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An Empirical Investigation Between CO_2 emission, Energy Consumption, Export and Economic growth: A Case of China

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Abstract

The purpose of this study is to examine the long-run and short-run relationship between environmental degradation (proxied by $C0_2$ emission), gross domestic product, energy consumption and exports in China over the period from 1971 to 2014, using time-series analysis. The study used the annual data which was obtained from a World Development Indicator of the World Bank. The Augmented Dickey-Fuller and Phillips-perron test is applied in this study to establish the stationarity among datasets. Their results show that all variables were non-stationary at level (I(0)). However, they became stationary at the first difference (I(1)). Base on the findings, a well-defined Autoregressive Distributed Lag Model (ARDL) was applied to the datasets, and the results were in support of the long-run and short-run relationships among the variables. $C0_2$ emission and exports accelerate economic growth, however, energy consumption has an inverse impact on economic growth; economic growth and energy consumption also play a significant impact on $C0_2$ emission whereas export has a significant negative impact. Furthermore, the granger causality test shows the existence of bi-directional causality between exports and economic growth. A unidirectional causality is running from energy consumption and $C0_2$ emission to economic growth as well as energy consumption and $C0_2$ emission to exports. The findings support that $C0_2$ emission and exports have a substantial impact on the economic growth of China. Furthermore, energy use and economic growth accelerate $C0_2$ emission. This study concludes with an examination of the policy implications of the findings.

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Keywords: Economic Growth; Environmental Degradation; $C0_2$ emission; Energy Consumption; Gross domestic product; ARDL model.

1. Introduction

The nexus between energy consumption, $C0_2$ emission, economic growth and environmental quality is one of the hot debates these days. Lots of past literature have focused on this issue with great importance. The association between $C0_2$ emission and economic growth of any country is puzzling and needs lots of attention. As economic growth increases, production and consumption level also increases. However, the overindulging behavior of consumers and over-zealous conduct of producers who aim to maximize profits do come with attendant problems to our environment. There is widespread global concern by many researchers and policymakers for fear of long-term effects caused by high energy consumption and increased economic growth on the environment leading to global warming and drastic climate changes as a result of increase $C0_2$ emission on to the atmosphere. Reference [1] analysis indicates that 2012 has been recorded as one of the hottest years in history based on average global temperature. This rising global temperature (termed as global warming) can be very devastating leading to heat waves, ozone layer depletion, storms, flooding, drought, and rising sea levels which in the long run cause massive economic destruction especially on agriculture and infrastructures. For the past few decades, China, India and Russia have undergone through rapid economic growth. Where there is economic growth, energy consumption is often inevitable. Therefore, higher energy consumption often drives economic growth. However, energy consumption mostly unsustainable energy use triggered through economic growth, often increase $C0_2$ emission hence leading to other environmental problems. Environmental disasters such as global warming as a result of $C0_2$ emission from the burning of fossil fuels are often caused by unsustainable energy consumption for economic growth [2]. Therefore, proper caution should be taken as an environmental problem such as global warming may have adverse effects on the economic growth of the country in the long run. China's current rapid growth and as the leading world economy has resulted in a high energy consumption level which could potentially damage the environment as a result of high fossil fuel demand for production. For instance, high demand for natural gas, coal and fossil fuel as a source of energy. These sources of energy are non-renewable energy source which stimulates a higher risk on the environment. As stated by [3], fossil fuels are the leading cause of greenhouse gas emission (GHG). It has raised a significant concern on whether we can maintain current economic growth patterns without causing damage to our environment. Based on the discussion above, the primary objective of this study is to analyze how energy consumption, economic growth and $C0_2$ emission are associated with each other and to analyze their role in environmental protection and sustainable economic development. Also, the effect of export and its connection with the environmental factor received much attention too. Previous related studies that have studied the association between economic growth, energy consumption and $C0_2$ emission had reported conflicting results. It could be due to differences in the techniques and testing procedures that have been used. The approaches that have been employed in these studies are simple linear model estimated by Ordinary Least Squares (OLS), Time series data analysis. This study attempts to analyze the association between energy consumption, economic growth and environmental degradation (proxied by $C0_2$ emission) in China over above 40 years from 1971 to 2014. Three-time series graphs for the data on $C0_2$ emission and economic growth are shown in figures 1 and 2, respectively. It can be seen that there exists an upward trend over time between $C0_2$ emission and economic growth. Figure 1 and 2 indicates that $C0_2$ emission has a direct link with the levels of economic growth, indicating the adequacy of using a linear specification. They are comparing with the Kuznets' hypothesis, which states that an increase in C02 emission levels often marks the initial stages of economic growth. This study also uses the Autoregressive Distributed Lag Model (ARDL) to analyze the impact of energy consumption and economic growth on the environment. The results of the unit root tests show that all variables are non-stationary in levels. However, they became stationary in first differences. The [4] cointegration analysis shows evidence of cointegration among the tested variables.

