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RESEARCH ARTICLE

Does financial development reduce environmental degradation? Evidence from a panel study of 129 countries

Usama Al-mulali[1] **· Chor Foon Tang**[2] **· Ilhan Ozturk**[3]

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Abstract The purpose of this study is to explore the effect of financial development on CO_2 emission in 129 countries classified by the income level. A panel CO_2 emission model using urbanisation, GDP growth, trade openness, petroleum consumption and financial development variables that are major determinants of CO_2 emission was constructed for the 1980–2011 period. The results revealed that the variables are cointegrated based on the Pedroni cointegration test. The dynamic ordinary least squares (OLS) and the Granger causality test results also show that financial development can improve environmental quality in the short run and long run due to its negative effect on CO_2 emission. The rest of the determinants, especially petroleum consumption, are determined to be the major source of environmental damage in most of the income group countries. Based on the results obtained, the investigated countries should provide banking loans to projects and investments that can promote energy savings, energy efficiency and renewable energy to help these countries reduce environmental damage in both the short and long run.

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✉ Ilhan Ozturk
ilhanozturk@yahoo.com

Usama Al-mulali
usama81za@gmail.com

Chor Foon Tang
tcfoon@usm.my

[1] Faculty of Business, Multimedia University, 75450 Melaka, Malaysia

[2] Centre for Policy Research and International Studies, Universiti Sains Malaysia, 11800 USM Penang, Malaysia

[3] Faculty of Economics and Administrative Sciences, Cag University, 33800 Mersin, Turkey

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Introduction

The rapid increase in greenhouse gas emission such as CO_2 emission is one of the major issues that the world is facing, especially in the last four decades. This has caught the attention of many researchers to investigate the determinants of CO_2 emission at the macro and micro levels. For the sake of brevity, energy consumption, output, trade and urbanisation are some of the common factors found to explain pollution (Omri et al., 2015; Kasman and Kasman, 2015; Tang and Tan, 2015; Hossain, 2011; Sharma, 2011). It is generally known that research investigating the relationship between them and pollution using different econometric analyses has been overstudied.

In the last few years, however, a number of studies explored the link between financial development, energy consumption and pollution in different countries and regions. Although these studies are relatively few, they have arrived at different conclusions. On one hand, a group of studies found that financial development can increase both energy consumption and CO_2 emission. This conclusion was reached by Shahbaz and Lean (2012) in Tunisia, Tang and Tan (2014) and Islam et al. (2013) in Malaysia, Zhang (2011) in China, Al-mulali and Che Sab (2012a, b) in Sub-Saharan African countries and 11 selected countries where financial development constitutes a large share of their total GDP growth, Sadorsky (2010, 2011) in Central and Eastern Europe countries and emerging countries, and Çoban and Topcu (2013) in the European Union (EU).

On the other hand, a number of studies found that financial development can reduce CO_2 emission and energy consumption. This conclusion was reached by Tamazian and Rao (2010) in transition countries, Shahbaz et al. (2013) in Indonesia and Jalil and Feridun (2011) in China. However, Ozturk and Acaravci (2013) concluded that the financial development has no effect on CO_2 emission in Turkey. Table 1 summarises the previous studies that explored the effect of the financial development on energy consumption and CO_2 emission.

The main contribution of this study to the literature, unlike the earlier studies, is to investigate the effect of financial development on CO_2 emission in 129 countries categorised by income level since the level of financial development indicators and level of CO_2 emission may vary based on the income level. In other words, the higher the level of financial development and CO_2 emission, the higher the income level is. Thus, categorising the countries based on their level of income reveals the similarities and differences between them in relation to the impact of financial development on CO_2 emission. To achieve this objective, a panel model for the CO_2 emission is established with urbanisation, GDP growth, trade openness, petroleum consumption and financial development as major factors that affect the level of CO_2 emission in a panel study for the period of 1980–2011.

The balance of this paper is organised as follows. "Data, empirical model and methodology" discusses the data, empirical model and methodology used in this study. "Empirical results" reports the analysis results of this study. Finally, the discussion of results, conclusion and its implication to policies will be presented in "Conclusion and policy implications".

