E3S Web of Conferences **361**, 03008 (2022) https://doi.org/10.1051/e3sconf/202236103008
IConARD 2022

The effect of agricultural productivity and fossil energy use on co₂ emissions in the Philippines; an environmental Kuznets curve approach

Agung Suwandaru[1,*], *Rooswidjajani*[2], and *Harril* Brimantyo[3]

[1]School of Business, Western Sydney University – Bankstown Campus, Milperra, NSW, Australia
[2]Postgraduate Program, University of Merdeka Malang, Indonesia
[3]Faculty of Administrative Science, University of Merdeka Malang, Indonesia

Abstract. This study examines the relationship between agricultural productivity, fossil energy use, urbanization, and economic growth on CO2 emissions. We use data from 1970 to 2015 from the Philippines with data analysis using the ARDL and cointegration. The results confirm that all models have a positive outcome on CO2 emissions. The use of fossil energy and urbanization have a significant effect on CO2 emissions. However, agricultural productivity and economic growth have no significant effect on CO2 emissions. The model shows that the Kuznets curve hypothesis does not happen in the Philippines context. According to the results, the study suggests that the government should pay more attention to environmental impacts and development. Mitigation of the environmental efforts can be supporting the use of renewable energy, low emissions machines, and the effective implementation of environmental regulations.

1 Introduction

Agriculture contributes to the increase in carbon dioxide (CO2) by converting natural ecosystems into agricultural land. This, agricultural productivity is a livelihood in tropical and developing countries such as the Philippines, which undoubtedly plays an essential role in the country's economy. The relatively large population and geographically located close to the equator make the Philippines still dependent on the agricultural sector. However, the relationship between agricultural productivity will affect pollutant emissions, especially CO2, which still requires further investigation. Efforts are generally made to reduce land conversion into agriculture to reduce CO2 emissions. In this case, they experience several obstacles, such as increasing population, socio-political factors, and land tenure.

Concerning carbon dioxide emissions, the Philippines has actively signed the Kyoto Protocol and the United Nations Framework Convention on Climate Change (UNFCCC) treaty in 1994 to reduce the effects of climate change and combat the effects of human activities on the climate system. On the other hand, agricultural mitigation is generally divided into two categories: reducing fossil C consumption and reducing emissions through agricultural production of biofuels. Second, planning and maintaining the stock of biomass

* Correspondent author: 19587312@student.westernsydney.edu.au

and organic C on soils. Furthermore, the Philippines also actively issues laws relating to environmental conservation and reducing gas emissions to support sustainable development goals [1].

This study employs several socio-economic variables (economic growth and urbanization) and environmental degradation (CO2 emissions). In developing countries, urbanization is the economy's main motor. It is the movement of people to cities to fill jobs in the industrial sector and impact the economy. Meanwhile, economic growth is a parameter of a country's development. The relationship between economic growth to CO2 emissions is measured through the Kuznets curve hypothesis [2]. This hypothesis explains that economic growth does not always increase the amount of CO2 emissions. However, at a certain point, there is a reduction in CO2 emissions and an increase in economic growth.

This study aims to fill the gap in the previous literature by using time series data in the Philippines for 46 years, namely from 1970-2015. Several previous studies raised the topic of the Kuznets hypothesis in developing countries. However, in the context of the Philippines, those associated with agricultural productivity and fossil energy use have not been studied further. Therefore, we apply the Autoregressive Distributed Lag (ARDL) and cointegration analysis to examine agricultural productivity, energy fossil use, urbanization, and economic growth on CO2 emissions in the Philippines.

2 Literature review

The study of agricultural productivity is part of the production process, and its effect on CO2 emissions has not been investigated much to enrich the previous literature. Jebli and Youssef [3] found a positive bidirectional correlation between agriculture and CO2 emissions in the north side of African countries. In the same vein, research by Sebri and Abid [4] found that there is a causal effect on agricultural output and the use of energy from oil and electricity.

Furthermore, urbanization is often associated with environmental degradation, but this opinion is still debatable. Wang, Rasool [5] and Bekhet and Othman [6] suggested that urbanization positively affects CO2 emissions. However, Dou, Shahbaz [7] revealed that urbanization in China could significantly reduce CO2 emissions. The implication of reducing CO2 emissions happens because of the policies that recommend the use of clean energy use, including wind energy, bioenergy, hydropower, solar energy, and tidal energy.

