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Impact of Globalisation and Energy Consumption on CO_2 Emissions: Empirical Evidence from Lithuania Using Linear and Non-linear ARDL Bound Testing Approach

Habib Ur Rahman

[1]*Faculty of Higher Education (Accounting and Finance) Holmes Institute*
Gold Coast, QLD 4217, Australia
E-mail: HRahman@Holmes.edu.au; Habib_hailian18@yahoo.com

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This study examines the symmetric and asymmetric impact of globalisation and energy consumption on Lithuania's carbon dioxide (CO_2) emissions using the KOF index of globalisation. Interestingly, the KOF database applies several globalisation gauges, including financial, trade, and overall globalisation. This study employs a series of econometrics techniques using data from 1988 to 2018. The results of the linear and non-linear Autoregressive Distributed Lag (ARDL) bounds testing approach reveal substantial evidence of a long-run association between the study variables. The OLS estimates of the non-linear ARDL model explain that the positive shock in financial globalisation deteriorates CO_2 emissions. I could not find such evidence for trade globalisation and overall globalisation. Conversely, energy consumption is the primary source of CO_2 emissions in Lithuania.

Keywords: *Globalisation; Energy Consumption; ARDL; CO_2 Emissions.*

Introduction

Foreign investors started investing in Lithuania due to the higher trustworthiness in its financial markets, which affects financial globalisation[1] through different economic transaction costs (Tisdell, 2008). The overall globalisation index of Lithuania (0 to 100) for 2018 is 81.29 points which is 19.12 points above the world average for 196 countries (Gygli et al., 2019). In good governance and macroeconomic policies, globalisation appears to be conducive to economic growth, raising some critical concerns about CO_2 emissions. Contemporaneously, Greenhouse gas (GHG) emission reduction is the top priority of the Lithuanian Sustainable Development Strategy.[2] Therefore, policymakers and academicians are interested in the environmental consequences of globalisation.

Further, energy consumption is one of the prominent sources of CO_2 emissions. The Lithuania Energy Report 2019 reveals that total energy consumption has increased by 2 per cent since 2014. From a global perspective, energy consumption and carbon emission are growing alarmingly. The consistent carbon emission will likely lead to catastrophic issues, including the greenhouse effect (Ramanathan, 2005). Therefore, policymakers and academicians are also interested in the environmental consequences of energy consumption. This research attempts to analyse the impact of globalisation and energy consumption on CO_2 emissions in Lithuania.

Over the last decade, there have been a couple of published papers on the impact of globalisation on CO_2 emissions, explaining the income effect (Jena & Grote, 2008), technique effect (Dasgupta *et al.*, 2006), and composition effect (Shahbaz, Shahzad, & Mahalik, 2018). However, there are still many aspects of globalisation, including (1) overall globalisation, (2) trade globalisation and (3) financial globalisation, that needs investigation. The understanding of the association between globalisation and CO_2 emissions is highly partial. Some studies measure the incidence of economic globalisation through trade openness (See Jorgenson & Givens, 2014; Li, Xu, & Yuan, 2015; Le, Chang, & Park, 2016). The association between trade openness and the environment is undeniably essential and relevant to policy concerns.

Nonetheless, trade openness does not capture other aspects of economic globalisation, including trade regulation, trade taxes, tariffs, trade agreements, trade partner diversity, investment restrictions, capital account openness, international investment agreements and knowledge beyond borders. Consequently, ignoring these essential dimensions is expected to adversely affect our perception of the association between globalisation and environmental degradation. I include these other aspects to empirically test the association between globalisation and CO_2 emissions in Lithuania.

Further, the existing literature on the association between trade openness and the environment is inconsistent (See You, & Lv, 2018). One strand of the research reveals that trade openness deteriorates the environmental quality since international trade compels local and federal governments to lower their production costs by neglecting ecological regulations (Drezner, 2000; Managi & Kumar, 2009; Kellenberg, 2009). Conversely, international and environmental economics theories provide a basis for this view's proponents. These proponents believe that trade

[1] The financial globalisation is the cross-border linkage through the financial flow, which is becoming the integral component of the top emerging economies like Lithuania.

[2] Also, see SDG 7 from the Voluntary National Review on the Implementation of the UN 2030 Agenda for Sustainable Development in Lithuania.

liberalisation protects the environment by giving economic benefits (Alam *et al.,* 2016; Balsalobre-Lorente *et al.,* 2018; Antweiler *et al.,* 2001; Zhang *et al.,* 2017; Zhang, Liu & Bae, 2017).[3] However, Le, Chang, and Park (2016) reveal that the effect of trade openness on the environment depends upon income level. They further explain that globalisation benignly impacts the environment in developed economies. However, this effect is harmful in low- and middle-income economies. Trade globalisation is also linked with financial globalisation (Lane & Milesi-Ferretti, 2008). Further, foreign investments transfer alternative technologies to protect the environment from degradation (Christmann & Taylor, 2001). Also, globalised information and knowledge have enhanced the general awareness of ecological issues. Therefore, the impact of different dimensions of globalisation on CO_2 emissions needs empirical investigation.

Besides globalisation, environmental degradation is driven by several other sources, including forest fires and floods in most economies (See Khan *et al.,* 2019). However, energy consumption from fossil fuels and economic activities are two prominent sources of environmental degradation. Therefore, researchers have analysed energy consumption and environmental degradation in other regions. The existing literature provides several patterns in different countries' energy consumption and CO_2 emissions. Mielnik and Goldemberg (1999) analysed the carbon emission intensities for a group of developing economies. Schipper, Ting, Khrushch, and Golove (1997) investigate the long-term evolution of carbon dioxide emission from energy consumption from 1971 to 1993 in OECD economies (also see Ang, 1994; Dogan, & Inglesi-Lotz, 2017). Despite this apparent nexus between energy consumption and CO_2 emissions, I could not find any empirical study on the impact of energy consumption on CO_2 emissions in Lithuania.

Considering the discussion above, the research question for this empirical investigation is: what is the impact of globalisation and energy consumption on CO_2 emissions in Lithuania? This study contributes to the existing empirical literature by providing empirical evidence on the effects of globalisation and energy consumption on CO_2 emissions in Lithuania. In particular, this study contributes to the current literature in several ways. First, this paper examines the presence of a long-term association between financial integration, energy consumption and CO_2 emissions. Second, the empirical findings of this study contribute to the empirical literature by adding financial globalisation and energy consumption to the CO_2 emission function to avoid specification biases. Third, the results of this study provide valuable insights to policymakers by suggesting that energy consumption is Lithuania's primary source of CO_2 emissions. Thus, this study aims to investigate the linear and non-linear impact of financial globalisation, trade globalisation, overall globalisation and energy consumption on carbon emission in Lithuania. For this purpose, this study applies a linear and non-linear ARDL bound testing approach from 1988 to 2018.