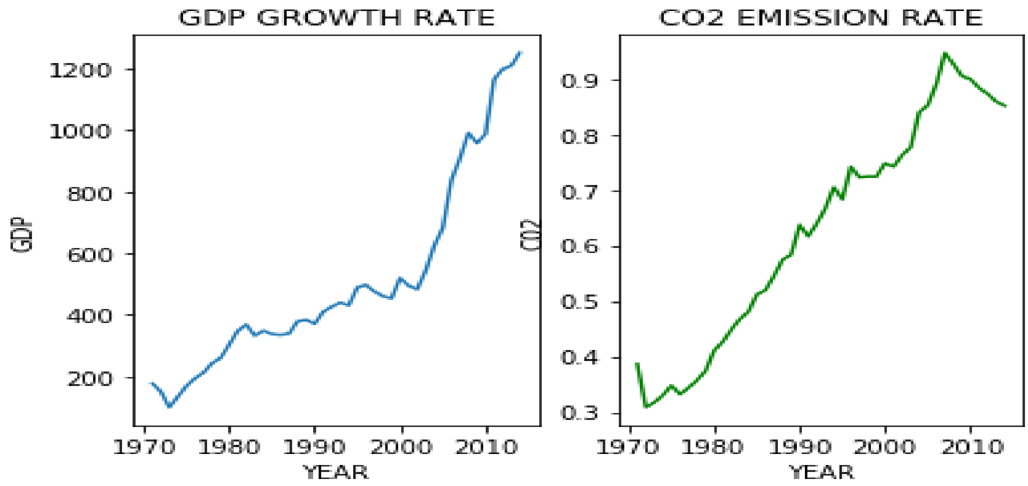

Figure 1: Time series subplots for $C0_2$ emission levels and Economic growth (GDP)

Source: Authors own computation

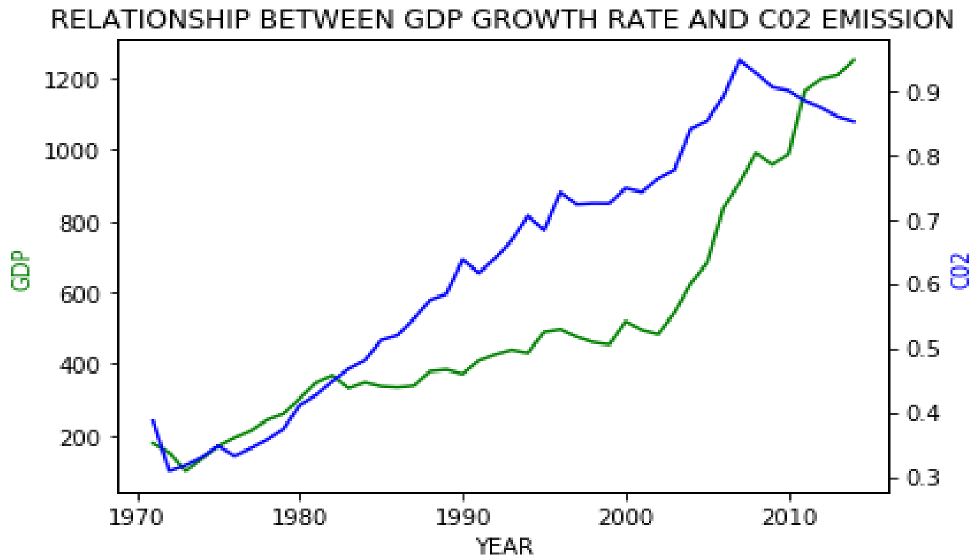

Figure 2: Time series chart for $C0_2$ emission levels and Economic growth (GDP)