Likewise, the use of fossil energy does not always affect increasing CO2 Emissions. Chen and Geng [8] explained that 26 countries of the organization for economic cooperation and development (OECD) members, and Russia, China, India, and Brazil had proven fossil energy use and reduction of CO2 emissions. The results are in line with Yang, Wang [9]. On the other hand, Ali, Gong [10] observed that fossil energy consumption positively affects carbon dioxide emissions.

Meanwhile, economic growth is usually associated with CO2 emissions. A study which revealed that GDP positively affected CO2 emissions is Rauf, Liu [11], who took samples from 52 countries from 1980-2016. Similar studies are conducted by Abid [12], Maji, Habibullah [13] and Sethi, Chakrabarti [14]. In contrast, Lee [15] explained that economic growth negatively affected on CO2 emissions in countries that are members of the G20.

Concerning CO2 emissions, the Kuznets hypothesis is often used to measure the effects of economic development on the environment. Several works of literature focus on the Kuznets curve hypothesis, where economic growth positively affects increasing pollution emissions. For example, research by Alper and Onur [16] taking samples from China from 1977-2013, found evidence of a Kuznets curve in the output of CO2 emissions from gaseous transportation and solid and liquid fuel consumption. The results of this study are supported by Benavides, Ovalle [17], Kasman and Duman [18] and Rafindadi and Usman [19].

However, studies that are not in the same direction include Fujii and Managi [20], and Sunday Adebayo, Saint Akadiri [21].

3 Data, empirical model, and methodology

The study measures the effect of agricultural productivity (*Agri*), urbanization (*Urban*), fossil energy use (*Fossil*) and economic growth (*GDP*) on Carbon dioxide emissions (*CO2*) using the Kuznets method in the Philippines. The annual data used is multivariate time series data from 1970 to 2015 from World Bank Data [22]. The advantage of annual data is that it eliminates seasonal variations in the dataset.

We apply the Cobb-Douglas Production function to measure the effect of agricultural productivity and use of fossil energy and other variables of interest on CO2 emissions in the Philippines. The Cobb-Douglas production function with a constant yield and an aggregate output function using t as a time symbol can be expressed as follows.

$$Y_t=AK_t^{\mu}L_t^{1-\mu} \tag{1}$$

$$CO2=f\ (Y_t) \tag{2}$$

Where μ is the symbol parameter $\mu\,\epsilon$ (0,1), the degree of capital intensity in the mdel production function. Y_t is the dependent variable which indicates a scalar measurement of a production function. This study assumes that an increase in the economy is usually indicated by a positive increase in carbon-dioxide emissions. The human economic activity causes pollution to the environment and causes an increase in the amount of CO2 emissions as seen in equation (2).

The symbol A is an endogenous variable. L represents the number of effective workers. We use urbanization as the economy's driving force as proxy for L. in most of developing countries, urbanization can trigger to create fast economic activities. K indicates the accumulation of physical capital and the use of technology levels. The capital that causes intensive pollution can be reflected in the non-renewable energy resources. Meanwhile, capital that does not cause pollution can be replaced with the renewable energy resource and does not emit CO2 emissions, which is shown below.

$$K=K_{NR}+K_R \tag{3}$$

Where K_NR is a capital that drains the energy resource and contributes significantly to environmental pollution. Therefore, this study will only take this K_{NR} variable in the model and use fossil fuel energy consumption as a proxy variable. We add Gross domestic per capita (GDP) because produce emission output to increase it. Then, the measurement of the existence of the environmental Kuznets curve to urbanization is by adding the squared of gross domestic product ($GDPSq$). General form for the model as written as:

$$CO2=f\,(Urban,\ Fossil, GDP, GDPSq) \tag{4}$$

Furthermore, there is still uncertainty about whether the country's economic activities, such as agricultural productivity can affect CO2 emissions. Agricultural productivity is the result of activities in the agricultural sector to produce various agricultural products. These activities can be in the form of land clearing, tillage before and after agricultural planting, the use of fertilizers that can be in the form of natural (compost) or chemical fertilizers (fertilizers from chemical compounds), harvesting crops and transporting crops to marketplaces. These activities can undoubtedly affect CO2 emissions. Research linking agriculture with CO2 emissions includes Jebli and Youssef [3] and Sebri and Abid [4]. The model will be as;

$$CO2=f\,(Urban,\ Fossil, GDP, GDPSq,\ Agri) \tag{5}$$

Then we change the equation into a multivariate regression in the form of natural logarithms. The advantage of changing variables in the form of natural logarithms is to facilitate the calculation process and minimize the heterogeneity bias in the regression model. The regression model is as follows.