Data, empirical model and methodology

The balance panel for 129 countries from 1980 to 2011 is utilised in this study. The sample will be segregated into four sub-groups based on income group classified by the World Bank as per Table 2. Specifically, there are 25 low-income countries, 33 lower-middle-income countries, 32 upper-middle-income countries and 39 high-income countries. Six variables, namely CO_2 emissions, urbanisation indicated by the size of population living in urban areas, real GDP measured in USD at 2000 price level, trade openness proxied by total trade of goods and services measured in USD at 2000 price level, consumption of petroleum and financial development proxied by domestic credit to the private sector measured in USD at 2000 price level, are used in this study. All data are collected from World Bank's *World Development Indicators* (WDI), except for consumption of petroleum and CO_2 emission which are collected from *Energy Information Administration* (EIA).

According to Baltagi (2005), panel data methods are superior to time series methods especially in controlling endogeneity, heteroscedasticity, serial correlation and multicollinearity. In addition, the panel estimation results are likely to be more robust than time series analysis as it takes into consideration both time series and cross-sectional dimensions. In light of these, we employed the panel data methods to analyse the impact of real GDP, urbanisation, trade openness, petroleum consumption and financial development on CO_2 emission. The estimation model for CO_2 emission can be written as follow:

$$\mathrm{LCO}_{2it} = \beta_{1i}\mathrm{LUR}_{it} + \beta_{2i}\mathrm{LGDP}_{it} + \beta_{3i}\mathrm{LTD}_{it} + \beta_{4i}\mathrm{LPC}_{it} + \beta_{5i}\mathrm{LFD}_{it} + \varepsilon_{it} \quad (1)$$

where LCO_{2it} is the log of CO_2 emission, LUR_{it} is the log of urbanisation, LGDP_{it} is the log of real GDP, LTD_{it} is the log of trade openness, LPC_{it} is the log of petroleum consumption and LFD_{it} is the log financial development. ε_{it} are the residuals assumed to be normally distributed and white noise.

The variables in the model were used by previous studies that examined the effect of financial development on CO_2 emission as major determinants of its emission. However, this study added another variable "urbanisation" since a large number of studies found it as a major contributor to CO_2 emission in different countries and regions (e.g. Feng et al., 2011; Zarzoso and Maruotti 2011; Al-mulali et al., 2012; O'Neill et al., 2012; Al-mulali et al., 2013). Moreover, as an alternative to total energy consumption, this study used petroleum energy consumption because this source of energy is the major contributor of CO_2 emission. Based on EIA (2013), energy consumption from petroleum constitutes more than 37 % of the world's total CO_2 emission in 2011. Petroleum consumption still is a vital source of energy since it provides more than 37 % of the world's energy needs; thus, it is important to include it in the CO_2 emission model.

Identifying the order of the integration for each variable is important since the cointegration tests require all the variables to be integrated in order one; thus, the panel unit root test can be performed. Maddala and Wu (1999) proposed nonparametric techniques that were able to conduct panel unit root tests by using the Fisher-PP and Fisher-ADF tests. These tests allow for heterogeneity across the units as much as possible. The Fisher-PP and the Fisher-ADF panel unit tests work under the null hypothesis of a panel unit root while the alternative hypothesis is that the variables do not contain a panel unit root, so they are deemed to be stationary.

Subsequently, if the variables are stationary at the first difference, the Pedroni cointegration test will be performed. This is to examine whether CO_2 emission, urbanisation, GDP, total trade, petroleum consumption and financial development are cointegrated. Pedroni (1999, 2004) proposed a heterogeneous panel cointegration test that permits cross-sections to be

Table 1 Summary of previous studies that explored financial development, energy consumption and CO_2 emission relationship