Source: Authors own computation

The increase in economic growth accompanied by the unsustainable use of non-renewable energy source has resulted in global environmental pollution problem. As a result, it has drawn attentions from various scholars and policymakers around the world to investigate the above problems and find a solution of how economic growth can increase with an increase in energy consumption efficiency without any harm onto the environment. Among the studies that have investigated the impact of economic growth and energy consumption on environmental degradation are [5]. They study the long run relationship and short run dynamic interactions between $C0_2$ emission and the independent variables of GDP and energy consumption over the period 1971 to 2008 using a time series analysis. They employed the multivariate cointegration methodology. The cointegration test and the vector error correction model indicated a positive long-run relationship between GDP and $C0_2$ emission while the energy use is negatively related to $C0_2$ emission. The long-term elasticity coefficients of the exploratory variables on $C0_2$ emission display relationship that are theoretically grounded. Also, the variance decomposition analysis shows evidence that GDP and energy consumption have a dominant influence on forecasting $C0_2$ emission. The study suggests that the government must put into place regulatory measures to enforce green laws that will reduce C02 emission stringently. Reference [6] studied the impact of $C0_2$ emission, population density and trade openness on the economic growth of five South Asian countries. They employed a panel cointegration approach of extended neoclassical growth model and lastly a granger-causality test to examine the relationship between the $C0_2$ emission, population density, trade openness and economic growth using data from 1990 to 2017, the granger-causality results exhibit a bidirectional causality between economic growth and $C0_2$ emission which support our conclusion but at the cost of environmental degradation. Therefore, the study suggests that smart national policies should be adopted to find out an alternative source of energy (e.g., renewable energy) to minimize the $C0_2$ emissions of energy use. Reference [7]evaluated the impact of economic growth, electricity consumption, Foreign Direct Investment (FDI) and financial investment on $C0_2$ emission in Kuwait. They used the time series data for the period between 1980 to 2013. An Autoregressive Distributed Lag (ARDL) bounds testing approach was applied to observe the cointegration among the series. Their results indicate that economic growth, electricity consumption and FDI stimulate $C0_2$ emission in both the short and long run. Also, the VECM Granger Causality test shows that FDI, economic growth and electricity consumption strongly Granger-cause $C0_2$ emission. Their study recommended that Kuwait should reduce $C0_2$ emission through expansion of its carbon capture, utilization and storage plants, capitalization on its vast solar and wind energy, reduction in high subsidies of residential electricity scheme and also investing in energy research for energy efficiency. Reference [8] analyzed the short-run and long-run relationship between GDP per capita, energy use, trade openness and population on $C0_2$ emission. The study used the annual data for the period 1980 to 2016 for Pakistan. The study employed the Augmented Dickey-Fuller (ADF) test and Johansen Cointegration test to test the presence of a long-run relationship. Besides, the Error Correction Model was also applied to test the short-run relationship between the series. The results show that there is a long-run co-integrated relationship between all variables. The VECM Granger causality test shows that there is a bidirectional relationship moving from energy consumption and GDP per capita to $C0_2$ emission. Also, there is a unidirectional relationship of population to $C0_2$ emission, energy use and GDP per capita. The study suggests that the government should pay attention to the importation of cleaner technology and also need to implement environmental policies such as green taxes. Reference [9] study has focused on the conclusion of previous earlier existing literature mainly focusing on the relationship between energy consumption, economic growth and $C0_2$ emission for both single and multi-countries covering the periods up to present 2019. The study mainly focused on different methodology modelling, periods, and countries with their empirical conclusions. The research study mainly focused on the direction of causalities amongst the variables of economic growth, $C0_2$ emission and energy consumption. From reviewing the previous related existing literature, the study concluded that energy consumption and economic growth have a positive direct impact on $C0_2$ emission. As observed from the previous studies, economic growth is seen to have a high impact on $C0_2$ emission, especially for highly developing countries. On the other hand, the link between economic development and $C0_2$ emission is insignificant for developed countries. As in the case of developing countries, energy consumption is seen to have a high impact on their economic growth. Whereas, for developed countries, energy consumption and economic growth have less evidence of dependency. Lastly, for both developing and developed countries, higher energy use is being reported as the significant leading impact of $C0_2$ emission. Therefore, the government and industries have to find solutions on how to curb $C0_2$ emission through