$$lnCo2= \vartheta_0+ \vartheta_1 lnUrban_t+ \vartheta_2 lnFossil_t+ \vartheta_3 lnGDP_t+ \vartheta_4 lnGDPSq_t+ \vartheta_4 lnAgri_t \quad (6)$$

Based on equation (8), the value of ϑ_0 will be positive if energy use increases in economic activity. The increasing value because the consumption of energy sources driven by economic activity will cause an increase in CO2 emissions. Likewise, an increase in the number of urban residents is expected to cause the value of ϑ_1 to be positive. The rate of urbanization is fuel for the productivity of factories to increase production capacity due to the increasing number of workers who are ready to work. The value of the coefficient ϑ_2 is also expected to be positive, as stated above; namely, fossil energy use will increase carbon dioxide emissions. In line with that, the positive sign of ϑ_3 is due to economic activities as aggregate in the country, which is still dominated by non-renewable energy in economic activity. In other words, it can be said that an increase in per capita income will aggravate environmental conditions. On the other hand, the EKC hypothesis is expected to contribute a negative ϑ_4 value to developing and becoming rich countries. The EKC hypothesis will be different if it occurs in countries with strong economic and government foundations. Acceleration of economic activity is supported by advanced technology so that it is more efficient and friendly to the environment.

The agricultural sector is one of the characteristics of developing countries such as the Philippines. The country's location near the equator makes the tropical climate suitable for agriculture. The effects of agriculture can be positive and negative (ϑ_5 and - ϑ_5) depending on how farming is to be done. A positive impact is obtained if agricultural activities consider a friendly environment. On the other hand, exploitative agricultural activities can threaten environmental sustainability.

Model analysis using autoregressive distributed lag (ARDL) for cointegration [23]. ARDL can be used if the data variables in the model are stationary at the level *I(0)* or *I(1)* or a mixture of them. Moreover, the ARDL method is very suitable for small samples and can simultaneously provide short-run and long-run independent variables [24]. ARDL framework representation will be as:

$$\begin{aligned}\Delta\, lnCO2_t = {} & \rho_0 + \beta_1 lnCO2_{t-1} + \beta_2 lnUrban_{t-1} + \beta_3 lnFossil_{t-1} + \beta_4 lnGDP_{t-1} + \\ & \beta_5 lnGDSq_{t-1} + \beta_6 lnAgri_{t-1} + \textstyle\sum_{i=1}^{n} \delta_{1i} \Delta lnCO2_{t-i} + \\ & \textstyle\sum_{i=1}^{n} \delta_{2i} \Delta lnUrban_{t-i} + \sum_{i=1}^{n} \delta_{3i} \Delta lnFossil_{t-i} + \sum_{i=1}^{n} \delta_{4i} \Delta lnGDP_{t-i} + \\ & \textstyle\sum_{i=1}^{n} \delta_{5i} \Delta lnGDPSq_{t-i} + \sum_{i=1}^{n} \delta_{6i} \Delta lnAgri_{t-i} + \varepsilon_t \quad (7)\end{aligned}$$

In equation (7), ρ and ε are constant and error term respectively. $\delta_1, \delta_2, \ldots, \delta_6$ denote the error correction dynamics. $\beta_1, \beta_2, \ldots \beta_6$ are long-run relationship. The general error correction model (ECM) can be estimated as follows:

$$\begin{aligned}\Delta lnCO2_t = {} & \gamma_0 + \textstyle\sum_{i=1}^{n} \delta_{1i} \Delta lnCO2_{t-i} + \sum_{i=1}^{n} \delta_{2i} \Delta lnUrban_{t-i} + \\ & \textstyle\sum_{i=1}^{n} \delta_{3i} \Delta lnFossil_{t-i} + \sum_{i=1}^{n} \delta_{4i} \Delta lnGDP_{t-i} + \sum_{i=1}^{n} \delta_{5i} \Delta lnGDPSq_{t-i} + \\ & \textstyle\sum_{i=1}^{n} \delta_{6i} \Delta lnAgri_{t-i} + nECT_{t-1} + \partial_t \quad (8)\end{aligned}$$

ECT is the speed of adjustment in the model. It shows how quickly for the variable to return in the long-run equilibrium. The coefficient sign should be in the negative sign.

 https://doi.org/10.1051/e3sconf/202236103008

4 Results and discussion

Graph (1) describes the trend of all variables in one frame with a span of 46 years from 1970 to 2015. The GDP variable is a portrait of the Philippine economy yearly and experienced a drastic decline from 1984-1985. The $lnGDP$ squared variable looks dynamic, moving up and down from time to time during the study period. Meanwhile, the agricultural variable gradually decreased during the research period. On the other hand, variable agricultural productivity and consumption of fossil energy are relatively stable from time to time.

