentioned variables in each country from 1972 to 2013

	CO_2 emissions (%)	Real GDP (%)	Primary energy (%)	International trade (%)
Brazil (BRA)	3.972	3.896	4.904	6.043
China (CHN)	6.152	9.155	6.187	16.083
Indonesia (IDN)	6.653	5.957	7.602	7.947
India (IND)	5.645	5.571	5.469	10.888
Mexico (MEX)	3.423	3.479	4.176	7.381
Malaysia(MYS)	6.899	6.373	4.176	8.173
Philippines (PHL)	3.292	3.951	3.313	5.290
Thailand (THA)	6.981	5.836	7.402	9.612
Turkey (TUR)	4.797	4.307	5.362	9.185
South Africa (ZAF)	2.591	2.525	2.911	3.681
World average	2.063	3.112	0.864	5.205

Calculated by authors based on World Bank (2016) and BP (2016)

Table 3 The correlation matrix of the growth rates

	CO_2 emissions	Real GDP	Primary energy	International trade
CO_2 emissions	1.000000			
Real GDP	0.509779***	1.000000		
Primary energy	0.576281***	0.511505***	1.000000	
International trade	0.153557***	0.331445***	0.205500***	1.000000

*** Indicates at the 1% significant level

statistics. The first group includes panel ν statistic, panel ρ statistic, panel PP statistic, and panel ADF statistic, and the second group includes group ρ statistic, group PP statistic, and group ADF statistic. These seven statistics are based on the autoregressive coefficients for separate country in the panel. If the residuals of Eq. (2) tested by the Eq. (3) are I (1) (τ_{it} stands for error terms), the null hypothesis of no co-integration (π_i = 1) is accepted, while whereas if the residuals are I (0), alternative hypothesis is accepted, namely the variables are co-integrated.

$$\varepsilon_{it} = \pi_i \varepsilon_{it-1} + \tau_{it} \quad (3)$$

The findings of panel residual co-integration tests are showed in Table 5. Three out of four statistics in the within-dimension and all three statistics in the between-dimension reject the null hypothesis of no co-integration and accept the alternative hypothesis in the 1% significant level. In total, six out of seven statistics suggest the effect of co-integration between the selected time series data. Namely, long-run linkage is found among the dependent variable (CO_2 emissions) and the independent variables (real GDP, the square of real GDP, total primary energy, and trade openness).

In addition, we also employed Johansen Fisher panel co-integration test proposed by Maddala and Wu (1999). The Fisher statistics of co-integration test, based on individual Johansen (1988), contains two parts, trace and max-eigenvalue test. The results in Table 6 present the hypothesized number of co-integration using one lag and show evidence of co-integration relationships between these time series.

For the findings of panel co-integration among the five time series data, the parameters of long-run co-integration in Eq. (2) are computed. The long-run elasticities of independent variables (GDP, GDP^2, energy, and trade) with regard to the dependent variable (CO_2 emissions) are calculated by panel OLS, FMOLS, and DOLS methodologies, developed by Pedroni (2001, 2004). In general, FMOLS and DOLS are more effective in dealing with endogeneity problems and serial correlation troubles than OLS. Table 7 presents the results of long-run estimates from panel OLS, FMOLS, and DOLS. Regardless of their signs, values, and significances, the three coefficients of independent variables from these three technologies are very similar. From the sign of *gdp* and gdp^2 in these three estimates, the empirical results all support the inverted U-shaped EKC hypothesis. Namely, along with the economic