Author(s)	Time sample	Country/region	Variables	Methodology	The results	
					Financial development effect on energy	Financial development effect on CO_2 emission
Tamazian and Rao (2010)	1993–2004	Transitional countries	CO_2 emission per capita, GDP per capita, inflation, foreign direct investment, price liberalisation as an indicator of financial development and trade liberalisation	Panel random effect and the GMM model	Not investigated	Negative effect on CO_2 emission
Shahbaz and Lean (2012)	1971–2008	Tunisia	Energy consumption, GDP per capita, financial development and industrial share from total GDP	ARDL bounds testing approach, Johansen cointegration test and VECM Granger causality	Positive effect on energy consumption	Not investigated
Shahbaz et al. (2013)	1975–2011	Indonesia	CO_2 emission per capita, GDP per capita, energy consumption per capita, trade openness and domestic credit to the private sector as an indicator of financial development	ARDL bounds testing approach and VECM Granger causality	Not investigated	Negative effect on CO_2 emission
Sadorsky (2011)	1996–2006	Central and Eastern European countries	Energy consumption per capita, oil prices, several financial variables as indicators of financial development	Panel GMM model	Positive effect on energy consumption	Not investigated
Islam et al. (2013)	1971–2009	Malaysia	Energy consumption, population, GDP and financial development	ARDL bounds testing approach and VECM Granger causality	Positive effect on energy consumption	Not investigated
Zhang et al. (2011)	1992–2009	China	Energy consumption, financial development	Grey relational analysis approach and VAR Granger causality	Stock market capitalisation positively affect energy consumption	Not investigated
Tang and Tan (2014)	1972–2009	Malaysia	Energy consumption per capita, GDP per capita, foreign direct investment per capita, price of energy goods, price of nonenergy goods and financial development index	Johansen 1988, Johansen and Juselius 1990 and ARDL bounds testing cointegration	Positive effect on energy consumption	Not investigated
Al-mulali and Che Sab (2012a)	1980–2008	Sub-Saharan African countries	GDP, CO_2 emission and financial development	Pedroni cointegration test and VECM Granger causality	Positive effect on energy consumption	Positive effect on CO_2 emission
Al-mulali and Che Sab (2012b)	1980–2008	19 developed and developing countries	Energy consumption, CO_2 emission, GDP per capita and financial development	Pedroni cointegration test and VECM Granger causality	Positive effect on energy consumption	Positive effect on CO_2 emission
Zhang (2011)	1980–2009	China	CO_2 emission, GDP and financial development (several financial variables) and foreign direct investment	Johansen cointegration test, Toda and Yamamoto Granger causality and variance decomposition	Not investigated	Positive effect on CO_2 emission
Sadorsky (2010)	1990–2006	Emerging countries	Energy consumption per capita, inflation rate, several financial variables as indicators of the financial development and foreign direct investment (FDI)	Panel GMM model	Positive effect on energy consumption	Not investigated
Jalil and Feridun (2011)	1953–2006	China	CO_2 emission per capita, GDP per capita, trade openness and financial development	ARDL bounds testing and Granger causality	Not investigated	Financial development negatively affects CO_2 emission
Ozturk and Acaravci (2013)	1960–2007	Turkey	CO_2 emission per capita, GDP per capita, trade openness and financial development	ARDL bounds testing and VECM Granger causality	Not investigated	Financial development has no effect on CO_2 emission

Table 1 (continued)

Author(s)	Time sample	Country/region	Variables	Methodology	The results	
					Financial development effect on energy	Financial development effect on CO_2 emission
Çoban and Topcu (2013)	1990–2011	European Union countries	Energy consumption per capita, oil prices, GDP per capita, foreign direct investment share of total GDP and several financial variables as indicators of financial development	Panel GMM model	Positive effect on energy consumption	Not investigated
Omri et al. (2015)	1990–2011	12 MENA countries	CO_2 emission, economic growth, financial development and trade openness	Simultaneous-equation panel data models	Positive effect on energy consumption	Financial development has no effect on CO_2 emission

Table 2 The list of investigated countries based on their income level

Low-income countries	Bangladesh, Benin, Burkina Faso, Burundi, Central African Republic, Chad, Comoros, Congo, Dem. Rep., Ethiopia, Gambia, Guinea-Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Nepal, Niger, Rwanda, Sierra Leone, Togo, Uganda and Zimbabwe
Lower-middle-income countries	Belize, Bhutan, Bolivia, Cameroon, Cape Verde, Congo, Rep., Cote d'Ivoire, Egypt, El Salvador, Fiji, Ghana, Guatemala, Guyana, Honduras, India, Indonesia, Lesotho, Morocco, Nicaragua, Nigeria, Pakistan, Papua New Guinea, Paraguay, Philippines, Samoa, Senegal, Sri Lanka, Sudan, Swaziland, Syrian Arab Republic, Tonga, Vanuatu and Zambia
Upper-middle-income countries	Algeria, Antigua and Barbuda, Argentina, Botswana, Brazil, Chile, China, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, Gabon, Grenada, Iran, Jamaica, Jordan, Malaysia, Mauritius, Mexico, Panama, Peru, Seychelles, South Africa, St. Lucia, St. Vincent and the Grenadines, Suriname, Thailand, Tunisia, Turkey, Uruguay and Venezuela and RB
High-income countries	Australia, Austria, Bahamas, Bahrain, Barbados, Belgium, Canada, Cyprus, Denmark, Equatorial Guinea, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Rep., Luxembourg, Macao, Malta, Netherlands, New Zealand, Norway, Oman, Portugal, Saudi Arabia, Singapore, Spain, St. Kitts and Nevis, Sweden, Switzerland, Trinidad and Tobago, UK and US

mutually dependent on each other with different individual effects. The null hypothesis indicates that there is no cointegration among the variables. To determine whether to reject the null hypothesis or not is dependent on a number of statistics in the Pedroni cointegration, namely statistics within dimension: panel v-statistics, panel p-statistics, panel t-statistic (nonparametric) and panel t-statistic (parametric) and between dimension: group ρ-statistics, group t-statistics (nonparametric) and the group statistics (parametric).