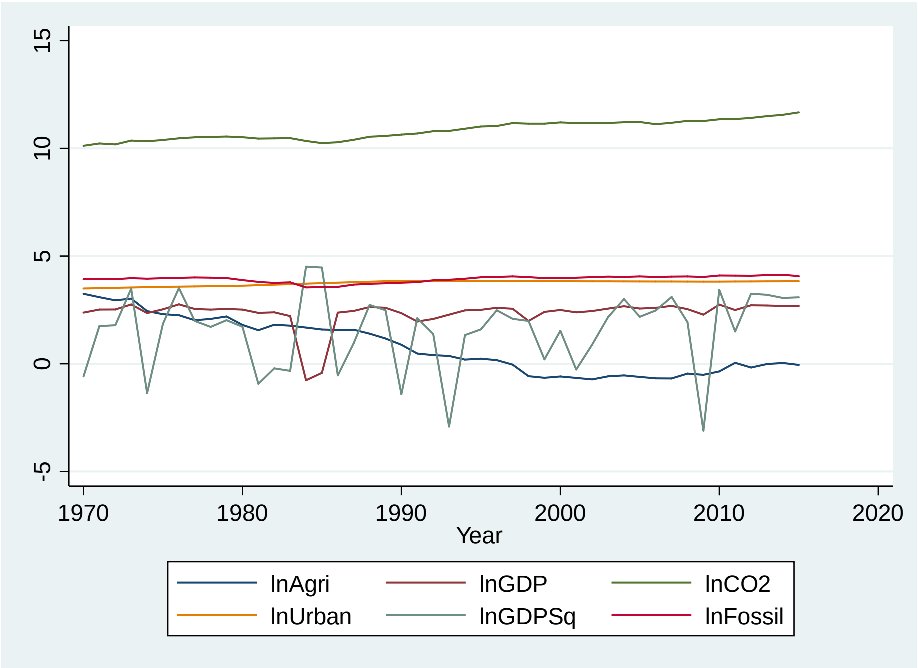

Fig. 1. Trend of Variables

To test the data, we implement the augmented Dickey-Fuller (ADF) and Phillip-Perron (PP) unit root tests. The null hypothesis for ADF and PP is that the data series has a unit root, and the alternative hypothesis is stationary. Table 1 describes the results of the unit root tests for ADF and PP on all variables and the natural logarithm and first difference levels. The results show that all variables are stationary at the first difference level (*I(1)*) except for the urbanization variable, which is stationary at level (*I(0)).* The findings of this root test validate the use of ARDL in the next step.

Table 1. Unit Root Test Results

Variable	ADF		PP	
	I(0)	I(1)	I(0)	I(1)
$lnCO2$	0.033	-5.909***	-0.133	-5.996***
$lnUrban$	-5.076***	n/a	-3.061**	n/a
$lnGDP$	-3.625***	-6.421 ***	-3.581***	-6.631***
$lnGDPsq$	-6.577***	-10.036***	-6.600***	-13.323***
$lnFossil$	-1.012	-5.724***	-1.301	-5.831***
$lnAgri$	-2.310	-5.912***	-2.283	-5.932***
Note: *, ** and *** indicate 10%, 5% and 1% significancy level.				

Table 2 confirms the cointegration results between CO2 emissions, urbanization, fossil energy use, gross domestic product, and agricultural productivity variables in the context of the Kuznets hypothesis. The results show that the F-static value is 12,172 is greater than lower critical bounds and upper critical bounds at 1%, 5% and 10%. This F statistic value indicates the existence of cointegration, which means there is a long-run relationship in the model of the Philippines case.

Table 2. Cointegration Test

Test statistics	**Value**	**K**
F-Stats	12.172	5
Probability	F stats	
	I(0)	*I(1)*
1%	3.41	4.68
5%	2.62	3.79
10%	2.26	3.35
Note: H_0: No relationship and H_1: Relationship presents		

The long-run ARDL regression of CO2 emissions, urbanization, fossil energy use, Gross domestic product and agricultural productivity is reported in Table 3. The ECT test result shows significance at the 10% level. The ECT coefficient value, which is -0.095, indicates that the speed equilibrium adjustment from short-run to long-run is 0.095% of the distortion model that occurred in the first year. The long-run coefficient of 8.912 for the urbanization variable indicates that an upsurging of 1% will increase CO2 emissions by 8.9%. The correlation between the urbanization variable and CO2 emissions has a significance of 1%. Research that supports this result is Wang, Rasool [5].