The rest of the paper is organised as follows. The second section of this paper synthesises the related literature, followed by the data and empirical strategy section. The fourth section presents the result and discussion. The last section concludes this paper.

Literature Review

Globalisation and Carbon Emission

Globalisation affects the environment through different channels (Shahbaz, Shahzad, & Mahalik, 2018), including income, technique, and composition. The income effect reveals that globalisation facilitates production and trade, enhancing carbon emissions (Jena & Grote, 2008). The technique effect indicates that globalisation enables a country to get energy-efficient techniques that reduce carbon emissions (Dasgupta *et al.,* 2006). The composition effect reveals that moving from agriculture to industrial increases carbon emissions. However, moving from the industrial to the services sector reduces carbon emissions (Shahbaz, Shahzad, & Mahalik, 2018). This research focuses on two aspects of globalisation: financial and trade globalisation. Therefore, the rest of the section first presents the relevant studies on the linkage between financial globalisation and the environment. Then, this section presents the relevant studies on the association between trade globalisation and the environment, followed by reviews on the linkage between energy consumption and the environment.

Several studies have considered the impact of financial globalisation on the environment. One strand of the literature reveals that financial globalisation deteriorates the environment (see Usman *et al.,* 2020). For instance, Doytch and Uctum (2016) indicate that globalisation worsens the environment through investment inflow. Sadorsky (2011) reveals that financial development accelerates economic growth by consuming energy in the production and development processes. In these production processes, the higher level of energy consumption adversely affects the environment and helps to increase the level of CO_2 emission. Saint Akadiri, Lasisi, Uzuner, and Akadiri (2019) recently revealed that globalisation and energy consumption positively and significantly influence CO_2 emissions in fifteen countries. This transmission mechanism works through economic growth. Globalisation accelerates economic growth in emerging economies (Gandhi & Zhou, 2014), which destroys the natural resources of industrialisation (Feridun *et al.,* 2006). This natural resource destruction adversely affects the environment (Wijen & van Tulder, 2011). Working on similar lines, Katircioglu and Taşpinar (2017) indicate that financial growth causes economic development. This financial development-driven economic development and energy consumption are the key elements of enhancing CO_2 emission. Haseeb, Xia, Baloch, and Abbas (2018) and Pao and Tsai (2010) also provide similar results from BRICS.[4]

[3] See Balsalobre-Lorente, Shahbaz, Roubaud, and Farhani (2018) for the transmission mechanism of economic growth and environmental degradation, including scale, composition, and technical effects.

[4] Haseeb, Xia, Baloch and Abbas (2018) reveal that financial development and energy consumption positively influence CO_2 emission in BRICS economies. Pao and Tsai (2010) report a piece of similar evidence using economic development instead of financial development.

Another strand of literature provides contradictory evidence on this nexus (Mallick, & Mahalik, 2014; Nasreen, Anwar, & Ozturk, 2017; Shahbaz, Hye, Tiwari, & Leitao, 2013; Shahbaz, Tiwari, & Nasir, 2013; and Tamazian, Chousa, & Vadlamannati, 2009). These studies claim that financial development reduces CO_2 emissions by providing less energy-consuming technologies. The current level of development matters in this nexus since globalisation motivates developed economies to invest in green technologies worldwide (also see Bridge, 2002; Dreher, 2006). Therefore, the impact of globalisation depends upon the country's economic condition. For instance, Shahbaz, Mahalik, Shahzad, and Hammoudeh (2019) divulge that globalisation in high- and middle-income economies is expected to decrease CO_2 emissions in future (Jorgenson, & Givens, 2014; Li, Xu, & Yuan, 2015).[5] However, globalisation in low-income economies will positively influence CO_2 emissions. Shahbaz, Mallick, Mahalik, and Sadorsky (2016) reveal that globalisation and financial development in India decrease energy demand in contrast to economic growth and urbanisation. Similar results are observed in Pakistan.[6]

Recent studies also investigate the asymmetric and indirect behaviour of these variables. For instance, Koengkan et al. (2020) report the asymmetric impact of globalisation on the carbon emission of 18 Latin American and Caribbean economies using data from 1990 to 2014. Similarly, You and Lv (2018) analyse globalisation's direct and indirect impact on CO_2 emission (also see Shahbaz, Khan, Ali, & Bhattacharya, 2017). They report that globalisation positively affects CO_2 emissions when analysed directly. However, they reveal that indirectly economic globalisation negatively influences CO_2 emission. A wide range of studies applies the environmental Kuznets curve to investigate the sources of CO_2 emission.[7]

Another strand of literature studies the impact of trade globalisation on carbon emissions. For instance, Managi and Kumar (2009) argue that openness to trade positively influences CO_2 emission through the efficient production process in terms of cost. In particular, trade openness reduces the production cost, due to which companies produce on a large scale by ignoring environmental regulations. Conversely, another strand of literature reports that trade openness deteriorates CO_2 emissions in developed economies (Zhang, Yang, Sun, & Wu, 2017; Zhang, Liu, & Bae, 2017). Consistent with this environmental literature, Le, Chang, and Park (2016) reveal that the sensitivity of ecological degradation is associated with the current income level of the economies. Environmental degradation is less sensitive to trade openness in developed economies than the low- and middle-income economies. The following sub-section synthesises the literature on energy consumption and carbon emission.

Energy Consumption and Carbon Emission

A critical review of the existing literature on the nexus between energy consumption and carbon emission reveals that energy consumption may deteriorate the environment. For instance, Saboori and Sulaiman (2013) report that energy consumption and economic development worsen environmental quality. Similarly, Nasreen, Anwar, and Ozturk (2017) reveal that energy consumption, economic development and population enhance CO_2 emissions and deteriorate environmental quality. A wide range of studies reports that economic growth and energy consumption positively influence environmental degradation (Usman *et al.*, 2020; Soytas *et al.*, 2007; Apergis & Payne, 2010; Alam *et al.*, 2011; Al Mamun *et al.*, 2014; Asif, Sharma & Adow, 2015; Nguyen & Wongsurawat, 2017; Dar & Asif, 2017; Nguyen, 2018). Another strand of literature reports that industrialisation, energy consumption, and urbanisation enhance environmental degradation (Cole & Neumayer, 2004; Parikh & Shukla, 1995; Ma & Du, 2012; York, 2007). Similarly, Zhang and Cheng (2009) report that energy consumption and economic development positively influence CO_2 emissions in China. Looking at the Lithuanian evidence, Liobikiene, Mandravickaite, Krepstuliene, Bernatoniene, and Savickas (2017) compare the economic growth with the environment and reveal that the development of the Lithuanian economy is three times faster than the GHG emission (also see Rahman et al., 2020). Liobikiene et al. (2017) highlight some sectors whose technological contribution to the changes in carbon emission is problematic. Interestingly, this list includes the financial industry.