After cointegration, panel dynamic ordinary least squares (DOLS) was performed to examine the long-run relationship. The panel dynamic OLS proposed by Kao and Chiang (2000) is utilised in the analysis because it uses the ordinary least squares to estimate an augmented cointegrating regression equation. The last step in the analysis is to investigate the causality between the variables in Eq. 2. This can be done by utilising the Granger causality test which was proposed by Engle and Granger (1987). If cointegration is realised, the Granger causality based on vector error correction model (VECM) will be used. This is performed by estimating the long-run equation (Eq. 2) from which the residual can be extracted. The lagged values of the residuals are called the error correction term. The VEC Granger causality can reveal the short-run causality based on the F-statistics and the long-run causality based on the lagged error correction term ECT_{t-1}. The Granger causality based on the VECM can be written as follows:

$$\begin{bmatrix} \Delta LCO_{2it} \\ \Delta LUR_{it} \\ \Delta LGDP_{it} \\ \Delta LTD_{it} \\ \Delta LPC_{it} \\ \Delta LFD_{it} \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \end{bmatrix} + \sum_{p-1}^{r} \begin{bmatrix} B_{11,p} & B_{12,p} & B_{13,p} & B_{14,p} & B_{15,p} & B_{16,p} \\ B_{21,p} & B_{22,p} & B_{23,p} & B_{24,p} & B_{25,p} & B_{26,p} \\ B_{31,p} & B_{32,p} & B_{33,p} & B_{34,p} & B_{35,p} & B_{36,p} \\ B_{41,p} & B_{42,p} & B_{43,p} & B_{44,p} & B_{45,p} & B_{46,p} \\ B_{51,p} & B_{52,p} & B_{53,p} & B_{54,p} & B_{55,p} & B_{56,p} \\ B_{61,p} & B_{62,p} & B_{63,p} & B_{64,p} & B_{65,p} & B_{66,p} \end{bmatrix} \times \begin{bmatrix} \Delta LCO_{2it-p} \\ \Delta LUR_{it-p} \\ \Delta LGDP_{it-p} \\ \Delta LTD_{it-p} \\ \Delta LPC_{it-p} \\ \Delta LFD_{it-p} \end{bmatrix} \begin{bmatrix} \varphi_1 \\ \varphi_2 \\ \varphi_3 \\ \varphi_4 \\ \varphi_5 \\ \varphi_6 \end{bmatrix} \times [\mathrm{ECT}_{it-1}] + \begin{bmatrix} e_{1it} \\ e_{2it} \\ e_{3it} \\ e_{4it} \\ e_{5it} \\ e_{6it} \end{bmatrix} \quad (2)$$

The i denotes the cross section (number of countries), t denotes the time (1980–2011), e_{it} is the error term, ECT_{t-1} is the lagged error correction term and Δ is the first difference indicator. The short-run Granger causality is calculated by restricting the first difference explanatory variables using the joint significant χ^2 tests. However, the long-run causality is captured via the t-significance of the ECT_{t-1} coefficient.

On the other hand, if cointegration is not realised, one can only capture the short-run causality based on the first difference vector autoregression (VAR) model presented below:

