Asymmetric Determinants of CO2 Emissions in China: Do Government Size and Country Size Matter?

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Abstract

CO_2 emission reduction is a long-term strategy for China to promote its government and country size. However, this study examines the asymmetric impact of government size and country size on CO_2 emissions in China. The study embraces the nonlinear ARDL framework of time series data analysis as proposed by Shin et al. (2014), which disentangles the positive and negative shocks to government size and country size. We find that the response of CO_2 emissions to government size and country size positive shocks differs from the negative shocks. Empirical outcomes revealed that a positive shock of government size exerts an insignificant positive on CO_2 emissions, while a negative shock of government size reduces CO_2 emissions. More specifically, a positive shock of country size mitigates the CO_2 emissions of China in long run. Policymakers should redesign the energy and environment policies in the framework of government size and country size.

Introduction

In recent times, the most daunting challenges faced by the world are climate change and global warming (Apergis and Ozturk 2015 and Khan and Ozturk 2021). According to Danish et al. (2018), anthropogenic activities are infusing massive amounts of carbon emissions into the atmosphere, which is a major cause behind rising temperatures, floods, droughts, weather fluctuations, famine and storms. As a result, a plethora of studies tried to find the factors that could ease the pressure on the environment without compromising economic growth. Particularly, the efforts to control greenhouse gas (GHG) emissions gathered the pace by signatory of the Kyoto Protocol. The agreement was signed in 1997 and became functional in 2005. In 2015, United Nations (UN) also joined the efforts to control GHG emissions and asked for greater production and consumption for renewable energy in the 7th goal of sustainable development. Attaining net-zero status by 2050, i.e. to keep the 1.5°C targets, the GHS emissions should be controlled by 45% till 2030 compared to the 2010 level (Marcucci et al. 2019). Literature on the determinants of environmental degradation suggests that economic growth is one of the most significant factors in determining environmental quality. According to Grossman and Kreuger (1994), the relationship between economic development and environmental quality follows an inverted U-shaped path known as the Environmental Kuznets Curve (EKC), suggesting that environmental quality worsens at the early stages of economic development and improves at the later stages. After that, many other empirics also found support for the EKC hypothesis for many other countries and regions (Ozturk and Salah Uddin 2012 and Aslam et al. 2021). Despite the growing body of literature on the EKC hypothesis, there is still an ambiguity or inconclusiveness in the effects of economic growth on environmental quality.

The relationship between economic growth and environmental quality depends on various other factors. The size of the government and the size of the country play an important role in determining this relationship. Debate in the context of the government's role in improving environmental quality is becoming more and more significant in the field of economics as well political sciences (Ozturk and Acaravci 2010; Salahuddin et al. 2018). Most of the debate on the relationship between government size and environmental quality mainly revolves around a few critical questions: whether the large size of government increases environmental pollution or not; whether good governance improves environmental quality or not; and through which channels government size affects the environmental quality. However, the theoretical and empirical literature has not reached any conclusion regarding the effects of government size on environmental quality. It is considered that rising government size can have positive external effects on environmental quality, and as a result, the size of governments in emerging economies is growing (Vogler and Jordan 2003; Apergis and Ozturk 2015).

In recent times, environmental quality factors hold a key position in empirical analysis and policymaking in applied economics (Acaravci and Ozturk 2010; Danish et al. 2021). For instance, if government size can affect the economy's growth rate, it can also be considered an important long-run factor in determining energy consumption and environmental quality in any economy. Nevertheless, in this context, there is a contradiction in empirical findings and theoretical positions. Theoretically, one strand of literature highlighted the negative impact of large government size on environmental quality because the government sectors are often termed to be inefficient in their working and waste a lot of resources. For instance, investments by subsidized and inefficient public sector enterprises in different fields such as manufacturing, banking, agriculture, and energy are more likely to infuse a massive amount of CO_2 emissions into the atmosphere (Zimmerman 2005; Lopez and

Palacios 2010; Ullah et al. 2020a). Contrariwise, another strand of literature highlighted that role of government is very important in policymaking regarding the protection of the environment. The government can also push the society towards the use of more energy-efficient products, clean and green technology, and renewable energy, which indicates that the larger the government size of any country, the better the environmental quality will be. The basic logic behind this argument is that government plays a critical role in bridging the differences between public and private interests and providing an optimal solution for protecting the environment (Galinato and Islam 2017; Halkos and Paizanos 2016).

Thus, a plethora of empirical analyses on the effect of government spending on CO2 emissions was made by Lopez et al., 2011; Halkos and Paizanos, 2016, Ullah et al., 2020), among others. While the empirical literature on country size and the environment nexus is ignored. The linkage between country sizes with quality of environment is complex because it affects through different channels, like economic structure, technology, and preferences. The nature of degradation of the environment also depends on the structure of economic size that varies with the size of the economy. The large economy structure is different than the small economy. A large economy consumes more energy consumption than a small economy, thus large economies generate more carbon emissions (Ang, 2008). There is also a need to consider the fundamental values of various natural resources. It is generally assumed that higher levels of economy allow the comparative amenity of caring about conveniences such as biodiversity and landscapes. Several higher economies place a higher value on conservation and protection (Davis, 1992 and Ullah et al., 2020). Different preferences between the large economies than small economies are essentially a query because it is more important for economic as well environmental pollution.