The above discussion, especially on globalisation and the environment, reveals that the existing literature is inconsistent. There are different reasons for disagreement, including other econometric methods and methodologies and lack of data. Furthermore, to the best of my knowledge, no one has analysed the impact of globalisation and energy consumption on CO_2 emissions in the case of Lithuania. Therefore, further empirical investigation is worthy of applying the appropriate methodology and data (the updated KFI index). This investigation will provide the correct information to the policymakers. In this way, this research aims to fill this research gap, and thus, this study will contribute substantially to the existing body of knowledge.

Data and Empirical Strategy

I use annual time series data from 1988 to 2018 for Lithuania. Table 1 presents a detailed description of each variable. The CO_2 emission values from 1989 to 1994 and from 2014 to onwards are unavailable in World Development Indicators (WDI, 2018). Therefore, I collect the CO_2 emission data from 1992 to 1994 and 2014 to 2016

[5] These studies apply trade openness as a measure of globalisation.

[6] Applying dynamic ARDL simulation model, Khan, Teng, Khan, & Khan (2019) reveal that financial development and energy consumption deteriorates the environment in Pakistan.

[7] For instance, Ahmad, Zhao, Shahbaz, Bano, Zhang, Wang and Liu (2016), Akbostancı, Türüt-Aşık and Tunç (2009), Al Mamun, Sohag, Mia, Uddin and Ozturk (2014), Al-Mulali, Saboori and Ozturk (2015), Begum, Sohag, Abdullah and Jaafar (2015), Jebli and Youssef (2015), Elliott and Shanshan (2008); Dogan and Seker, 2016; Farhani and Ozturk (2015), Halicioglu (2009), Jalil and Mahmud (2009), Jayanthakumaran, Verma and Liu (2012), Nasir and Rehman (2011), Onafowora and Owoye (2014), Pao and Tsai (2011), Ren, Yuan, Ma and Chen (2014), Saboori, Sulaiman and Mohd (2012), Shahbaz, Khraief, Uddin and Ozturk (2014), Tang and Tan (2015), and Tiwari, Shahbaz and Hye (2013).

from the Carbon Dioxide Information Analysis Centre and OCED (2019).[8] Later, I apply backward forecasting to find some missing values. Similarly, the energy consumption values are available from 1989 to 1994 and from 2015 onwards. I use backward and forward forecasting to fill these values. For this purpose, I apply the Autoregressive Integrated Moving Average (ARIMA) model. Existing literature relies on trade oppresses to measure globalisation (See Jorgenson & Givens, 2014; Li, Xu, & Yuan, 2015; Le, Chang, & Park, 2016). I attempt to overcome this issue by including (1) financial globalisation, (2) trade globalisation, and (3) overall globalisation. Financial globalisation consists of foreign direct investment, portfolio investment, international debt, international services, international income payments, investment restrictions, and capital accounts' openness to international investment agreements.[9] Trade globalisation includes trade in goods, services, trade partner diversity, trade regulations, taxes, tariffs, and trade agreements.[10] The overall KOF Globalisation Index is the de facto and de jure Globalisation Index average.[11]

For the variable selection, I include financial globalisation (Shahbaz *et al.*, 2016; Coban & Topcu, 2013; Shahbaz *et al.*, 2018; Abbasi & Riaz, 2016; Charfeddine & Khediri, 2016), trade globalisation (Frankel & Romer, 1999), and overall globalisation (Antweiler *et al.*, 2001; You & Lv, 2018; Shahbaz *et al.*, 2016; Solarin *et al.*, 2017; Solarin *et al.*, 2017), energy consumption (Sadorsky, 2011), economic growth (Shahbaz *et al.*, 2016; Kayhan, Adiguzel, Bayat & Lebe, 2010; Khan *et al.*, 2019), innovation (Potepa & Welch, 2018; Dauda *et al.*, 2019; Gotsch, & Hipp, 2014; Flikkema *et al.*, 2015) and urban population growth (Khan, Sisi & Siqun, 2019) to analyse the impact of these variables on CO_2 emission.

Table 1

Variables of the ARDL Model

V Name	Variable Definition	Source	Code
CO_2	CO_2 emissions (kt)	WDI (2018)	EN.ATM.CO2E.KT
FDG	Financial Globalisation	Gygli et al. (2019)	KOFFiGIdf
TRG	Trade Globalisation	Gygli et al. (2019)	KOFTrGIdf
GLI	Overall Globalisation	Gygli et al. (2019)	KOFGI
ECN	Energy use (kg of oil equivalent per capita)	WDI (2018)	EG.USE.PCAP.KG.OE
GDP	GDP per capita (constant 2010 US$)	WDI (2018)	NY.GDP.PCAP.KD
INV	Innovations, Trademark applications, total	WDI (2018)	IP.TMK.TOTL
URP	Urban population growth % of annual	WDI (2018)	SP.URB.GROW

Model and Bounds Testing Approach

A simple regression model can express the theoretical association between the variables.

$$\mathrm{CO2_t} = \beta_0 + \beta_1 \mathrm{FDG_t} + \beta_2 \mathrm{TRG_t} + \beta_3 \mathrm{GLI_t} + \beta_4 \mathrm{ECN_t} + \beta_5 \mathrm{GDP_t} + \beta_6 \mathrm{INV_t} + \beta_7 \mathrm{URP_t} + e_t \quad (1)$$

I apply linear and non-linear ARDL-Bounds testing approaches for this empirical investigation (also see Rahman, Ghazali, Bhatti, & Khan, 2020). The ARDL modelling approach was initially introduced by Pesaran and Shin (1998) and later extended by Pesaran, Shin, and Smith (2001). The ARDL bounds testing has advantages over other cointegration techniques, including Engle and Granger (1987) and Johansen and Juselius (1990). For instance, the ARDL model does not impose any restrictive assumption that all the variables used in the model must be integrated of the same order. The ARDL model can be applied irrespective of whether the variables are integrated to order zero, order one or fractionally integrated. Second, the ARDL model provides unbiased estimates in the presence of endogenous regressors (Boutabba, 2014; Narayan, 2005). Third, the estimates of most of the cointegration techniques are sensitive to the sample size. I use the following model to test the long-run association under the ARDL bound testing approach.