Table 4 Panel unit root tests

Method	Common unit root process		Individual unit root process		
	LLC	Breitung	IPS-W	ADF Fisher	PP Fisher
Level					
co	0.00719	0.96913	0.23644	17.3217	17.6470
gdp	−2.04606	0.63065	−1.14514	30.3829	30.1450
gdp^2	−1.91090	0.48598	−0.86031	27.7915	28.0060
en	−3.47012*	2.55562	−1.09808	33.6674	31.3358
trade	0.52249	1.57779	1.43854	15.1037	14.6865
First difference					
Δco	−15.4288*	−8.40806*	−13.9889*	183.677*	186.617*
Δgdp	−11.9637*	−9.25760*	−10.5822*	135.605*	222.767*
Δgdp^2	−11.9602*	−9.28225*	−10.5524*	135.016*	212.617*
Δen	−12.9226*	−9.91257*	−13.7891*	179.904*	182.442*
Δtra	−16.5636*	−12.1694*	−13.8939*	179.306*	206.625*

Test equation is with individual intercept and trend. The lag length is based on automatic selection of Schwarz Info Criterion (SIC)

* Indicates at the 1% significant level

Table 5 Panel residual co-integration test

	Statistic	Prob.	Weighted statistic	Prob.
Alternative hypothesis: common AR coefs. (within-dimension)				
Panel ν statistic	−0.269546	0.6062	−2.610153	0.9955
Panel ρ statistic	−2.237927**	0.0126	−3.721338*	0.0001
Panel PP statistic	−6.026433*	0.0000	−7.813098*	0.0000
Panel ADF statistic	−6.556083*	0.0000	−8.028907*	0.0000
Alternative hypothesis: individual AR coefs. (between-dimension)				
Group ρ statistic	−1.804033**	0.0356		
Group PP statistic	−6.133973*	0.0000		
Group ADF statistic	−6.427472*	0.0000		

* and ** indicate at the 1% and 5% significant level

growth, the level of environment gets worse, until reaching the inflection point, then declines in the panel of NICs-10. Developing the local economy contributes to the improvement of environment. From the DOLS approach, the long-run elasticity of emissions in regard of GDP is 0.590–0.005*gdp*. The results are the same as Lean and Smyth (2010) for a sample of ASEAN-5 and Boutabba (2014) for India, but different from Ben Jebli and Ben Youssef (2015) for Tunisia. Moreover, an augmentation in 1% energy use generates a 0.779% augmentation of emissions, while an augmentation in 1% trade openness in these NICs-10 reduces carbon dioxide emissions by 0.202%. Indeed, energy consumption, especially fossil fuels, is the main source (72%) of CO_2 emissions (IRENA 2015). The result of increasing international trade leading to the decline of emission is interesting. As we discuss in "Model" section, the sign of trade is supposed to be positive for developing countries, but the result is on the contrary. Such result may contribute to the governments of NICs paying more attention to the environmental impact by drawing lessons from industrialized countries. As the trade-based countries, the NICs require all the enterprises to realize clean production and cease the export-oriented enterprises of higher-polluting, meanwhile, and encourage imports of clean goods and service from other countries. Moreover, trade openness can promote the transfers of advance technologies, and thus lower emissions. The result is in line with Dogan and Seker (2016) for a sample of the 23 top renewable energy countries, but disagrees with Kasman and Duman (2015) for a sample of 15 new European Union member and candidate countries.

Panel VECM Granger causality

In the above, we have verified the finding of co-integration among the four time series data. In this section, we employ panel VECM Granger causality test to check the short- and long-run directional linkages of variables. This technology is based on Engle and Granger (1987), who used two stages to build the causal linkage. One is used to examine the long-run causalities based on analyzing the residuals of Eq. (2), and the other is used to explore the short-run causalities based on dynamic VECM.