While the GDP variable has a positive coefficient value of 0.485, an increase of 1% will step up CO2 emissions by 0.48% in the long run. The $lnGDPSq$ variable also gets a positive coefficient value of 0.083, which means that every 1% increase will increase CO2 emissions by 0.083% in the long run. The results indicate that there is no effect of the Kuznets hypothesis in the Philippines. A positive coefficient value is evidence of the absence of a relationship of U-shaped between GDP and CO2 emissions. Increased economic growth cannot reduce the amount of CO2 emissions. Various regulations relating to laws in the Philippines, such as Law no. 3572 concerning the Prohibition of Cutting down Tindalo, Akle or Molave Trees, under certain conditions, impose penalties for violations, Law of The Republic of No. 9154, namely the Law on Mount Kanla-on Natural Park (TNMK) of 2001, Presidential Decree No. 984, which regulates the revision of the Republic of Indonesia Law No. 3931 on pollution control laws, and for other purposes and other environmental laws have not been able to effectively reduce CO2 emissions. Supporting research is Narayan and Narayan [25]

The $lnFossil$ variable has a significant coefficient value of 2,937, meaning that every 1% addition of $lnFossil$ will increase CO2 emissions by 0.029%. These results indicate that the Philippines' dependence on fossil energy sources is still high for motor fuels and production machines. Research that has the same result is Ali, Gong [10].

Finally, the agricultural productivity variable with coefficient value of 0.587. The value means that every 1% increase in agricultural productivity will increase the amount of CO2 emissions by 0.59%. Agricultural productivity cannot reduce CO2 emissions even though it operates in the natural sector. This result indicates that agricultural products in the Philippines are still exploitative and do not support environmental sustainability. Research that supports the results of the study is Sebri and Abid [4]

Table 3. ARDL Regression

Dependent Variable	$lnCO2$ (1,0,0,0,0,0)		
Variable	Coefficient	SE	t-stats
ECT_{t-1}	-0.095	0.051	-1.85*
Long-run			
$lnUrban$	8.912	4.723	1.89*
$lnGDP$	0.485	0.336	1.43
$lnGDPsq$	0.083	0.058	1.45
$lnFossil$	2.937	1.197	2.45**
$lnAGRI$	0.587	0.445	1.32
Constant	-3.367	0.872	-3.86***
R-sq	0.676		
Observation	42		
Diagnostic Tests	**Probability**	**Note**	
Jarque bera	0.348	Normal	
White's test	0.687	Homoscedastic	
Breusch-Godfrey LM	0.1192	No serial correlation	
Durbin-Watson	2.301	No autocorrelation	
Note: ***,** and * signs indicate 10%, 5%, and 1%.			

The diagnostic tests show that all variables are normal where there is no non-normality in the residual term. Evidence of normality implies that the error term is distributed at zero mean and covariance. The autoregression test shows no autoregressive; the same is true for white heteroscedastic. The Breusch-Godfrey LM test shows no serial-correlation in the chosen model.

5 Conclusions

This study objectives to measure the effect of agricultural productivity, urbanization, and economic growth on CO2 emissions in the Philippines from 1970 to 2015. Data analysis using ARDL shows a long-term relationship between variable interests and CO2 emissions. The variable of fossil energy use and urbanization has a positive and significant effect on CO2 emissions. Meanwhile, agricultural productivity and economic growth variables have a positive and insignificant effect. Interestingly, this study reveals no U-shape between economic growth and CO2 emissions. The Kuznets hypothesis does not occur, possibly due to several factors, namely regulatory, implementation factors, and the lack of a strategic road map that supports sustainable development. At the regulatory level, this study suggests that to encourage the implementation of environmental laws, energy efficiency, emissions audits, carbon tests for car motors, and fuel replacement for public transportation should be carried out effectively.

References

1. Lloyd, S. and T. Nakamura, *Public Perceptions of Renewable Energy in the Philippines.* Sustainability, (2022). **14**(16): p. 9906.
2. Shahbaz, M. and A. Sinha, *Environmental Kuznets curve for CO2 emissions: a literature survey*. Journal of Economic Studies, (2019).