$$\Delta \mathrm{CO2_t} = \beta_0 + \sum_{i=1}^{p} \varphi_i \Delta \mathrm{CO2_{t-i}} + \sum_{i=1}^{p} \omega_i \Delta \mathrm{FDG_{t-i}} + \sum_{i=1}^{p} \gamma_i \Delta \mathrm{TRG_{t-i}} + \sum_{i=1}^{p} \eta_i \Delta \mathrm{GLI_{t-i}} + \sum_{i=1}^{p} \delta_i \Delta \mathrm{ECN_{t-i}} + \sum_{i=1}^{p} \theta_i \Delta \mathrm{GDP_{t-i}} + \sum_{i=1}^{p} \xi_i \Delta \mathrm{INV_{t-i}} + \sum_{i=1}^{p} \varsigma_i \Delta \mathrm{URP_{t-i}} + \zeta_1 \mathrm{FDG_{t-1}} + \zeta_2 \mathrm{TRG_{t-1}} + \zeta_3 \mathrm{GLI_{t-1}} + \zeta_4 \mathrm{ECN_{t-1}} + \zeta_5 \mathrm{GDP_{t-1}} + \zeta_6 \mathrm{INV_{t-1}} + \zeta_7 \mathrm{URP_{t-1}} + \varepsilon_t \quad (2)$$

Where β_0 the drift component, the rest of the variables are defined above in Table 1, and ε_t denotes the white noise. The first step in the ARDL bound testing approach is to test the long-run association between the variables by applying F-tests. For this purpose, the null and alternative hypotheses are as follows.

$$H_0: \zeta_1 = \zeta_2 = \zeta_3 = \zeta_4 = \zeta_5 = \zeta_6 = \zeta_7 = 0 \quad (3)$$

$$H_2: \zeta_1 \neq \zeta_2 \neq \zeta_3 \neq \zeta_4 \neq \zeta_5 \neq \zeta_6 \neq \zeta_7 \neq 0 \quad (4)$$

The test which normalises CO_2 is represented as follows.

$$F_{CO2} = \left({CO2}/{FDG, TRG, GLI, ECN, GDP, INV, URP} \right) \quad (5)$$

The calculated F-statistics decide the long-run association between the variables. For this purpose, the calculated F-statistics are compared with two sets of critical values estimated by Pesaran, Shin, and Smith (2001). The first set assumes all variables are I(0), and another assumes I(1). In particular, F-statistics higher than the upper bound value indicate the cointegration at a different significance level. Conversely, F-statistics lower than the lower bound value indicate no cointegration at a different significance level. However, the ARDL bounds testing results are

[8] Retrieved from https://cdiac.ess-dive.lbl.gov/ftp/trends/emissions/lit.dat on 25th July 2019.

[9] For further details and sources, see the third and fourth dimension of 2019 KOF Globalisation Index: Variable description (Gygli et al., 2019).

[10] For further details and sources, see the first and second dimension of 2019 KOF Globalisation Index: Variable description (Gygli et al., 2019).

[11] See 2019 KOF Globalisation Index: Methods of Calculation of Gygli et al. (2019).

inconclusive if the calculated F-statistics value lies between the upper and lower bounds. ARDL model estimates $(p+1)^k$ regressions to choose the optimal lag length for each variable, where p and k indicate the maximum number of lags and the number of variables in the model. I apply Akaike's Information Criteria (AIC) and the Schwartz-Bayesian Criteria (SBC) to select the appropriate model. I estimate the following error correction model in case of a long-run relationship between the variables.

$$\Delta CO2_t = \beta_0 + \sum_{i=1}^{p} \varphi_i \Delta CO2_{t-i} + \sum_{i=1}^{p} \omega_i \Delta FDG_{t-i} + \sum_{i=1}^{p} \gamma_i \Delta TRG_{t-i} + \sum_{i=1}^{p} \eta_i \Delta GLI_{t-i} + \sum_{i=1}^{p} \delta_i \Delta ECN_{t-i} + \sum_{i=1}^{p} \theta_i \Delta GDP_{t-i} + \sum_{i=1}^{p} \xi_i \Delta INV_{t-i} + \sum_{i=1}^{p} \varsigma_i \Delta URP_{t-i} + \alpha ECM_{t-1} + \mu_t \quad (6)$$

The results of the error correction model indicate the speed of adjustment back to long-run equilibrium after a short-term shock. The above ARDL measures the long-term and short-term relationship between the variables. However, these models fail to incorporate the asymmetric behaviour of the variables. Considering this non-linearity, Shin et al. (2014) extended the ARDL framework of Pesaran, Shin, and Smith (1999 & 2001). Following Shin et al. (2014), I apply the non-linear ARDL to capture the asymmetric impact of globalisation and energy consumption on CO_2 emissions. In this framework, I extend Equation (1) as follows.

$$CO2_t = \beta_0 + \beta_1 FDG_t^+ + \tau_1 FDG_t^- + \beta_2 TRG_t^+ + \tau_2 TRG_t^- + \beta_3 GLI_t^+ + \tau_3 GLI_t^- + \beta_4 ECN_t^+ + \tau_4 ECN_t^+ + \beta_5 GDP_t + \beta_6 INV_t + \beta_7 URP_t + \mu_t \quad (7)$$

Where the FDG_t^+ and FDG_t^- are the positive and negative partial sum process variations in FDG. These variations are derived as follows:

$$FDG_t^+ = \sum_{j=1}^{t} FDG_j^+ = \sum_{j=1}^{t} \max(FDG_j, 0), FDG_t^- = \sum_{j=1}^{t} FDG_j^- = \sum_{j=1}^{t} \min(FDG_j, 0) \quad (8)$$

Similarly, the positive and negative partial sum variations in TRG, GLI and ECN are derived as follows (also see Malik et al., 2020):

$$TRG_t^+ = \sum_{j=1}^{t} TRG_j^+ = \sum_{j=1}^{t} \max(TRG_j, 0), TRG_t^- = \sum_{j=1}^{t} TRG_j^- = \sum_{j=1}^{t} \min(TRG_j, 0) \quad (9)$$

$$GLI_t^+ = \sum_{j=1}^{t} GLI_j^+ = \sum_{j=1}^{t} \max(GLI_j, 0), GLI_t^- = \sum_{j=1}^{t} GLI_j^- = \sum_{j=1}^{t} \min(GLI_j, 0) \quad (10)$$

$$ECN_t^+ = \sum_{j=1}^{t} ECN_j^+ = \sum_{j=1}^{t} \max(ECN_j, 0), ECN_t^- = \sum_{j=1}^{t} ECN_j^- = \sum_{j=1}^{t} \min(ECN_j, 0) \quad (11)$$

I follow similar steps as performed in the linear ARDL methodology. The multiple lag selection methods indicate that 2 is the appropriate lag for the non-linear ARDL model. I modify Equations 2 and 6 by incorporating the positive and negative partial sum process variations as given in Equations 8 to 11.