The VECM formula can be expressed as follows:

$$\begin{bmatrix} \Delta co_{it} \\ \Delta gdp_{it} \\ \Delta gdp^2_{it} \\ \Delta en_{it} \\ \Delta tra_{it} \end{bmatrix} = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \end{bmatrix} + \sum_{p-1}^{q} \begin{bmatrix} b_{11,p} & b_{12,p} & b_{13,p} & b_{14,p} & b_{15,p} \\ b_{21,p} & b_{22,p} & b_{23,p} & b_{24,p} & b_{25,p} \\ b_{31,p} & b_{32,p} & b_{33,p} & b_{34,p} & b_{35,p} \\ b_{41,p} & b_{42,p} & b_{43,p} & b_{44,p} & b_{45,p} \\ b_{51,p} & b_{52,p} & b_{53,p} & b_{54,p} & b_{55,p} \end{bmatrix} \begin{bmatrix} \Delta co_{it-1} \\ \Delta gdp_{it-1} \\ \Delta gdp^2_{it-1} \\ \Delta en_{it-1} \\ \Delta tra_{it-1} \end{bmatrix} + \begin{bmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \\ c_5 \end{bmatrix} ect_{it-1} + \begin{bmatrix} \theta_{1it} \\ \theta_{2it} \\ \theta_{3it} \\ \theta_{4it} \\ \theta_{5it} \end{bmatrix} \quad (4)$$

where Δ, p, ect, and θ stand for the first difference operator, the lag length, the error correction term, and a random error term (ECT), respectively. Based on the automatic Schwarz information criterion (SIC), the lag length is equal to 2.

Table 6 Johansen Fisher panel co-integration test

Unrestricted co-integration rank test (trace and maximum eigenvalue)				
Hypothesized no. of CE(s)	Fisher stat.* (from trace test)	Prob.	Fisher stat.* (from max-eigen test)	Prob.
None	151.9**	0.0000	90.99	0.0000**
At most 1	75.69**	0.0000	52.62	0.0001**
At most 2	38.30**	0.0081	28.18	0.1051
At most 3	21.05	0.3943	16.24	0.7014
At most 4	16.72	0.6711	16.72	0.6711

*Probabilities are computed using asymptotic chi-square distribution. Superscripts ** denote statistical significance at 1% levels

Table 7 Panel long-run estimates from OLS, FMOLS, and DOLS

Variables	OLS		FMOLS		DOLS	
	Coefficient	*t* statistic	Coefficient	*t* statistic	Coefficient	*t* statistic
gdp	0.589705*	12.68493	0.592054*	76.00998	0.589705*	36.85447
gdp^2	−0.002304**	−2.070624	−0.002350*	−12.78595	−0.002304*	−6.015937
en	0.779299*	26.02892	0.780943*	158.2634	0.779299*	75.62373
tra	−0.201636*	−6.364871	−0.203130*	−38.38571	−0.201636*	−18.49233

Superscripts * and ** denote statistical significance at 1% and 5% levels

Table 8 shows the results of panel VECM Granger causality test. The ECT from Eq. (4) in the equations of CO_2 emissions, real GDP (the square of real GDP), and trade are negative at the 5% significant level. Namely, there are long-run causalities in these equations of dependent variables. In the short- and long-run, energy Granger causes emissions, but not vice versa. The finding differs from Dogan and Turkekul (2016), which suggests the feedback hypothetical causality of energy and emissions in the USA and is supported by Farhani and Ozturk (2015) for Tunisia. Moreover, feedback causal linkages are found between emissions and trade, as well as between emissions and economic growth only in the long run. Such result is different from Al-Mulali and Ozturk (2015), who report a long-run feedback linkage of emissions and trade, and short-run unidirectional causal linkage from trade to emissions with a sample of the Middle East and North African (MENA) countries. Feedback hypothetical causal linkage exists between trade and GDP in both the short and long run. Any fluctuation in trade openness influences economic growth and vice versa. Indeed, these selected countries depend deeply on the international trade. According to the World Bank (2016), the average percentage of trade to total GDP in NICs-10 was 69.64% in 2013. This finding is in accordance with Nasreen and Anwar (2014) for 15 Asian countries. In addition, energy is short-run Granger caused by trade, while energy long-run Granger causes trade. This means that any fluctuation in international trade reflects energy consumption immediately, while energy consumption can stimulate the trade openness in the long-run. The findings are inconsistent with Kyophilavong et al. (2015), who find the feedback causal linkage of energy and trade in Thailand. Finally, energy use long-run Granger causes real GDP. Any expansion of primary energy use affects the economic development in the long period. This result is supported by Lean and Smyth (2010) in ASEAN.