From a theoretical perspective, it is not potential to forecast how the quality of the environment will change with changes in country size, specifically in the case of involvement of public goods. The query becomes more submissive empirically where some particular patterns are observed. The empirical evidence recommends that, although there is no predictable pattern of the transformation of environment with respect to country size at a comprehensive level, there are clear associations between country size and environmental factors. The literature noted that the quality of the environment is directly influenced by human wellbeing, higher incomes level, and economic activities. The country's size has significantly improved the use of energy over the last few decades.

Empirically, the consensus has not reached whether the government size improves the environmental quality or deteriorates it. For instance, Carlsson and Lundström (2001) observed that government size supports a decrease in energy effectiveness and a rise in CO2 emissions. On the other side, Halkos and Paizanos (2013) pointed out the direct and indirect effects of government size on environmental pollution. They observed that direct effects couldn’t be clearly stated, whereas indirect effects come through the channel of economic growth. Moreover, the effects of government size on the environment can vary significantly across different economies. According to Kotera et al. (2012) a large government can effectively control corruption, thus improving the environmental quality. The contradictory results in empirical findings suggest that the relationship between government size and environmental quality is dubious and not clear. The researchers are still unable to find a clear direction of the effects of government size on environmental quality. Previous studies have relied on panel data that suffer from aggregation bias (Ullah et al. 2020a). There are very few studies that exist in the available literature that has used time series analysis. Therefore, we aim to investigate the short and long-run impact of government size and country size on CO2 emissions in China, a larger global emitter of carbon and the world's largest economy.

Model And Methods

In this paper, we want to capture the asymmetric contribution of government size, country size, trade, and energy consumption in polluting the environment of an emerging economy viz. China. The previous studies have guided us to the following long-run specification (1):

$$CO_{2,t} = \alpha_0 + \alpha_1 Gsize_t + \alpha_2 Csize_t + \alpha_3 Trade_t + \alpha_4 EC_t + \mu_t \quad \text{-------} \ (1)$$

In this model (1) CO_2 emissions in kilotons is used as a proxy of environmental quality. The main contributors in emitting CO_2 include government size (Gsize), country size (Csize), trade, and energy consumption (EC). Equation (1) is a basic long-run model and we need to represent it in an error correction form as prescribed by Pesaran et al. (2001).

$$\Delta CO_{2,t} = \pi + \sum_{p=1}^{n1} \pi_{1p}\, \Delta CO_{2,t-p} + \sum_{p=0}^{n3} \pi_{2p}\, \Delta Gsize_{t-p} + \sum_{p=0}^{n4} \pi_{3p}\, \Delta Csize_{t-p} + \sum_{p=0}^{n5} \pi_{4p}\, \Delta Trade_{t-p} + \sum_{p=0}^{n5} \pi_{5p}\, \Delta EC_{t-p} + \beta_1 CO_{2,t-1} + \beta_2 Gsize_{t-1} + \beta_3 Csize_{t-1} + \beta_4 Trade_{t-1} + \beta_5 EC_{t-1} + \mu_t \quad \text{---------} (2)$$

Pesaran et al. (2001) called model (2) as a linear ARDL model. This model performs well even if the sample size is small. Besides, this single model can provide both the short-run and the long-run estimates. The coefficient estimates attached to the variables with Δ signs provide the short-run effects and the long-run effects are provided by the estimates of β_2-β_4 normalized on β_1. However, the long-run results are considered genuine only if co-integration is confirmed among them. Pesaran et al. (2001) proposed two different co-integration tests namely, bounds F-test and t-test and developed critical values for both these tests. Another and foremost advantage of this technique is that it can estimate the variables with different integrating properties i.e. I (0) or I (1) and even a mixture of both. Next, the asymmetric impacts are to be calculated. For that purpose, we first divide the main independent variables into their positive and negative components with the aid of partial sum procedure as shown below:

$$Gsize^{+}{}_{t} = \sum_{n=1}^{t} \Delta Gsize^{+}{}_{t} = \sum_{n=1}^{t} \max\ (Gsize^{+}{}_{t}, 0) \qquad (3a)$$

$$Gsize^{-}{}_{t} = \sum_{n=1}^{t} \Delta Gsize^{-}{}_{t} = \sum_{n=1}^{t} \min\ (\Delta Gsize^{-}{}_{t}, 0) \qquad (3b)$$

$$Csize^{+}{}_{t} = \sum_{n=1}^{t} \Delta Csize^{+}{}_{t} = \sum_{n=1}^{t} \max\ (\Delta Csize^{+}{}_{t}, 0) \qquad (4a)$$

$$Csize^{-}{}_{t} = \sum_{n=1}^{t} \Delta Csize^{-}{}_{t} = \sum_{n=1}^{t} \min\ (\Delta Csize^{-}{}_{t}, 0) \qquad (4b)$$