Results and Discussion

The first step of the empirical investigation is to check the time-series properties of the variables since none of the variables should be integrated to order two or above (Jalil, Feridun, & Ma, 2010). Table 2 presents the results of unit root tests for each variable using the augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. A critical analysis of Table 2 reveals that all variables are stationary either at the level or at the first difference, confirming that the ARDL Bound testing approach can be applied.

Table 2

Unit Root Test

Variables	**Constant**	**C&T**	**WC&T**	**Constant**	**C&T**	**WC&T**
(1)	(2)	(3)	(4)	(5)	(6)	(7)
At level (ADF)				*PPP*		
CO_2	-1.6175	-3.3341*	-0.5574	-1.6175	-3.3341*	-1.0222
FDG	-1.1223	-1.0388	2.1746	-1.1212	-1.0388	2.1746
TRG	-2.2554	-2.6352	2.0393	-1.9559	-1.5347	2.8297
GLI	-4.7623***	-2.8048	0.4472	-3.1536**	-0.8800	2.6284
ECN	-2.7274*	-2.5117	-1.1290	-3.6951***	-2.6302	-1.2298
GDP	0.9182	-3.0303	2.8803	0.5076	-3.0303	2.2127
INV	-3.2761**	-2.7596	0.5606	-5.1725***	-3.7373**	0.6369
URP	-2.7954*	-3.0678	-0.5354	-7.0136***	-5.9297***	-1.1741
At First Difference (ADF)				*PPP*		
CO_2	-3.0581**	-2.8818	-6.8117***	-7.3537***	-7.2608***	-6.9935***
FDG	-3.9795***	-4.0258**	-3.5148***	-3.9652***	-3.8992**	-3.5065***
TRG	-3.7967***	-4.0977**	-2.9253***	-4.3857***	-6.2821***	-3.7033***
GLI	-2.3927	-4.3597**	-1.8939*	-2.4224	-3.7518**	-1.6554*
ECN	-4.3274***	-4.4128***	-4.2586***	-4.2347***	-4.3383***	-4.1641***
GDP	-3.1529**	-3.2146	-2.5590**	-2.9774**	-3.0689	-2.4808**
INV	-4.3614***	-4.6665***	-4.3280***	-4.2751***	-4.7450***	-4.2403***
URP	-4.7215***	-4.3497**	-4.6582***	-5.9164***	-7.2088***	-5.6901***

Note. C&T and WC&T indicate constant and trend, and without constant and trend, respectively.

Table 3 presents the results of the sequentially modified LR test statistic (each test at a 5 % level), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC), and Hannan-Quinn Information Criterion (HQ) based on the VAR model. The Lag selection criteria for the ARDL model are consistent across all the gauges, and I selected two lags for the ARDL model.

Table 3

Lag Selection for ARDL Model

Lag	LR	FPE	AIC	SC	HQ
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
0	NA	0.0000	-7.3781	-6.9975	-7.2618
1	302.8290	0.0000	-18.7451	-15.3194	-17.6978
2	116.3315*	1.17e-20*	-24.7492*	-18.2785*	-22.7710*

*Note. * indicates lag order selected by the criterion. LR, FPE, AIC, SC, and HQ indicates sequentially modified LR test statistic (each test at 5% level), Final Prediction Error, Akaike Information Criterion, Schwarz Information Criterion, and Hannan-Quinn Information Criterion.*

Then, this study applies the bound test to analyse the long-run association between the variables. Table 4 presents the ARDL bound tests' results and the Bound critical values for F-statistics. Equation 2 is estimated through the OLS procedure, and the calculated test statistics (F=5.5287) is higher than the upper bound value at all level of significance. This indicates strong evidence of a long-run association between the study variables.[12]

Table 4

ARDL Bound Tests

Test Statistic	Value	K
(1)	**(2)**	**(3)**
F-statistic	5.5287	7.0000
Bounds Critical Values for F-statistics		
Significance	Lower Bound	Upper Bound
(1)	(2)	(3)
10%	2.0300	3.1300
5%	2.3200	3.5000
2.50%	2.6000	3.8400
1%	2.9600	4.2600

I estimate Equation 2 through ARDL methodology. In this framework, the total number of estimated regressions is 6561 [$(2+1)^8$]. Table 5 presents the long-run co-efficient results from the ARDL model and the residual diagnostics. The most striking result from Table 5 is that financial globalisation (ζ_1=-0.5213, p<0.01) negatively and statistically significantly impacts CO_2 emissions. This indicates that a one per increase in financial globalisation deteriorates CO_2 emission by 0.52 per cent in the long run. Table 5 provides similar evidence for the short-run since financial globalisation (ω=-0.5665, p<0.01) has a negative statistically significant impact on CO_2 emissions. These results contrast one strand of literature (Doytch & Uctum, 2016; Sadorsky, 2011; Saint Akadiri *et al.*, 2019; Wijen & van Tulder, 2011). However, these results are consistent with another strand of literature (Balsalobre-Lorente *et al.*, 2020; Lin *et al.*, 2014; Lin *et al.*, 2014; Usman *et al.*, 2020; Tamazian, & Rao, 2010; Tamazian *et al.*, 2009; Teng *et al.*, 2020). Our results support the technique effect (Dasgupta *et al.*, 2006), where globalisation enables a country to get energy-efficient techniques that reduce the level of carbon emission. Balsalobre-Lorente et al. (2020) reveal that globalisation reduces international tourism emissions. Another possible reason can be the composition of financial globalisation and its impact on the renewable energy sector. As mentioned, financial globalisation is measured through foreign direct investment, portfolio investment, international debt, international services, international income payments, investment restrictions, and capital accounts' openness to international investment agreements. These financial components increase the renewable energy sector by providing finances to such energy projects, which ultimately help to deteriorate environmental degradation.[13]

Table 5

Long-Run and Short-run Co-Efficient from ARDL Model

Variable	**LRC**	**SRC**	***Variable***	**LRC**	**SRC**
(1)	(2)	(3)	(4)	(5)	(6)
CO_2_1	0.1692	-0.241	GDP_1	-0.8867	-0.511
	0.1736	0.2211		0.4183	0.5071
FDG	-0.5213***	-0.5665***	INV	0.0181	0.0771**
	0.1666	0.1832		0.0387	0.0329
TRG	-0.332	-0.079	URP	0.002	0.0019

[12] The critical values for I (0) and I (1) are 2.96 and 4.26, respectively at 1 per cent level of significance (See Pesaran, Shin, & Smith, 2001).