replacement of non-renewable energy sources with renewable energy resources to generate electricity, for industrial operation and transportation purpose for a cleaner environment. Reference [10] analyses the impact of non-renewable energy consumption on economic growth and $C0_2$ emission among the top oil-producing countries in Africa. The used was for the period between 1980 to 2015. After performing a unit root test and cointegration analysis, the paper employed Non-linear Autoregressive Distributed Lag (NARDL) model. The empirical results show evidence of an asymmetric effect of non-renewable energy consumption on economic growth and $C0_2$ emission in the selected African economies except Algeria. Therefore, policymakers in the selected African economies should invest in and promote Carbon-reducing technology in the production processes in their quest for economic growth. Reference [11] study the non-linear relationship between energy consumption, total factor productivity and $C0_2$ emission for seventeen African countries. The study applies the new hybrid nonparametric quantile causality approach. The results show that there is a strong causality among the variables in the middle-lower, middle-upper and middle quantiles. Therefore, energy consumption, total factor productivity and $C0_2$ emission are closely linked in African economies. There is bidirectional causality between total factor productivity and energy consumption for Angola, Benin, Botswana, Cote d'Ivoire, Kenya, Morocco, Egypt, Nigeria and Tunisia. There is also a bidirectional linkage between energy consumption and $C0_2$ emission for Angola, Benin, Cote d'Ivoire, Cameroon, Kenya, Morocco, Egypt, Mozambique, Nigeria, Senegal and Tunisia. As the economic development is still an objective for all these countries, therefore, several environmental policies should be implemented by the government to promote both economic development and also a clean, renewable energy consumption to solve environmental problems. In terms of efficient energy use, it is surprising to note that some countries were able to lower their rate of $C0_2$ emission irrespective of their increase economic growth. For instance, Reference [12] discovered that there was a variation in the rate of $C0_2$ emission among the middle east and north Africa countries in terms of the size of its operation scale. Apart from the economic growth level, the rates of $C0_2$ emission intensity is also determined by how well a given country manage the usage and efficiency of its energy source. This brings the question of whether there is a long-term relationship between energy consumption, economic growth and $C0_2$ emission. As evidenced by the existing literature, the link between economic growth and environmental degradation and also the link between energy consumption and environmental degradation is still inconclusive. Therefore, there is still ample room for further research in these areas to acquire a deep understanding of the nexus between economic growth-energy use and economic growth-environmental degradation. Additionally, the inclusion of exports factor could also and significantly influence the economic growth, energy consumption and environmental degradation of China. This is another contribution of the current study, which has been ignored by various researchers in the existing literature. This study contributes to the existing literature in general and the literature for the nexus between energy consumption, exports, $C0_2$ emission, economic growth and environmental quality in particular in the following ways. The present study is different from the existing literature in several ways in both econometric methods and appropriate model used to examine the potential associations among the variables. Furthermore, previous studies have only focused on investigating the impact of economic growth and energy consumption on $C0_2$ emission [3,13,14]. However, no studies have included export factor which could affect and significantly influence $C0_2$ emission either directly from the production of exported goods from the host country or indirectly through the consumption of the exported goods in the import country. This is another contribution of the current study that is ignored by researchers according to the existing literature. Second, The study has some similarities with [13] who analyze data that covered 28 years from 1971 to 1999 . and also similar with [5] who analyses data covering from 2000 to 2008. In this study, we analyzed data from a more extended period covering an additional year of more five years from 2009 to 2014. Third, Also, this study analyses the impact of economic growth, energy consumption and export on pollution level ($C0_2$ emission). Causalities between the variables have also been analyzed using the Granger causality test in order to display the association among the variables. In addition, the study also employed the ARDL test which the previous studies didn’t used. Fourth, our findings can also be applied to other similar emerging economies where environmental degradation has been becoming increasingly devastating and where economic growth and energy consumptions are at a tremendous increased in recent years. While the real motivations of environmental quality protection in emerging countries are difficult to realize [1,8,11], the demonstrations of caring for the natural environment, as reported in the current study, would serve as referral points for regulators and policy makers of other emerging countries, given that other emerging economies share a similar institutional and governance structure.