$$\begin{bmatrix} \Delta LCO_{2it} \\ \Delta LUR_{it} \\ \Delta LGDP_{it} \\ \Delta LTD_{it} \\ \Delta LPC_{it} \\ \Delta LFD_{it} \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \end{bmatrix} + \sum_{p-1}^{r} \begin{bmatrix} B_{11,p} & B_{12,p} & B_{13,p} & B_{14,p} & B_{15,p} & B_{16,p} \\ B_{21,p} & B_{22,p} & B_{23,p} & B_{24,p} & B_{25,p} & B_{26,p} \\ B_{31,p} & B_{32,p} & B_{33,p} & B_{34,p} & B_{35,p} & B_{36,p} \\ B_{41,p} & B_{42,p} & B_{43,p} & B_{44,p} & B_{45,p} & B_{46,p} \\ B_{51,p} & B_{52,p} & B_{53,p} & B_{54,p} & B_{55,p} & B_{56,p} \\ B_{61,p} & B_{62,p} & B_{63,p} & B_{64,p} & B_{65,p} & B_{66,p} \end{bmatrix} \times \begin{bmatrix} \Delta LCO_{2it-p} \\ \Delta LUR_{it-p} \\ \Delta LGDP_{it-p} \\ \Delta LTD_{it-p} \\ \Delta LPC_{it-p} \\ \Delta LFD_{it-p} \end{bmatrix} + \begin{bmatrix} \upsilon_{1it} \\ \upsilon_{2it} \\ \upsilon_{3it} \\ \upsilon_{4it} \\ \upsilon_{5it} \\ \upsilon_{6it} \end{bmatrix} \quad (3)$$

Empirical results

Since the cointegration test works with variables that are integrated in order one, it is important to test the stationarity of each variable. This is carried out using the panel unit root tests of Fisher-ADF and Fisher-PP. The results of the unit root test are presented in Table 3. The null hypothesis of a panel unit root cannot be rejected as all variables are not significant at the levels. On the other hand, the variables are significant at the first difference confirming that the variables are integrated of order one.

Panel cointegration results

As the variables are integrated in order one, the Pedroni cointegration test can be utilised to examine the presence of a cointegrating relationship between CO_2 emission and its determinants. The results of the Pedroni cointegration test can be seen in Table 4. We find that the variables LCO_2, LUR, LGDP, LTD, LPC and LFD are cointegrated since four out of seven statistics reject the null hypothesis of no cointegration in all income group countries at the 1 % significance level. This indicates that a long-run relationship exists

Table 3 Panel unit root test results

Income groups	Fisher-ADF					Fisher-PP			
	Variables	Level		First difference		Level		First difference	
		Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend
Low	LCO_2	35.22	41.76	100.19[a]	93.44[a]	17.90	19.19	478.94[a]	104.55[a]
	LUR	32.59	53.93	70.80[b]	82.88[a]	13.33	57.70	87.93[a]	25.694
	LGDP	11.20	32.57	246.71[a]	222.76[a]	16.48	49.52	436.02[a]	456.58[a]
	LTD	18.61	34.99	300.02[a]	259.75[a]	25.09	46.20	562.84[a]	1190.67[a]
	LPC	39.39	33.42	335.79[a]	293.09[a]	27.50	24.35	586.83[a]	1454.74[a]
	LFD	15.87	28.59	180.98[a]	171.77[a]	15.65	15.19	347.80[a]	363.30[a]
Lower-middle	LCO_2	42.13	59.30	388.15[a]	310.26[a]	67.94	46.83	689.94[a]	1189.34[a]
	LUR	68.49	55.01	60.556	227.79[a]	50.44	55.22	85.70[c]	924.40[a]
	LGDP	9.518	65.60	257.41[a]	210.51[a]	16.17	69.48	418.23[a]	446.17[a]
	LTD	24.37	65.67	361.92[a]	298.04[a]	36.92	51.25	614.24[a]	1165.06[a]
	LPC	33.18	65.27	282.33[a]	356.20[a]	56.84	60.95	666.24[a]	1507.15[a]
	LFD	25.89	53.79	157.24[a]	120.75[a]	34.63	39.52	516.81[a]	662.45[a]
Upper-middle	LCO_2	37.98	43.58	424.70[a]	357.92[a]	64.24	44.16	737.98[a]	1850.22[a]
	LUR	51.50	63.66	101.72[a]	159.07[a]	76.52	66.32	189.39[a]	535.56[a]
	LGDP	27.04	50.00	198.31[a]	164.78[a]	31.52	56.96	404.16[a]	370.12[a]
	LTD	32.19	47.77	190.73[a]	150.41[a]	33.70	39.65	390.33[a]	394.58[a]
	LPC	44.42	53.88	212.08[a]	182.79[a]	57.77	18.40	710.70[a]	2283.63[a]
	LFD	36.61	37.55	155.58[a]	127.03[a]	70.31	48.49	414.69[a]	385.24[a]
High	LCO_2	89.48	67.53	423.19[a]	383.81[a]	79.16	83.36	756.02[a]	1242.75[a]
	LUR	46.06	56.63	184.85[a]	153.40[a]	39.91	61.23	97.74[b]	71.27
	LGDP	59.96	81.55	267.58[a]	231.07[a]	68.63	88.61	357.44[a]	339.23[a]
	LTD	17.14	71.32	429.40[a]	322.74[a]	14.82	76.69	696.49[a]	896.56[a]
	LPC	69.15	36.56	385.78[a]	319.48[a]	86.45	32.70	673.09[a]	1414.33[a]
	LFD	46.76	74.56	269.49[a]	200.23[a]	52.83	45.07	458.25[a]	429.12[a]