The positive series are provided in equations 3a & 4a, whereas, the negative series are presented in equations 3b & 4b. The next step towards non-linear analysis is to replace these positive and negative series in place of original variables in equation (2).

$$\Delta CO_{2,t} = \omega_0 + \sum_{k=1}^{n} \pi_{1k} \Delta CO_{2,t-k} + \sum_{k=0}^{n} \pi_{2k}\, \Delta Gsize^{+}{}_{t-k} + \sum_{k=0}^{n} \pi_{3k}\, \Delta Gsize^{-}{}_{t-k} + \sum_{k=0}^{n} \pi_{4k}\, \Delta Csize^{+}{}_{t-k} + \sum_{k=0}^{n} \pi_{5k}\, \Delta Csize^{-}{}_{t-k} + \sum_{k=0}^{n} \pi_{6k}\, Trade_{t-k} + \sum_{k=0}^{n} \pi_{7k}\, EC_{t-k} + \omega_1 CO_{2,t-1} + \omega_2 Gsize^{+}{}_{t-1} + \omega_3 Gsize^{-}{}_{t-1} + \omega_4 Csize^{+}{}_{t-1} + \omega_5 Csize^{-}{}_{t-1} + \omega_6 Trade_{t-1} + \omega_7 EC_{t-1} + \varepsilon_t \qquad (6)$$

After the replacement of partial sum variables in equation (2) the resulting equation (6) will be called the NARDL model proposed by Shin et al. (2014). According to Shin et al. (2014) both the partial sum variables are closely related to each, hence, they can be treated as one. Therefore, the estimation technique of equation (2) and equation (6) will not alter. Moreover, the co-integration and other diagnostic tests for both models will remain the same. However, after estimating the NARDL mode, a few asymmetric tests are necessary before we can conclude that, whether the effects of the variables are asymmetric or not.

Firstly, the difference in the lag length attached to positive and negative parts is an indication of short-run adjustment asymmetry. Secondly, if the combined effect of the estimates attached to the positive parts is not the same as the combined effect of the estimates attached to negative parts this ensures the short-impact asymmetry. This asymmetry is tested through the null hypothesis of the short-run Wald test i.e. $\sum\pi_{2k} = \sum\pi_{3k}, \sum\pi_{4k} = \sum\pi_{5k}$. Lastly, the long-run asymmetric effects are confirmed if we are able to reject the null hypothesis of the long-run Wald test i.e. $\frac{\omega_2}{-\omega_1} = \frac{\omega_3}{-\omega_1}, \frac{\omega_4}{-\omega_1} = \frac{\omega_5}{-\omega_1}$

Data

The dataset of all variables has been taken from the World Bank and covers the period 1971–2019. Annual time series data of China is used in this study. We used CO2 emissions in kilotons to get the dependent variable. Government size is proxied by final government consumption expenditure in the percentage of GDP. We measure the size of the country by GDP per capita in constant 2010 US dollars. We measured trade as in percentage of GDP, while energy consumption is calculated in kg of oil equivalent per capita. We transformed CO2 emissions, country size, and energy consumption data series into logarithmic form. Descriptive statistics is offered in Table 1, the mean of CO2, Gsize, Csize, Trade, and EC are 14.9kt, 14.3%, 7.12$, 31.7%, and 6.86 kg, while the standard deviation are 0.77kt, 1.47%, 1.15$, 16.6%, and 0.50kg, respectively.

Table 1
Variables definitions and description

Variable	**Symbol**	**Definitions**	**Mean**	**S.D**	**Min**	**Max**
CO2 emissions	CO2	CO2 emissions (kt)	14.9	0.77	13.6	16.1
Government size	Gsize	General government final consumption expenditure (% of GDP)	14.3	1.47	11.4	16.8
Country size	Csize	GDP per capita (constant 2010 US$)	7.12	1.15	5.47	9.02
Trade	Trade	Trade (% of GDP)	31.7	16.6	4.92	64.4
Energy consumption	EC	Energy use (kg of oil equivalent per capita)	6.86	0.50	6.14	7.71

Results And Discussion

Table 2 reports the outcomes of unit root tests. To confirm the stationarity properties of data, the study has employed structural break unit root tests and without structural break unit root tests. Both test results confirm that all the variables are stationary at their first difference except government size that is stationary at level. However, none of the variables is stationary at the second difference. Table 3 reports the findings of the BDS test. BDS test confirms the non-linearity in CO2 emissions, government size, and country size.