Conclusions and implications

The purposes of this study are to explore the hypothetical EKC and to investigate the causal linkage of CO_2 emissions, real GDP, total primary energy use, and trade openness with a sample of ten selected NICs-10 from 1971 to 2013. In order to accomplish the goal, we employ five panel unit root tests to analyze whether the five time series data were stationary or not and use panel co-integration tests to investigate the co-integrating relationship between them. We also use panel long-run estimation test (OLS, FMOLS, and DOLS) to confirm the long-run estimates of independent variables to emissions and lastly, use panel VECM Granger causality test to analyze the directional causalities.

Table 8 Panel VECM Granger causality test

Dependent variables	Short run				Long run
	Δco	$\Delta gdp/\Delta gdp^2$	Δen	Δtra	ECT
Δco	–	1.264 (0.284)	11.990* (0.000)	0.656 (0.519)	−0.004** [−2.397]
$\Delta gdp/\Delta gdp^2$	0.020 (0.980)	–	0.959 (0.384)	4.355** (0.014)	−0.003* [−3.548]
Δen	0.781 (0.459)	2.267 (0.105)	–	2.418*** (0.090)	0.001 [1.426]
Δtra	0.408 (0.665)	6.078* (0.003)	1.130 (0.324)	–	−0.006** [−2.368]

p value is in parenthesis; *t* statistics is in bracket

*, **, and *** indicate statistical significance at the 1, 5, and 10% level, respectively

The long-run estimates from three technologies support the hypothetical EKC. Moreover, DOLS suggests that the long-run elasticity of emissions in regard of real GDP is 0.590–0.005*gdp*. In addition, an augmentation of 1% primary energy use generates 0.779% augmentation of emissions, and an augmentation of 1% international trade leads to a 0.202% decrease of CO_2 emissions. Indeed, trade openness can increase the circulation of goods and services, especially technology transfer, and reduce excess capacity, and thus reduce the emissions. The short-run causality results reveal the presence of feedback hypothetical causal linkage of real GDP and international trade, unidirectional causal linkages from primary energy use to emissions, and from international trade to primary energy. Moreover, the long-run Granger causalities reveal feedback linkages of international trade, CO_2 emissions, and real GDP, as well as unidirectional causal linkages from primary energy to emissions, to real GDP, and to international trade.

The econometric analysis of these NICs-10 supports the following recommendations. Firstly, according to the linkage of emission and energy, reducing energy consumption, especially fossil fuels, and making energy use more efficient are the short- and long-term policy goals for these countries. Meanwhile, policymakers should increase their investments in energy purification technology, promote energy purification, and develop renewable energy. Power generation from renewable energy accounts for more than 22% of the global total, while the emissions would be 20% higher without renewable-based generation. With technological improvement, the cost of renewable energy has fallen dramatically. For example, the cost of solar photovoltaic (PV) fell by 80% from 2009 to 2014 (IRENA 2015). In addition, due to environmental pollution and limited resources, fossil energy should be replaced gradually by clean and renewable energy sources for sustainable development. The NICs-10 governments should introduce renewable energy sources vigorously by establishing policies of fiscal subsidy, priority, and privilege. Secondly, the governments should continue to simulate economic development to reduce carbon dioxide emissions because of the finding of hypothetical EKC linkage of real GDP and emissions. Along with economic prosperity, these NICs can invest more funds into environmental protection to pursue living, study, and work quality. Thirdly, the linkage of trade openness and carbon dioxide emissions indicates that these countries should stimulate the development of international trade to reduce trade protectionism, especially technology and efficient utilization of renewable and non-renewable energy. In addition, trade in environmental goods and services exchanges should be encouraged, which can help to combat the challenges of climate change.

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