2. Methods

The purpose of this research is to examine the long-run relationship and the short-run dynamic interactions between environmental degradation (proxied by carbon dioxide, C02 emission), and the independent variables of economic development (proxied by gross domestic product, GDP per capita), energy consumption and exports in China over the period 1971 to 2014, using time series analysis. The study used annual data from world development indicators of the World Bank. A clear referenced econometric framework was used to carry out the complete analysis. Three-way association among the variables empirically examined with the help of the following econometric models [14].

$$GDP_t = \beta_1 + \beta_2 CO_{2_t} + \beta_3 EC + \beta_4 EXPORTS_t + \mu_t .... Eq(1)$$

$$CO_{2_t} = \beta_1 + \beta_2 GDP2_t + \beta_3 EC + \beta_4 EXPORTS_t + \mu_t .... Eq(2)$$

$$EXPORTS_t = \beta_1 + \beta_2 CO_{2_t} + \beta_3 EC + \beta_4 GDP_t + \mu_t .... Eq(3)$$

Whereby:

GDP: Gross Domestic Product

$C0_2$: Carbon Dioxide Emissions

EC: Energy Consumption

EXPORTS: Exports of goods and services

μ : Error Term

A descriptive statistic which consist of the means that represents the central point of the data, standard deviation used to observe fluctuations among variables, and portrayed consistency towards variables was conducted. The maximum and the minimum are also displayed. The unit root test was also used to analyze stationarity of the data, and for this reason, the study has used an augmented Dicky Fuller Test (ADF) for comparison with Phillips-Perron (PP) deployed tests. Once the stationarity test is confirmed, it is vital to look into some lags that play a vital role in explaining the econometric framework and VAR model is used to get optimal lags through Schwarz Information Criteria (SIC), as this method always provide effective lag length and precise results.

Table 1: Variable Definition and Sources

Variables	**Indicator Name**	**Sources**
GDP	GDP per capita (current US$)	World Bank national accounts data, and OECD National Accounts data files.
$C0_2$	CO2 emissions (metric tons per capita)	Carbon Dioxide Information Analysis Center. United States
EC	Energy use (kg of oil equivalent per capita)	IEA Statistics © OECD/IEA
EXPORTS	Exports of goods and services (current US$)	World Bank national accounts data, and OECD National Accounts data files.