Table 2: Unit root testing

	Unit root without structural break			Unit root with structural break				
	I(0)	I(1)	Decision	I(0)	Break date	I(1)	Break date	Decision
CO2	-1.521	-4.406***	I(1)	-3.347	2001	-5.387***	2013	I(1)
CSIZE	-1.739	-4.272***	I(1)	-1.565	1990	-4.967***	1990	I(1)
Gsize	-2.608*		I(0)	-4.692*	1996			I(0)
Trade	-1.621	-5.052***	I(1)	-2.354	1990	-6.675***	2009	I(1)
EC	-0.312	-4.775***	I(1)	-3.456	2002	-6.489***	2015	I(1)

Note: *** p<0.01, ** p<0.05, * p<0.1, respectively.

Table 3: BDS test

	CO2			Csize			Gsize		
Dimension	BDS Stat	S.E	z-Stat	BDS Stat	S.E	z-Stat	BDS Stat	S.E	z-Stat
2	0.196***	0.006	32.58	0.199***	0.006	33.40	0.135***	0.007	19.80
3	0.329***	0.010	33.95	0.334***	0.010	34.80	0.214***	0.011	19.51
4	0.420***	0.012	35.99	0.428***	0.012	36.91	0.260***	0.013	19.78
5	0.482***	0.012	39.12	0.494***	0.012	40.42	0.277***	0.014	20.01
6	0.525***	0.012	43.69	0.542***	0.012	45.37	0.284***	0.013	21.06

Note: *** p<0.01, ** p<0.05, * p<0.1, respectively.

The study makes an effort to investigate the effect of government size and country size on carbon emissions in the case of China. The study has executed both symmetric and asymmetric effects by employing ARDL and NARDL estimation techniques. Table 4 reports the outcomes of short-run and long-run relationships along with the findings of other diagnostic tests for both regressions. The long-run coefficient estimates of ARDL demonstrate that government size exerts a significant and negative impact on pollution emissions which states that 1 percent increase in government size results in decreasing pollution emissions in China by 0.041 percent. However, country size, trade, and energy consumption result in significantly increasing pollution emissions in the long-run. The coefficient estimates show that a 1 percent increase in country size, trade, and energy consumption leads to increase pollution emissions by 0.281, 0.007, and 0.715 percent, respectively. The short-run findings of ARDL demonstrate that government size has a significant and negative effect on pollution emission, but, country size and trade have a significant and negative effect on pollution emissions. However, energy consumption has no effect on pollution emissions in the short run as the associated coefficient estimate is statistically insignificant.

The findings of necessary diagnostic tests for ARDL suggest that F-stat is statistically significant that is confirming the presence of cointegration among variables. The coefficient estimate of ECM is also significant and negative confirming that about 45 percent convergence towards equilibrium takes place in a year in China. The coefficient estimates of LM test and BPG confirms the absence of serial correlation and heteroskedasticity. The findings of Ramsey RESET test also confirm the correct specification of the model. CUSUM test confirms the stability of model; however, according to CUSUMsq test the model is unstable as denoted by “US”.

Table 4: ARDL and NARDL estimates

	ARDL					NARDL			
Variable	**Coefficient**	**S.E**	**t-Stat**	**Prob.**	**Variable**	**Coefficient**	**S.E**	**t-Stat**	**Prob.**
Short-run					**Short-run**				
D(GSIZE)	-0.019**	0.008	2.439	0.021	D(GSIZE_POS)	0.007	0.012	0.604	0.551
D(CSIZE)	0.540**	0.227	2.379	0.024	D(GSIZE_NEG)	-0.089***	0.027	3.242	0.003
D(TRADE)	0.007***	0.002	3.755	0.001	D(CSIZE_POS)	0.902***	0.261	3.450	0.002
D(TRADE(-1))	-0.004**	0.002	2.313	0.028	D(CSIZE_POS(-1))	0.324	0.283	1.142	0.262
D(EC)	0.015	0.142	0.103	0.919	D(CSIZE_NEG)	0.019	1.196	0.016	0.987
D(EC(-1))	-0.550***	0.186	2.952	0.006	D(TRADE)	0.001	0.002	0.361	0.721
D(EC(-2))	0.696***	0.19	3.658	0.001	D(EC)	0.254*	0.133	1.915	0.065
D(EC(-3))	-0.365***	0.161	2.266	0.031	D(EC(-1))	-0.488**	0.189	2.574	0.015
Long-run					D(EC(-2))	0.284*	0.151	1.877	0.07
GSIZE	-0.041**	0.017	2.403	0.022	**Long-run**				
CSIZE	0.281***	0.086	3.26	0.003	GSIZE_POS	0.013	0.021	0.615	0.543
TRADE	0.007**	0.003	2.437	0.021	GSIZE_NEG	-0.159***	0.037	4.234	0.000
EC	0.715***	0.14	5.096	0.000	CSIZE_POS	-0.171*	0.093	1.838	0.074
C	8.460***	0.535	15.82	0.000	CSIZE_NEG	0.034	2.134	0.016	0.987
Diagnostic					TRADE	-0.004**	0.002	2.000	0.045
F-test	4.433***				EC	0.998***	0.138	7.255	0.000
ECM(-1)	-0.455***	0.102	-4.439	0.000	C	7.606***	0.858	8.861	0.000
LM	0.175				**Diagnostic**				
BGP	1.169				F-test	11.91***			
RESET	0.332				ECM(-1)	-0.561***	0.137	-4.088	0.000
CUSUM	S				LM	0.445			
CUSUMsq	US				BGP	1.203			
					RESET	0.948			
					CUSUM	S			
					CUSUMsq	S			
					Gsize-LR	7.764***			
					Gsize-SR	1.235			
					Csize-LR	0.009			
					Csize-SR	3.565*			