Optimal lag length is selected automatically using SBC

[a] Statistical significance at the 1 % level

[b] Statistical significance at the 5 % level

[c] Statistical significance at the 10 % level

Table 4 The results of the Pedroni cointegration tests

Tests	Income groups			
	Low	Lower-middle	Upper-middle	High
Panel v-statistic	−4.69	−3.85	−1.38	−2.23
Panel ρ-statistic	1.89	1.95	3.37	3.01
Panel PP-statistic	−7.08[a]	−8.65[a]	−9.93[a]	−12.15[a]
Panel ADF-statistic	−7.58[a]	−8.19[a]	−8.37[a]	−10.58[a]
Group ρ-statistic	2.15	3.77	3.63	5.28
Group PP-statistic	−20.86[a]	−13.96[a]	−17.14[a]	−16.33[a]
Group ADF-statistic	−12.70[a]	−8.40[a]	−10.01[a]	−9.64[a]

[a] Statistical significance at the 1 % level

between the variables. After confirming cointegration, we estimate the long-run coefficient using panel dynamic OLS (DOLS) and the results are presented in Table 5. For low-income countries, the results revealed that LUR, LTD and LGDP have no significant long-run relationship with LCO_2. However, LPC has a significant long-run positive relationship with LCO_2 where a 1 % increase in LPC will increase the level of LCO_2 emission by 0.995 %. In addition, LFD has a significant long-run negative relationship with LCO_2. A 1 % increase in the level of LFD will reduce the level of LCO_2 by 0.021 %.

The results for lower-middle-income countries show that LGDP has no long-run significant relationship with LCO_2. However, LUR, LTD and LPC have a positive and significant long-run relationship with LCO_2 while the LFD has a significant negative long-run relationship with LCO_2. A 1 %

Table 5 The results of panel DOLS

Income groups	Dependent variable: LCO_2		
	Explanatory variables	Coefficients	*t*-statistics
Low	LUR	0.010	1.086
	LGDP	0.029	1.341
	LTD	0.002	0.172
	LPC	0.995	10.219[a]
	LFD	−0.021	−3.539[a]
Lower-middle	LUR	0.242	2.369[b]
	LGDP	−0.009	−0.066
	LTD	0.556	8.073[a]
	LPC	0.866	12.267[a]
	LFD	−0.305	−4.404[a]
Upper-middle	LUR	0.298	1.891[c]
	LGDP	0.796	6.719[a]
	LTD	−0.159	−5.077[a]
	LPC	0.579	11.274[a]
	LFD	−2.851	−6.322[a]
High	LUR	0.393	3.951[a]
	LGDP	0.826	9.852[a]
	LTD	−0.101	−2.043[b]
	LPC	0.485	9.879[a]
	LFD	−0.212	−9.262[a]

[a] Statistical significance at the 1 % level

[b] Statistical significance at the 5 % level

[c] Statistical significance at the 10 % level

increase in LUR, LTD and LPC will increase the LCO_2 level by 0.242, 0.556 and 0.866 % respectively, while an increase in LFD by 1 % will reduce the level of LCO_2 emission by 0.305 %.

The panel DOLS results for upper-middle-income countries revealed that LUR, LGDP and LPC have a long-run significant positive effect on LCO_2, while LTD and LFD have a long-run significant negative effect on LCO_2. A 1 % increase in LUR, LGDP and LPC will increase LCO_2 by 0.298, 0.796 and 0.579 % respectively, while an increase in LTD and LFD by 1 % will reduce LCO_2 by 0.159 and 2.851 % respectively. The same results were found in high-income countries where LUR, LGDP and LPC increase LCO_2 in the long run by 0.393, 0.826 and 0.485 % correspondingly while LTD and LFDP reduce LCO_2 in the long run by 0.212 and 0.101 % respectively.