Source: Author own formation

However, some limitations are associated with the VAR model as it requires an estimation of large numbers, and its estimates are un-interpretable. However, the current research focus on the selection of only lag length produces by this method. Hence its outcome is not affected by these limitations. To estimate the long-run association among variables for the defined models, a well advance Autoregressive Distributed Lag (ARDL)/bounds testing cointegration method was applied and developed by [15,16].ARDL methods work well for small sample sizes [16] and remove the issue of omission bias and serial correlation in the residuals. The ARDL Method can also circumvent the problem of the order of integration associated with the Johansen likelihood approach [4]. It provides unbiased estimates of the long-run model and valid t-statistics even when some of the regressors are endogenous [17]. also, the technique gives reliable results even when the study has a mix of stationarity trends. That is when some of the variables are I(0), and some are I(1). However, ARDL is invalid in the case of I(2). The ARDL method has some limitations that need to be considered before analyzing data like error terms. They must not incur autocorrelation problems with each other, the mean and the variance of the model should remain constant, and data should also follow a normal distribution. To mitigate such limitations, this study has various econometrics before tackling such issues. The study used the granger causality test proposed by [18,19] to check the directional of causality between variables under estimation. However, there exist some limitations of the ARDL model like variance, and this means it should remain constant over the period, .and the granger causality test produces signals only for a linear form of the model. To curb this limitation, some diagnostic tests were applied to fulfilled the pre-requisite conditions before the model application. The diagnostic tests applied to review the efficiency of the model includes; the Breusch-Godfrey Serial Correlation LM Test, Heteroscedasticity Test of Breusch-Pagan-Godfrey Jarque-Bera test and the CUSUM test .

3. Results

The purpose of the study is to examine the impact of CO_2 emissions on the economic development of China and also to observe their behaviors in the long run and the short run inclusively. Similarly, it also checked how defined factors impact energy usage. Empirical findings ranged from detail descriptive statistics, unit root test for stationarity, ARDL techniques to judge long-run, and short-run association among variables and concluded with a residual diagnostic test to ensure the stability of the model under study. Table 2 represents the descriptive statistics for model one, and it is summarized as follows; the mean value of exports is -4.52 and is the lowest compared to other variables, however, the highest is with GDP. Looking at the minimum and the maximum value of the variables, the lowest is with exports. while the maximum is with GDP. Volatility analysis reveals that export is the most consistent variable that is not volatile throughout the data, whereas GDP has the highest standard deviation that represents high volatility (fluctuations). After descriptive analysis, Vector Autoregressive Model (VAR) is utilized to find out the selection of the optimal lag length, and four lags have been suggested by the AIC method (Table 3). Additionally, the unit root test was applied to check the presence of the unit root in the data using the augmented dicky fuller test. The results in Table 4 shows that all the time series used in this study are stationary at first difference. In other words, the variables used in this study are integrated of order I(1).

Table 2: Descriptive Statistics

Variables	Obs	Mean	Max	Min	SD
GDP	44	1377.166	7651.366	118.6546	1989.73
$C0_2$	44	3.038663	7.557211	1.04224	1.966727
EC	44	986.5826	2236.73	464.9332	527.1123
EXPORT	44	4.52e+11	2.46e+12	2.78e+09	7.17e+11

Table 3: VAR Lag Order Selection

VAR Lag Order						
Lag	**LogL**	**LR**	**FPE**	**AIC**	**HQIC**	**SBIC**
0	-1630.76		3.7e+30	81.7381	81.7992	81.907
1	-1405.95	449.63	1.1e+26	71.2974	71.6027	72.1418
2	-1377.96	55.981	6.1e+25	70.6979	71.2474	72.2179
3	-1345.85	64.22	2.9e+25	69.8924	70.6862	72.0879*
4	-1320.24	51.208*	2.1e+25*	69.4122*	70.4502*	72.2832
* indicate lag order selected by the criterion						
LR: Sequential modified LR test statistic (each test at 5% level)						
FPE: Final prediction error						
AIC: Akaike information criterion						
SBIC: Schwarz information criterion						
HQIC: Hannan-Quinn information criterion						

3.1. Unit roots Tests

Before embarking on the ARDL bound tests, the variables were tested to determine their order of integration. This was done basically to ensure that the variables were not I(2) stationary or of a higher order than I(1). According to [20], in the presence of I(2) variables, the computed F-statistics provided by [16] are not valid because the bounds test is based on the assumption that the variables are I(0) OR I(1). Therefore, to avoid spurious results, the times series have to be tested to determine their data generation process. Table 4 represents the results of the unit root test through ADF methods, and it is described that GDP, CO2, EC, and exports are non-stationary at level (I(0)). However, they became all stationary at the first difference (I(1)). For comparison, the study used the Phillips-perron method, and the results are consistent with the ADF technique. Additionally, the graph for stationarity tests are also represented in the appendix. Once the stationary test was approved, the research moved to check the long-run association among variables, in this case of variables being