Note: *** p<0.01, ** p<0.05, * p<0.1, respectively.

The long-run coefficient estimates of asymmetric effects of government size and country size on carbon emissions in China have been derived from NARDL estimation technique. The long-run findings of government size show that positive shock of government size does not have a significant effect on pollution emissions. However, the negative shock of government size has a significant and negative effect on pollution emissions in the long run. The coefficient estimate infers that 1 percent increase in government size tends to decrease pollution emission by 0.159 percent. In the case of country size, the positive shock of country size in the long-run results in decreasing pollution emission significantly, however, the negative shock of country size has no effect on pollution emission as the coefficient value of a variable is statistically insignificant. The 1 percent increase in positive shock of country size leads to reducing pollution emissions by 0.171 percent in the long-run.

This finding is also consistent with Ullah et al. (2020), who noted that government size is matter in carbon emissions. This finding infers that a large size of government promotes economic growth with greater usage of energy consumption, hence increased environmental pollution. While the small size of government has a negative impact on carbon emissions. This finding is inconsistent with Ullah et al. (2020), who reported that positive shock of economic size also positively affects environmental pollution. They also noted that most of the developing countries increase the economic size by affecting the environment quality; therefore, economic size has a positive significant factor in environmental pollution. This finding is inconsistent with Meadows et al. (1972), who argue that large size of economies uses larger inputs of materials and energy uses, adverse they generate larger quantities of waste and produce more environmental pollution. A positive change in country size is statistically negative significant on environmental pollution in China and implies that China is used advanced technologies for green productivity and environmental sustainability. This also means that the China economy increases the environmental quality by using the green GDP. From the supply side, the large size of the economy is consumed more clean energy in the industrial sector as well as the transport sector. This is also a basic source of environmental quality in large economies. Another possible reason is that the large size of the economy is mostly producing clean production. On the demand side, consumer of large economies has more incomes and spends on clean and green economic activities, and positively affect on environmental pollution. This means that China is producing less environmental pollution due to income and technology innovation. Large economies are mostly doing energy-efficient production with also mitigates environmental pollution.

In the long-run, an increase in trade results in reducing pollution emissions as due to 1 percent increase in trade the pollution emissions significantly reduced by 0.004 percent. But, the energy consumption effect on pollution emissions is significant and positive in the long-run. The value of coefficient estimates of energy consumption infers that in response to 1 percent increase in energy consumption pollution emission increases by 0.998 percent. The short-run findings of NARDL infer that positive shock of government size does not exert a significant impact on pollution emissions, however, the negative shock of pollution emissions results in significantly reducing pollution emissions in China. The positive shock of country size has a positive and significant impact on pollution emissions; however, the negative shock of country size does not exert any impact on pollution emissions due to insignificant value of coefficient estimate. Among control variables, trade variable has no impact on pollution emissions in the short-run. However, energy consumption's impact on pollution emissions is significant and positive.

To confirm the findings of NARDL estimates the study has performed various diagnostic tests. The coefficient estimate of F-statistics is statistically significant and endorses the existence of cointegrating relationship among variables of the model. The coefficient estimate of the error correction term is also significant and negative confirming that the speed of adjustment towards achieving stability is about 56 percent in a year in China. The coefficient estimates of LM test and BPG also confirms the absence of serial correlation and heteroskedasticity in the model. The result of Ramsey RESET test is statistically insignificant as required that confirms the correct specification of the model. CUSUM test and CUSUMsq test results confirm the stability of the model. The Wald test establishes the long-run asymmetry for government size and short-run asymmetry for country size. The dissimilarity between negative and positive shocks is shown by an asymmetry line in fig (1) and (2), which infers the non-linearity in dynamic multiplier in government size and country size on CO_2 emissions.

Conclusion And Implications

The influence of government size on economic growth has been the central point of academic research for many years (i.e. Barro 1990 and Li et al. 2020, among others). Over the last two decades, level of government size and country size has been at the center of environmental debates. The question is, does growing government size stimulate environmental quality? Does the size of a country affect its environmental quality? These questions have been raising the importance of research in this area. Various studies are carried out to inspect the effect of government size on economic growth, but still, the literature is missing to inspect the effect of government size on CO2 emission in China. Therefore, to fill the research gap, the study aims to carry out the asymmetric impact of government size and country size on CO2 emission in China.