Granger causality results

As cointegration exists between the variables in all income group countries, the Granger causality based on the vector error correction term (VECM) is used. In Table 6, Granger causality test results for low-income countries show that, with the exception of LPC, a bi-directional long-run causality is found between all the variables based on the one-period lagged error correction term (ECT_{t-1}). The short-run causality revealed a bi-directional causal relationship between LCO_2 and LPC, LUR and LGDP, LTD and LGDP and LFD and LGDP, while a uni-directional causal relationship was found from LPC to LFD.

For lower-middle-income countries, the results revealed that a long-run causality with feedback was confirmed in all the variables except for LGDP. However, the short-run causality revealed the existence of feedback causality between LTD and LFD, LCO_2 and LTD, LPC and LCO_2, LFD and LCO_2, LPC and LUR, LGDP and LTD, and LFD and LGDP. However, a uni-directional causal relationship was confirmed from LGDP to LCO_2, LFD to LPC and LPC to LTD.

For the upper-middle-income countries, the results show that apart from LUR, a bi-directional long-run causality was found between all the variables. The short-run causality revealed a one-way causal relationship from LCO_2 to LGDP, LUR to LTD, LPC to LTD and LFD to LTD, while a feedback short-run causality was found between LPC and LCO_2.

For high-income countries, the test results show a long-run bi-directional causal relationship between LCO_2, LGDP and LFD while the long-run causality was not confirmed for the rest of the variables. Furthermore, the short-run causality revealed a bi-directional causality between LGDP and LCO_2, LTD and LCO_2, PLC and LCO_2, LFD and LCO_2, LUR and LGDP, LUR and LTD, LTD and LGDP, LGDP and LPC, LGDP and LFD, LTD and LPC and LTD and LFD. However, a one-way causality from LPC to LFD was found.

Conclusion and policy implications

The lack of researches that explored the effect of financial development on pollution inspired this study to explore the role of financial development on CO_2 emission in 129 countries categorised by the income level. To achieve this objective, a panel model for CO_2 emission was established with urbanisation, GDP growth, trade openness, petroleum consumption and financial development as major factors that affect the level of CO_2 emission.

The results revealed that urbanisation increases the level of CO_2 emission in the long run in lower-middle-, upper-middle- and high-income countries while it has no effect in low-income countries. This result is in line with Al-mulali et al. (2012) that the impact of urbanisation on CO_2 emission is negative or insignificant in low-income countries that are in the early stages of development. In addition, GDP growth was significant in upper-middle- and high-income countries in increasing CO_2 emission, while it has no effect in lower-

Table 6 Panel Granger causality test results

Income groups	Dependent variable	Explanatory variables						
		ΔLCO_2	ΔLUR	ΔLGDP	ΔLTD	ΔLPC	ΔLFD	ECT_{t-1}
Low	ΔLCO_2	–	1.130	0.757	0.188	237.721[a]	1.815	−2.199[b]
	ΔLUR	0.502	–	10.021[a]	2.897[a]	0.395	0.754	−3.458[a]
	ΔLGDP	0.402	22.149[a]	–	14.631[a]	0.788	2.381	−4.486[a]
	ΔLTD	1.375	3.202	25.394[a]	–	0.456	1.057	−4.900[a]
	ΔLPC	19.916[a]	0.437	1.071	0.571	–	1.261	−1.248
	ΔLFD	1.055	0.304	5.018[a]	0.643	2.648[b]	–	−4.191[a]
Lower-middle	ΔLCO_2	–	0.547	2.184[b]	4.859[a]	108.387[a]	2.321[b]	−3.011[a]
	ΔLUR	1.254	–	1.549	1.113	2.154	0.656	−1.786[c]
	ΔLGDP	0.842	0.704	–	11.566[a]	0.288	3.195[a]	−0.638
	ΔLTD	4.664[a]	0.758	2.399[b]	–	10.108[a]	4.698[a]	−4.129[a]
	ΔLPC	123.232[a]	2.769[b]	1.111	1.082	–	2.552[b]	−2.458[b]
	ΔLFD	2.349[b]	1.080	17.098[a]	2.855[a]	1.468	–	−3.457[a]
Upper-middle	ΔLCO_2	–	0.957	1.648	0.304	142.330[a]	0.261	−5.077[a]
	ΔLUR	0.745	–	0.490	0.431	0.609	0.295	−1.007
	ΔLGDP	109.016[a]	1.386	–	0.139	0.284	0.653	−4.291[a]
	ΔLTD	0.365	2.585[b]	1.025	–	10.455[a]	114.978[a]	−7.752[a]
	ΔLPC	108.021[a]	1.255	1.410	0.104	–	0.110	−4.944[a]
	ΔLFD	0.506	0.578	0.590	0.378	0.120	–	−9.360[a]
High	ΔLCO_2	–	1.835	14.353[a]	45.084[a]	30.937[a]	10.557[a]	−2.058[b]
	ΔLUR	0.601	–	1.915	1.060	0.680	1.705	−2.037[b]
	ΔLGDP	10.900[a]	4.349[a]	–	40.804[a]	12.112[a]	8.047[a]	−2.788[a]
	ΔLTD	17.311[a]	2.323[b]	41.073[a]	–	4.307[a]	4.927[a]	0.263
	ΔLPC	16.552[a]	0.844	14.730[a]	3.083[a]	–	1.322	0.336
	ΔLFD	12.346[a]	0.612	3.919[a]	4.410[a]	4.857[a]	–	−4.305[a]