Table 4: Unit Root Tests

		ADF		**PP**
Variables	I(0)	I(1)	I(0)	I(1)
GDP	0.9731	0.0259*	0.9837	0.0000*
$C0_2$	0.5103	0.0268*	0.8317	0.0081*
EC	0.8355	0.0680*	0.9647	0.0064*
EXPORTS	0.1732	0.0001*	0.2589	0.0000*

*I(0) & I(1) stands for the order of integration at level & on first difference, ADF is an augmented dicky fuller. PP is Phillips-perron test for stationarity. * , ** , *** represents 1%, 5% and 10% level of significance.*

I(0) and I(1), ARDL model can be used for the estimation.

Table 5 represents ARDL results for the model one and (3,4,0,3) lags selected by the ARDL method to report the precise results. When the regression is normalized on economic growth (GDP), The calculated F-statistic 26.683 is higher than the upper bound critical value 5.61 at the 1% level. Thus, the null hypothesis of no cointegration is rejected, implying long-run cointegration relationships amongst the variables when the regression is normalized on GDP. The estimated coefficients of the long-run relationship show that CO2 emissions and exports have a very positive significant impact on economic growth. However, the coefficient of energy consumption is negatively and statistically significant. This result implies that the past trend of energy consumption harms current economic growth. The reason for this is not far-fetched, despite the remarkable growth of the energy sector, there is still an imbalance between energy supply and demand, and the country remained starved for energy. For instance, in 2003 and 2004, China experienced an acute shortage of energy which severely disrupted the industrial output of the country [21]. The consequence of this past energy shortages has harmed the current economic development. The long-run results also reveal that previous states of economic growth had a significant adverse effect on the current state of economic growth. A 10% decrease in the past economic growth has reduced the current economic growth by 32 %. The study also evaluates model two and found the presence of a long-run relationship between these variables with CO2 emissions. The outcome for model two of Table 6 shows that GDP and energy consumption (EC) accelerate CO2 emissions in the long-run. However, export is seen to be having a significant negative impact on CO2 emissions in the long-run. This might be due to China beginning to implement more robust climate policies, in combination leading to a decrease in the CO2 emissions from the production of exported products. It might have also been due to improvement in carbon intensity, which has reduced the potential increased in emissions. The study also evaluated model three and found no short-run and long-run relationship from GDP, CO2 emissions energy consumption (EC) to exports in the case of China.

Table 5: Model-1 Estimated Long Run Coefficients ARDL (3,4,0,3) Selected based on AIC

Dependent Variable: GDP				
Variable	Coefficients	SE	t-stat	P-Value
GDP(-1)	-0.3176557	0.0357731	-8.88	0.000
$C0_2$	476.2897	173.0791	2.75	0.011
EC	-1.908389	0.7699762	-2.48	0.020
EXPORTS	3.46e-09	4.64e-10	7.47	0.000
C	203.8807	69.07162	2.95	0.007
R-squared	0.9938			
Adj R-squared	0.9907			
Durbin Watson stat 1.794959				
BOUNDS TEST (at 1%)				
			LB	UB
F-Stat= 26.683			3.77	5.61

** , ** , *** represents 1%, 5% and 10% level of significance.*

Table 6: Model-2 Estimated Long Run Coefficients ARDL (2,1,0,0) Selected based on AIC

Dependent Variable: $C0_2$				
Variable	Coefficients	SE	t-stat	P-Value
$C0_2$(-1)	-0.5611294	0.0590453	-9.50	0.000
GDP	0.0001029	0.0000796	1.29	0.204
EC	0.0045197	0.0001896	23.84	0.000
EXPORTS	-1.16e-12	3.07e-13	-3.77	0.001
C	-.6423288	0.0769687	-8.35	0.000
R-squared	0.9269			
Adj R-squared	0.9144			
Durbin Watson stat 1.62144				
BOUNDS TEST (at 1%)				
			LB	UB
F-Stat= 39.497			3.77	5.61