The estimates of asymmetric ARDL infers that a positive shock of government size can insignificantly escalate the carbon pollution, while a negative shock of government size can reduce the carbon pollution of China in long run. Similarly, a positive shock is significant, and a negative shock is insignificant positive impact on CO2 emissions in short run. However, in the short run, positive and negative shocks of government size have similar results as found in long run. On the other hand, an increase in country size can decrease significantly the CO2 emission, while a decrease in country size insignificantly increases the CO2 emission of China in long run. While country size short-run results are found in opposite compared to long run. The China trade can decrease CO2 emissions, but energy consumption has a positive impact on CO2 emissions in the long run.

Based on findings, several policy implications can be suggested as follows. The government size and country size have been increasing in recent years, China should also treat the environment seriously. Since the increasing government size of China could reduce the emissions of CO2 by increasing the green public expenditure in the economy. Furthermore, the government should contribute significantly to green investment in the economy. China should increase the government and country size with green activity. Specifically, government spending should on education, health, green infrastructure investment, and research and development (R&D) affect clean energy and the environment. Government should allocate more resources to green economic development activities.

This study has some limitations. The study did not incorporate development and current government expenditures in the analysis. Authors should conduct similar empirical analyses for high-polluted economies by separating development and current government expenditures in the model. Future studies can also spread this work in the energy consumption model framework. Also, forthcoming empirical studies can extend this work in the asymmetric environmental Kuznets curve framework.

Declarations

Ethical Approval: Not applicable

Consent to Participate: I am free to contact any of the people involved in the research to seek further clarification and information

Consent to Publish: Not applicable

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References

1. Apergis, N., & Ozturk, I. (2015). Testing environmental Kuznets curve hypothesis in Asian countries. *Ecological indicators*, *52*, 16-22.

2. Baloch, M. A., & Wang, B. (2019). Analyzing the role of governance in CO2 emissions mitigation: The BRICS experience. *Structural Change and Economic Dynamics*, *51*, 119-125.
3. Barro, R. J. (1991). Economic growth in a cross section of countries. *The quarterly journal of economics*, *106*(2), 407-443.
4. Barro, R. J., & Sala-i-Martin, X. (1992). Convergence. *Journal of political Economy*, *100*(2), 223-251.
5. Carlsson, F., & Lundström, S. (2001). Political and economic freedom and the environment: the case of CO2 emissions. *Department of Economics, Goteborg University, Goteborg*.
6. Galinato, G. I., & Islam, A. (2017). The challenge of addressing consumption pollutants with fiscal policy. *Environment and Development Economics*, *22*(5), 624.
7. Halkos, G. E., & Paizanos, E. A. (2013). The effect of government expenditure on the environment: An empirical investigation. *Ecological Economics*, *91*, 48-56.
8. Halkos, G. E., & Paizanos, E. A. (2016). The effects of fiscal policy on CO2 emissions: evidence from the USA. *Energy Policy*, *88*, 317-328.
9. Islam, A. M., & López, R. E. (2013). *Government spending and air pollution in the US* (No. 1667-2016-136314).
10. Jafri, M. A. H., Liu, H., Majeed, M. T., Ahmad, W., Ullah, S., & Xue, R. (2020). Physical infrastructure, energy consumption, economic growth, and environmental pollution in Pakistan: an asymmetry analysis. *Environmental Science and Pollution Research*, 1-11.
11. Khan, M., & Ozturk, I. (2021). Examining the direct and indirect effects of financial development on CO2 emissions for 88 developing countries. *Journal of Environmental Management*, *293*, 112812.
12. Kotera, G., Okada, K., & Samreth, S. (2012). Government size, democracy, and corruption: An empirical investigation. *Economic Modelling*, *29*(6), 2340-2348.
13. Le, H. P., & Ozturk, I. (2020). The impacts of globalization, financial development, government expenditures, and institutional quality on CO 2 emissions in the presence of environmental Kuznets curve. *Environmental Science and Pollution Research*, *27*(18), 22680-22697.
14. Lopez, R. E., & Palacios, A. (2010). *Have government spending and energy tax policies contributed to make Europe environmentally cleaner?* (No. 1667-2016-136345).
15. Lu, W. C. (2018). The Impacts of Information and Communication Technology, Energy Consumption, Financial Development, and Economic Growth on Carbon Dioxide Emissions in 12 Asian Countries. *Mitigation and Adaptation Strategies for Global Change*, 1-15.
16. Marcucci, A., Panos, E., Kypreos, S., & Fragkos, P. (2019). Probabilistic assessment of realizing the 1.5 C climate target. *Applied Energy*, *239*, 239-251.
17. OECD (2010). Greener and Smarter: ICTs, The Environment and Climate Change. Paris, France: Organization for Economic Co-operation and Development. Available at www.oecd.org/ site/stitff/45983022.
18. Ozturk, I., & Salah Uddin, G. (2012). Causality among carbon emissions, energy consumption and growth in India. *Economic research-Ekonomska istraživanja*, *25*(3), 752-775.
19. Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of applied econometrics*, *16*(3), 289-326.
20. Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of applied econometrics*, *16*(3), 289-326.
21. Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of applied econometrics*, *16*(3), 289-326.
22. Salahuddin, M., Alam, K., Ozturk, I., & Sohag, K. (2018). The effects of electricity consumption, economic growth, financial development and foreign direct investment on CO2 emissions in Kuwait. *Renewable and Sustainable Energy Reviews*, *81*, 2002-2010.