[a] Statistical significance at the 1 % level

[b] Statistical significance at the 5 % level

[c] Statistical significance at the 10 % level

middle-income countries. Similarly, the results showed that the effect of GDP growth on CO_2 emission is more effective when income level is high; thus, it is affected by the level of development. This is supported by World Development Indicators (WDI) which states that the higher the level of CO_2 emission produced, the higher the income level is.

The results also revealed that trade openness has no significant effect on CO_2 emission in low-income countries, yet it significantly increases long-run CO_2 emission in lower-middle-income countries. Thus, trade openness can increase environmental damage in these countries. These results are in line with a number of studies (Al-mulali, 2012; Sharma, 2011; Ozturk and Acaravci, 2013). For upper-middle- and high-income countries, total trade of goods and services significantly reduces the level of CO_2 emission in the long run, which indicates that trade openness can improve the environmental quality in these income group countries. The increase in trade level in upper-middle- and high-income countries allows access to expensive high technologies that can reduce CO_2 emission, which is inaccessible to low- and lower-middle-income countries due to their high costs.

Moreover, the results show that petroleum consumption has a long-run positive significant impact on CO_2 emission in all income group countries. Furthermore, petroleum consumption is the major contributor of CO_2 emission in countries at all income levels since this energy source contributes more than 37 % of CO_2 emission globally by providing 37 % of the world's energy needs.

The most important finding is that financial development can reduce CO_2 emission in all income group countries. This finding is in line with that of Tamazian and Rao (2010), Shahbaz et al. (2013) and Jalil and Feridun (2011). Furthermore, the significance of financial development which has a negative impact on CO_2 emission implies that financial development can improve environmental quality. Therefore, our findings shed light that financial institutions in the 129 countries under investigation mostly lend to firms that establish investments on environmentally friendly projects.

The Granger causality test results (focusing on short-run causality) in low-income countries revealed that petroleum consumption is the only source of CO_2 emission. It also shows a positive feedback relationship between both components. On the other hand, the other variables including financial development have no causal effect on CO_2 emission. The same results were found in upper-middle-income countries. For lower-middle-income countries, the results concluded that GDP growth, trade openness and petroleum consumption increase the level of pollution because of their positive causal effect on CO_2 emission. However, it was found that financial development can improve environmental quality in the short run due to its negative causal effect on CO_2 emission. Similar results were arrived at in high-income countries. Nevertheless, the Granger causality results clearly revealed that petroleum consumption is the major source of pollution in all income group countries.

The results of this study revealed that financial development can be a good solution to reduce environmental degradation by its long-run and short-run negative effects on CO_2 emission in all income group countries. Thus, if the 129 investigated countries continuously provide loans to projects and investments that can promote energy savings, energy efficiency and renewable energy, they will reduce environmental damage in both the short and long run. In addition, petroleum consumption represents the major source of pollution in all income countries in the short and long run. Based on the Granger causality results, energy conservation policies on petroleum consumption are the optimal solutions to reduce the level of pollution produced by petroleum in low-, lower-middle- and upper-middle-income countries since petroleum consumption has no causal effect on the level of output (GDP). These policies might negatively affect the output level in high-income countries because feedback causality is established between petroleum consumption and GDP growth. Thus, the increase in energy efficiency (achieving the same amount of output with less energy) especially on petroleum consumption can help to reduce environmental damage without affecting its level of output in these countries. Besides, the energy efficiency policies can be a good strategy to reduce the level of pollution in all income group countries. Moreover, the CO_2 emission produced by urbanisation, GDP growth and total openness can be reduced by increasing energy efficiency.

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