[13] For the further details on this theoretical nexus, see Hamilton (1995) and Klassen and McLaughlin (1996).

Variable	**LRC**	**SRC**	***Variable***	**LRC**	**SRC**
	0.3982	0.4357		0.0461	0.0449
GLI	0.64	0.4611	URP_1	-0.117	-0.1019***
	0.5826	0.7058		0.0447	0.034
ECN	-0.131	-0.047	ECM		-0.7511**
	0.1817	0.1635			0.3611
ECN_1	0.6843***	0.5401***	C	3.3539	-0.02
	0.1818	0.1453		2.4093	0.0329
GDP	0.9597**	0.8835**			
	0.4523	0.3365			
Residual Diagnostics				ARDL-LR	ARDL-SR
(7)				(8)	(9)
R-square				0.8957	0.8412
Durbin-Watson stat				2.2794	1.8915
Normality Test					
Jarque-Bera				0.1083	1.7717
Probability				0.9473	0.4123
Breusch-Godfrey Serial Correlation LM Test:					
P-value of Chi-Square				0.5021	0.5578
Heteroskedasticity Test: Breusch-Pagan-Godfrey					
P-value of Chi-Square				0.9833	0.3898
Ramsey RESET Test					
F-statistic				1.2145	0.6029
Probability				0.2868	0.4504

*Note. LRC and SRC indicate long-run coefficient and short-run coefficient, respectively. The variables are defined in Table .1. CO_2_1 indicates lag 1 of the CO_2 variable. *, **, and *** indicate the levels of significance at 10 per cent, 5 per cent, and 1 per cent, respectively. Normality test. H_0: Errors are normally distributed. Breusch-Godfrey Serial Correlation LM Test. H_0: Errors are not serially correlated. Heteroskedasticity Test: Breusch-Pagan-Godfrey. H_0: Errors are homoscedastic. Ramsey RESET Test. H_0: The models are adequate.*

Looking at the other aspects of globalisation, I could not find any evidence of the impact of trade globalisation (ζ_2=-0.3322, p>0.10; γ=-0.0786, p>0.10) and overall globalisation (ζ_3=0.3982, p>0.10; η=0.4611, p>0.10) on the CO_2 emissions in the long run as well as in the short-run. These results are consistent with Khan, Teng, Khan, and Khan (2019).[14] One of its possible reasons can be the fact that manufacturing, mining and electricity positively boost CO_2 emissions, which is invalidated by the positive impact of trade openness (also see Solarin *et al.*, 2017; Solarin *et al.*, 2017; Sun *et al.*, 2017; Zakarya *et al.*, 2015; Behera & Dash, 2017). Turning now to energy consumption, Table 5 reveals that energy consumption has a positive and significant impact on CO_2 emission in the long run (ζ_4=0.6843, p<0.01) as well as in the short-run (δ=0.8835, p<0.01) with one-period lag. These results indicate that energy consumption is the primary source of CO_2 emissions in Lithuania, and these results are consistent with the existing literature (Bhattacharya *et al.*, 2017; Shahbaz *et al.*, 2013; Shahbaz *et al.*, 2013; Mehmet *et al.*, 2015; Sarkodie, & Strezov, 2019; Usman *et al.*, 2020; Khan *et al.*, 2020; Wang *et al.*, 2016; Jayanthakumaran *et al.*, 2012; Teng *et al.*, 2020). One may argue that the influence of energy consumption on CO_2 emissions depends upon the production of energy. The empirical evidence is based on the data from 1988 to 2018, and Lithuania has observed several energy transitions during this period. In short, Lithuania switched from a net exporter to a net importer, and the country still produces 25 per cent of the total energy supply domestically. Another possible explanation for these results may be that the country might use traditional fossil fuel sources for energy use, which deteriorates the environment (also see Khan, Teng, Khan, & Khan, 2019).

Looking at the control variables, Table 5 reveals that economic growth has a positive and statistically significant impact on CO_2 emission in the long run (ζ_5=0.9597, p<0.05) as well as in the short-run (θ=0.8835, p<0.05). These results are consistent with the existing literature (Khan *et al.*, 2019; Dinda, 2004; Acquaye *et al.*, 2017; Sharma, 2011; Lau *et al.*, 2014). The most striking observation from the control variables is that innovation positively and significantly impacts CO_2 emission in the short run (ξ=0.0771; p<0.05). These results contradict the existing literature (Khan, Sisi, & Siqun, 2019; Burchart-Korol, Pichlak, & Kruczek, 2016; Jordaan *et al.*, 2017; Lee & Min, 2015). This impact is positive and insignificant in the long run (ζ_6=0. 0181, p>0.10). These results are consistent with Khan, Teng, Khan, and Khan (2019). Interestingly, the urban population growth negatively and significantly impacts the CO_2 emission in the short-run (ς=-0.1019, p<0.01) with a one-period lag. However, this impact is negative and insignificant in the long run (ζ7=-0.117, p>0.10). These results are consistent with the one strand of literature (Cole, & Neumayer, 2004; Fan *et al.*, 2006; York, 2007; Liddle & Lung, 2010).[15]

[14] These results are consistent for the short run.

[15] For the detailed discussion on the urban-population and environment, see Martínez-Zarzoso, and Maruotti (2011).

Table 6

Non-Linear ARDL Bound Tests

Test Statistic	Value	K
(1)	(2)	(3)
F-statistic	4.5208	4.0000
Bounds Critical Values for F-statistics		
Significance	Lower Bound	Upper Bound
(1)	(2)	(3)
10 %	2.2000	3.0900
5 %	2.5600	3.4900
2.50 %	2.8800	3.8700
1 %	3.2900	4.3700

Then, I extend the analysis to the non-linear ARDL model as elaborated in the Data and Empirical Strategy. Table 6 presents the results of the non-linear ARDL bound tests and the Bound critical values for F-statistics. The non-linear form of Equation 2 is estimated through the OLS procedure, and the calculated test statistics (F=4.5208) is higher than the upper bound value at all levels of significance. This indicates strong evidence of a long-run association between the study variables.