23. Sohail, M. T., Xiuyuan, Y., Usman, A., Majeed, M. T., & Ullah, S. (2021). Renewable energy and non-renewable energy consumption: assessing the asymmetric role of monetary policy uncertainty in energy consumption. *Environmental Science and Pollution Research*, 1-10.
24. Ullah, S., Apergis, N., Usman, A., & Chishti, M. Z. (2020). Asymmetric effects of inflation instability and GDP growth volatility on environmental quality in Pakistan. *Environmental Science and Pollution Research*, 1-13.
25. Ullah, S., Ozturk, I., & Sohail, S. (2020). The asymmetric effects of fiscal and monetary policy instruments on Pakistan's environmental pollution. *Environmental Science and Pollution Research*, 1-12.
26. Vogler, J., & Jordan, A. (2003). Governance and the environment. *Negotiating Environmental Change: New Perspectives from Social Science, Cheltenham, UK and Northampton, MA, USA: Edward Elgar*, 137-58.
27. Zimmerman, R. (2005). Mass transit infrastructure and urban health. *Journal of Urban Health*, *82*(1), 21-32.

Figures

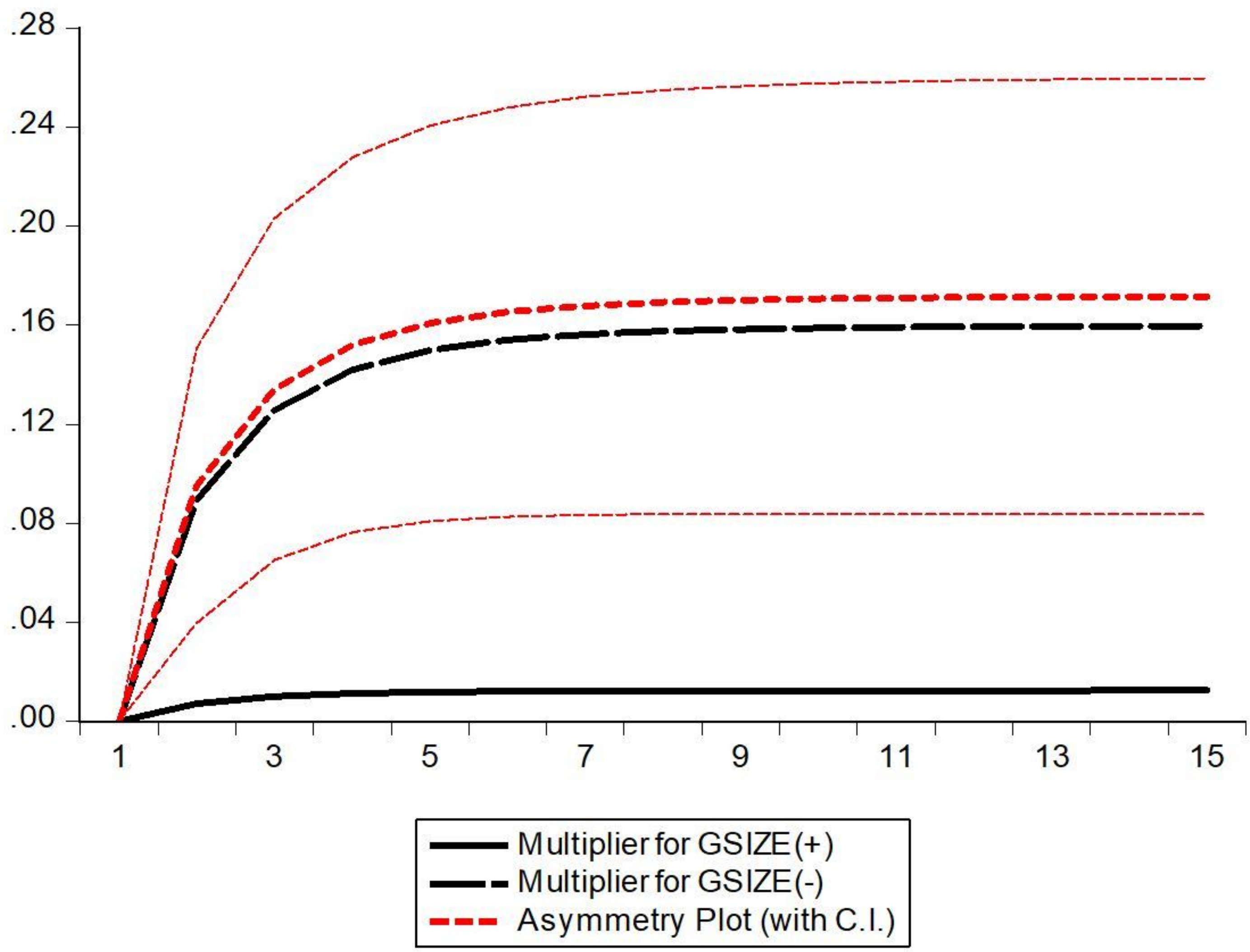

Figure 1

Asymmetric dynamic multipliers effects of government size on CO2 emission

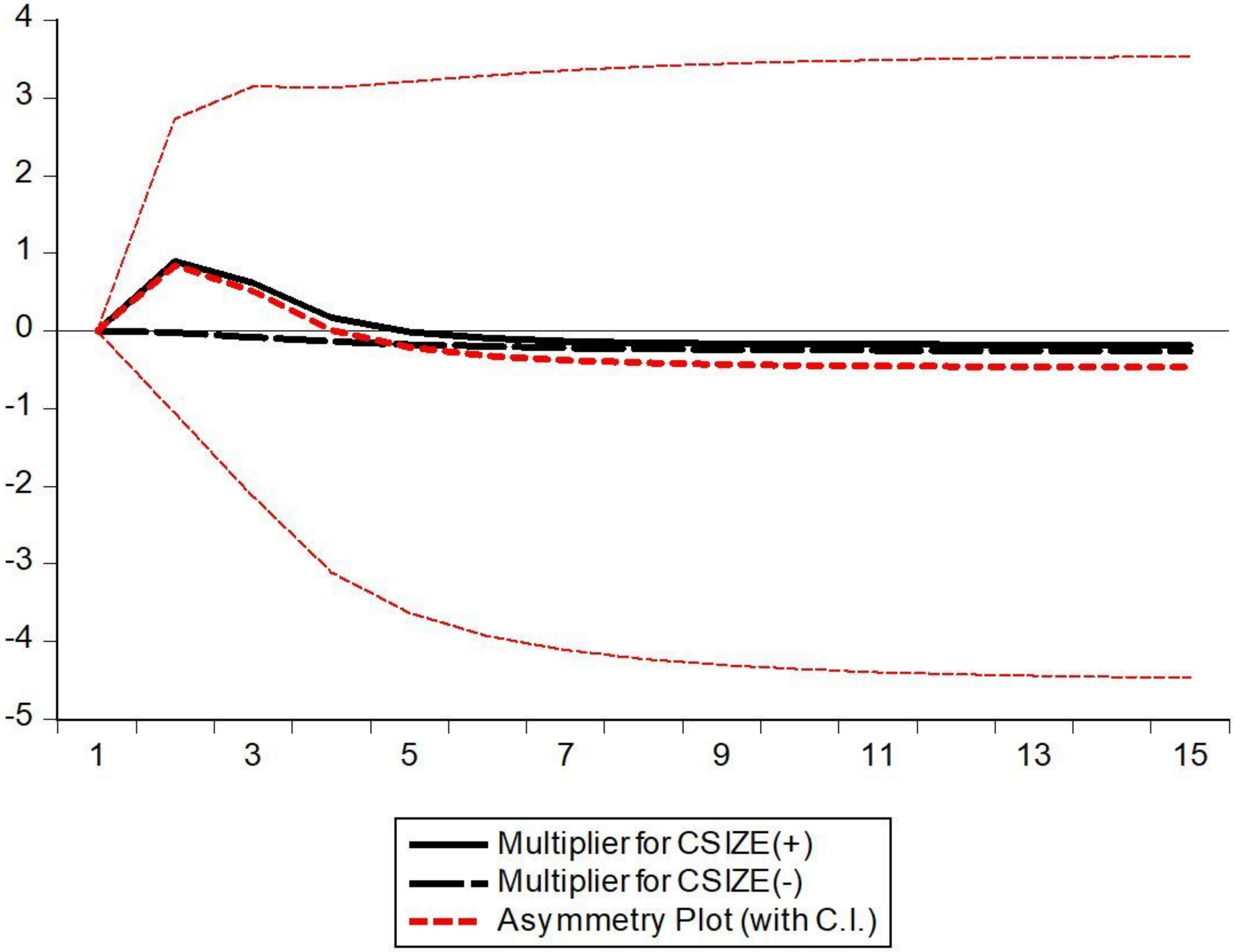

Figure 2

Asymmetric dynamic multipliers effects of country size on CO2 emission