3. Jebli, M.B. and S.B. Youssef, *The role of renewable energy and agriculture in reducing CO2 emissions: Evidence for North Africa countries.* Ecological indicators, (2017). **74**: p. 295-301.
4. Sebri, M. and M. Abid, *Energy use for economic growth: A trivariate analysis from Tunisian agriculture sector.* Energy policy, (2012). **48**: p. 711-716.
5. Wang, Z., et al., *Dynamic linkage among industrialisation, urbanisation, and CO2 emissions in APEC realms: evidence based on DSUR estimation.* Structural Change and Economic Dynamics, (2020). **52**: p. 382-389.
6. Bekhet, H.A. and N.S. Othman, *Impact of urbanization growth on Malaysia CO2 emissions: Evidence from the dynamic relationship.* Journal of cleaner production, (2017). **154**: p. 374-388.
7. Dou, Y., et al., *How natural disasters affect carbon emissions: the global case.* Natural Hazards, (2022): p. 1-27.
8. Chen, W. and W. Geng, *Fossil energy saving and CO2 emissions reduction performance, and dynamic change in performance considering renewable energy input.* Energy, (2017). **120**: p. 283-292.
9. Yang, X., et al., *Impacts of energy consumption, energy structure, and treatment technology on SO2 emissions: A multi-scale LMDI decomposition analysis in China.* Applied energy, (2016). **184**: p. 714-726.
10. Ali, M.U., et al., *Fossil energy consumption, economic development, inward FDI impact on CO2 emissions in Pakistan: testing EKC hypothesis through ARDL model.* International Journal of Finance & Economics, (2021). **26**(3): p. 3210-3221.
11. Rauf, A., et al., *Testing EKC hypothesis with energy and sustainable development challenges: a fresh evidence from belt and road initiative economies.* Environmental Science and Pollution Research, (2018). **25**(32): p. 32066-32080.
12. Abid, M., *Impact of economic, financial, and institutional factors on CO2 emissions: evidence from sub-Saharan Africa economies.* Utilities Policy, (2016). **41**: p. 85-94.
13. Maji, I.K., M.S. Habibullah, and M.Y. Saari, *Financial development and sectoral CO2 emissions in Malaysia.* Environmental Science and Pollution Research, (2017). **24**(8): p. 7160-7176.
14. Sethi, P., D. Chakrabarti, and S. Bhattacharjee, *Globalization, financial development and economic growth: Perils on the environmental sustainability of an emerging economy.* Journal of Policy Modeling, (2020). **42**(3): p. 520-535.
15. Lee, J.W., *The contribution of foreign direct investment to clean energy use, carbon emissions and economic growth.* Energy policy, (2013). **55**: p. 483-489.
16. Alper, A. and G. Onur, *Environmental Kuznets curve hypothesis for sub-elements of the carbon emissions in China.* Natural Hazards, (2016). **82**(2): p. 1327-1340.
17. Benavides, M., et al., *Economic growth, renewable energy and methane emissions: is there an enviromental kuznets curve in Austria?* International Journal of Energy Economics and Policy, (2017). **7**(1): p. 259-267.
18. Kasman, A. and Y.S. Duman, *CO2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: a panel data analysis.* Economic modelling, (2015). **44**: p. 97-103.
19. Rafindadi, A.A. and O. Usman, *Globalization, energy use, and environmental degradation in South Africa: startling empirical evidence from the Maki-cointegration test.* Journal of environmental management, (2019). **244**: p. 265-275.

20. Fujii, H. and S. Managi, *Which industry is greener? An empirical study of nine industries in OECD countries.* Energy Policy, (2013). **57**: p. 381-388.
21. Sunday Adebayo, T., et al., *A time-varying analysis between financial development and carbon emissions: evidence from the MINT countries.* Energy & Environment, (2022): p. 0958305X221082092.
22. Bank, W., *World Development indicators*. (2021).
23. Hussain, I. and A. Rehman, *Exploring the dynamic interaction of CO2 emission on population growth, foreign investment, and renewable energy by employing ARDL bounds testing approach.* Environmental Science and Pollution Research, (2021). **28**(29): p. 39387-39397.
24. Kripfganz, S. and D.C. Schneider. *ardl: Stata module to estimate autoregressive distributed lag models*. in *Stata Conference, Chicago*. (2016).
25. Narayan, P.K. and S. Narayan, *Carbon dioxide emissions and economic growth: Panel data evidence from developing countries.* Energy policy, (2010). **38**(1): p. 661-666.