Table 7

Non-Linear ARDL Long-run Estimates and Diagnostic Tests

Variable	Coefficient	Prob.
(1)	**(2)**	**(3)**
LFDG_POS	-0.36258	0.0978
LFDG_NEG	0.463212	0.1737
LECN_POS	0.788985	0.0729
LECN_NEG	0.202147	0.3298
C	9.720572	0
Residual Diagnostics		
R-square		0.8051
Durbin-Watson stat		2.0337
Normality Test		
Jarque-Bera		0.9738
Probability		0.6145
Breusch-Godfrey Serial Correlation LM Test:		0.1796
P-value of Chi-Square		0.9141
Heteroskedasticity Test: Breusch-Pagan-Godfrey		5.9249
P-value of Chi-Square		0.4316
Ramsey RESET Test		
F-statistic		0.6276
Probability		0.4375

*Note: _POS and _NEG indicate the partial sums of positive and negative changes. The variables are defined in Table .1. CO_2_1 indicates lag 1 of the CO_2 variable. *, **, and *** indicate the level of significance at 10 per cent, 5 per cent, and 1 per cent, respectively. Normality test. H_0: Errors are normally distributed. Breusch-Godfrey Serial Correlation LM Test. H_0: Errors are not serially correlated. Heteroskedasticity Test: Breusch-Pagan-Godfrey. H_0: Errors are homoscedastic. Ramsey RESET Test. H_0: The models are adequate.*

Table 7 presents the results of the long-term asymmetric association between the variables. For this estimation, I use the general to specific approach for the optimal lag selection (See Shin *et al.,* 2014) and drop all the little lags since these lags can create noise in dynamic multipliers (Katrakilidis & Trachanas, 2012; Fareed *et al.,* 2018). The first section of Table 7 reveals that the positive shock in financial globalisation deteriorates carbon emissions. However, I could not find any significant impact of the negative shock of financial globalisation on CO_2 emissions. In particular, one per increase in financial globalisation deteriorates CO_2 emission by 0.36 per cent in the long run. These results are consistent with the existing literature (Koengkan *et al.,* 2020; Lin, 2014; Lin, 2014; Tamazian, & Rao, 2010; Tamazian *et al.,* 2009). Table 7 further reveals that the positive shock in energy consumption increases carbon emissions. Conversely, the negative shock in energy consumption does not reveal any significant impact on CO_2 emissions. In particular, a one per cent increase in energy consumption enhances carbon emission by 0.79 per cent in the long run. These results reveal a significant asymmetric impact of energy consumption and financial globalisation on

CO_2 emissions. As discussed above, these results indicate that energy consumption is the primary source of CO_2 emissions in Lithuania, and these results are consistent with the existing literature (Sarkodie & Strezov, 2019; Bhattacharya *et al.*, 2017; Shahbaz, Hye, Tiwari, & Leitao, 2013; Shahbaz, Tiwari, & Nasir, 2013; Mehmet, Boluk, & Buyukyilmaz, 2015; Wang, Fang, & Zhou, 2016; Jayanthakumaran, Verma, & Liu, 2012). A possible explanation for these results may be that the country mainly depends upon traditional fossil fuel sources for energy use, which deteriorates the environment (also see Khan, Teng, Khan, & Khan, 2019).

The coefficient of EMC_{t-1} (α=-0.7511; $p<0.05$) has the correct sign. This sign implies that nearly 75.11 per cent of disequilibrium in CO_2 emission of the previous period shock adjusts back to the long-run in the current period. Further, the R^2 indicates that all the independent variables jointly explain 89.57 per cent of variations in CO_2 emission. Columns 7 to 9 of Table 5 present the residual diagnostics for ARDL long-run and short-run models. For the case of residual, null hypotheses are desirable. Columns 8 and 9 of Table 5 reveal that test statistics for all residual hypotheses fall under the non-reject region, indicating that none of the assumptions of OLS models is violated. I further check the stability of the long-run coefficients. For this purpose, Brown, Durbin, and Evans (1975) suggest the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUMSQ) tests. In this framework, The CUSUM and CUSUMSQ statistics are updated recursively, and these statistics are plotted against the breakpoints. For the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUMSQ) tests, the null hypothesis is that all coefficients in the given regression are stable. If the test statistics stay within the critical bounds of a 5 per cent significance level, then the null hypothesis cannot be rejected. This indicates that all coefficients are stable. Figure 4.1 and 4.2 reveals that the test statistics for the CUSUM and CUSUMSQ are within the critical bounds of a 5 per cent level of significance. I do not have enough evidence to reject the null hypotheses, which reveals that all the coefficients are stable.

Further, Column 3 of Table 7 presents the residual diagnostics for the non-linear ARDL long-run models. For the case of residual, null hypotheses are desirable. The respective test statistics for all residual hypotheses fall under the non-reject region, indicating that none of the assumptions of OLS models is violated (see Column 3 of Table 7). Further, Figure 4.3 and 4.4 reveals that the test statistics for the CUSUM and CUSUMSQ are within the critical bounds of a 5 per cent level of significance. I do not have enough evidence to reject the null hypotheses, which reveals that all the coefficients are stable.

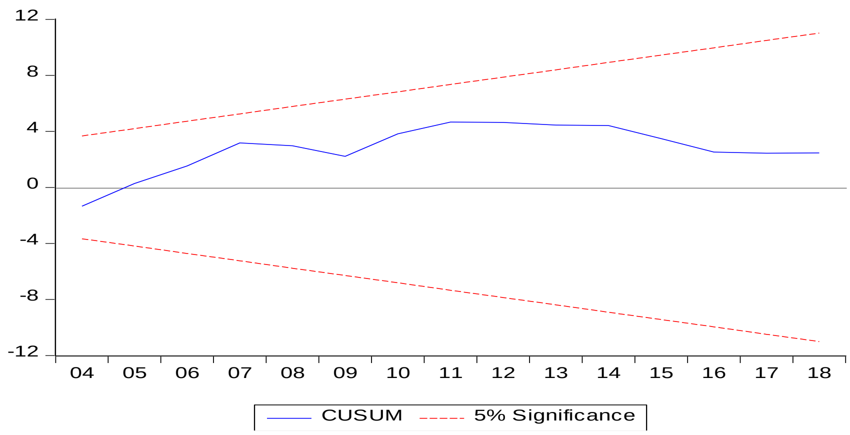

Figure 1. The Plot of the Cumulative Sum (CUSUM) of Recursive Residuals.

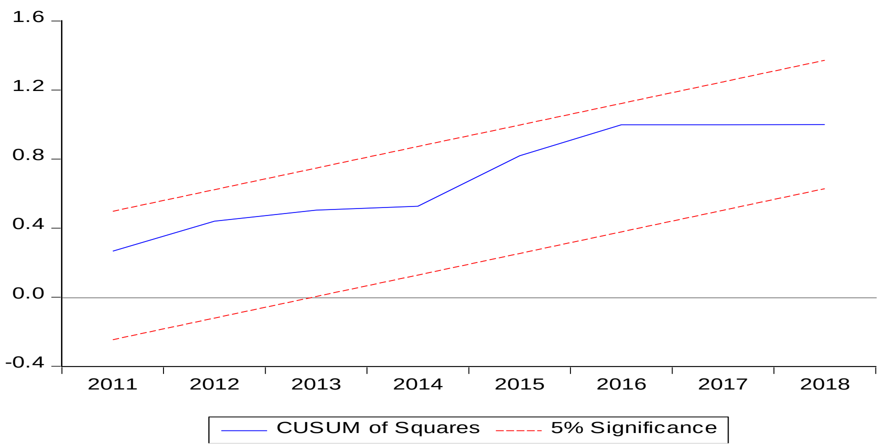

Figure 2. The Plot of the Cumulative Sum of Squares (CUSUMSQ) of Recursive Residuals.

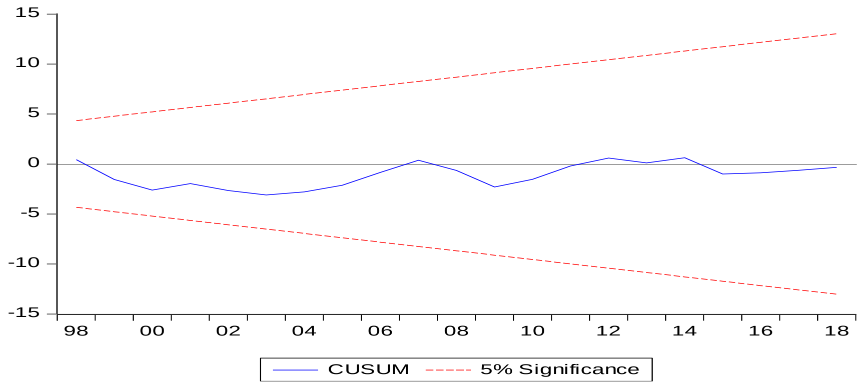

Figure 3. The Plot of the Cumulative Sum (CUSUM) of Recursive Residuals from Non-Linear ARDL

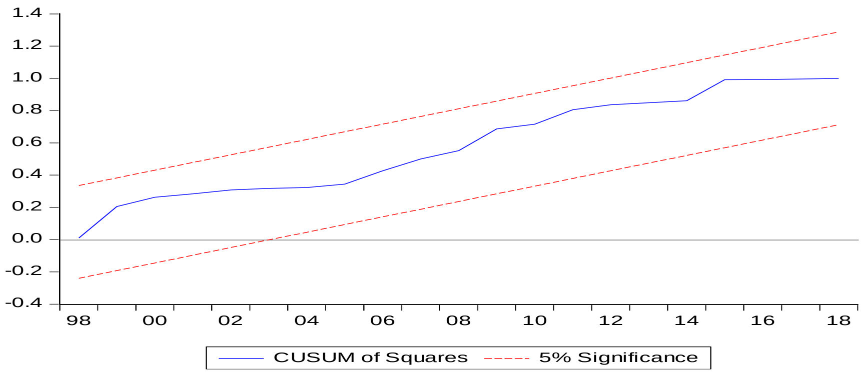

Figure 4. The Plot of the Cumulative Sum of Squares (CUSUMSQ) of Recursive Residuals from Non-Linear ARDL

Conclusion

This study examines the symmetric and non-symmetric impact of globalisation and energy consumption on the CO_2 emissions of Lithuania using the linear and non-linear ARDL bounds testing approach of cointegration. The existing literature ignores different dimensions of globalisation, which is expected to adversely affect our perspective of the association between globalisation and environmental degradation. I use the KOF indices for financial, trade, and overall globalisation to overcome this issue. Financial globalisation includes foreign direct investment, portfolio investment, international debt, international services, international income payments, investment restrictions, and capital accounts' openness to international investment agreements. Trade globalisation includes trade in goods, services, trade partner diversity, trade regulations, taxes, tariffs, and trade agreements. The overall KOF Globalisation Index is the de facto and de jure Globalisation average. The linear and non-linear ARDL bounds testing approach provides strong evidence of a long-run association between the study variables.

Further, financial globalisation has a negative, statistically significant impact on CO_2 emissions. These results support the technique effect where globalisation enables an economy to get energy-efficient techniques that reduce the level of CO_2 emissions. The non-linear ARDL analysis further reveals that the positive shock in financial globalisation deteriorates carbon emissions. The components of financial globalisation in the KOF globalisation index are expected to enhance the renewable energy sector by providing finances to such energy projects, which ultimately help to worsen CO_2 emissions. Future research could use the Maastricht Globalisation Index to analyse the impact of globalisation on carbon emissions. The second distinct section of this empirical investigation reveals that energy consumption positively and significantly impacts CO_2 emissions in the long run. The non-linear ARDL analysis further reveals that the positive shock in consumption enhances CO_2 emissions. The most prominent finding to emerge from this study is that energy consumption is a significant determinant of CO_2 emissions in Lithuania. The impact of energy consumption on CO_2 emissions also depends upon energy production. This study's empirical evidence is based on the data from 1988 to 2018, and Lithuania has observed several energy transitions during this period. In short, Lithuania switched from a net exporter to a net importer, and the country still produces 25 per cent of the total energy supply domestically. Therefore, these results should be interpreted carefully.

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Author's Biography

Habib Ur Rahman earned his PhD in Business from Bond University, Australia. Being an energetic academic and active researcher, Dr Rahman is actively performing his academic roles to promote inquiry, advance the sum of human knowledge, and develop capable and up-to-date business graduates. He is currently working as a Lecturer at the Holmes Institute Australia. Before that, he was associated with Bond University and the University of the Sunshine Coast as a semester teaching fellow and a sessional. Before his doctoral studies, he worked for seven years in the telecommunication industry, performing various roles, including Manager Interconnect Revenue.

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