LB & UB stands for lower and upper bound. SBIC is Schwarz information criterion for optimal lags. $*$, $**$, $***$ *represents 1%, 5% and 10% level of significance*

Table 7 and 8 represent the short-run association between variables, and it is noted in a negative error correction term and statistically significant and further indicates the existence of a short-run relationship between variables. In both Table 7 and 8, the equilibrium error correction coefficient (ECT) estimates of -0.37 and -0.50 are both significant and have the correct sign. This implies a high speed of adjustment to equilibrium after a shock. Approximately 37% and 50% of disequilibrium from the previous year’s shock converge back to the long-run equilibrium in the current year.

Table 7: Model-1: Error Correction Representation of ARDL (2,1,0,0) Selected based on SIC

ECT	**Coefficients**	**SE**	**t-stat**	**P-Value**
ECT (-1)	-0.3702696	0.1332257	-2.78	0.008$*$

ECT is the error correction term. $*$, $**$, $***$ *represents 1%, 5% and 10% level of significance*

Table 8: Model-2: Error Correction Representation of ARDL (2,1,0,0) Selected based on SIC

ECT	**Coefficients**	**SE**	**t-stat**	**P-Value**
ECT (-1)	-0.5033467	0.1355865	-3.71	0.001$*$

ECT is the error correction term. $*$, $**$, $***$ *represents 1%, 5% and 10% level of significance*

Table 9 and 10 represent the residual diagnostic tests for the residual of the regression for the ARDL model, and the model specification performed well. The residuals are normally distributed, and there is no higher-order serial correlation and heteroscedasticity in the model. In addition to this value of the Jarque-Bera test, it shows that the residuals are normally distributed.

Furthermore, the CUSUM test also ensured the stability of all the two models in figure 3 and 4 respectively.

Table 10: Model-1: Diagnostic Test

	Statistics	**P-Value**
Serial Correlation LM test	0.545	0.4603
Heteroscedasticity	40.00	0.4256
Jarque-Bera	0.6949	0.7065
Adjusted R-Squared	0.9998	

, **, * represents 1%, 5% and 10% level of significance.*

Table 10: Model-2: Diagnostic Test

Tests	**Statistics**	**P-Value**
Serial Correlation LM test	2.381	0.1228
Heteroscedasticity	23.03	0.6836
Jarque-Bera	2.702	0.259
Adjusted R-Squared	0.9992	

, **, * represents 1%, 5% and 10% level of significance.*

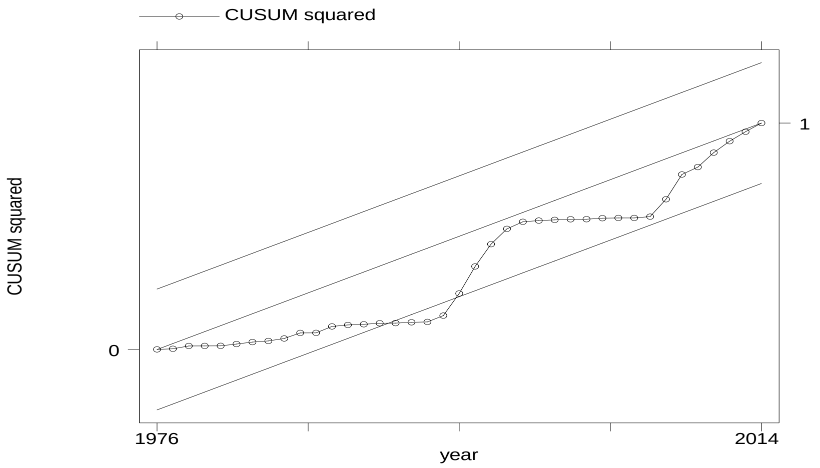

Figure 3: Model-1: CUSUM Test for stability

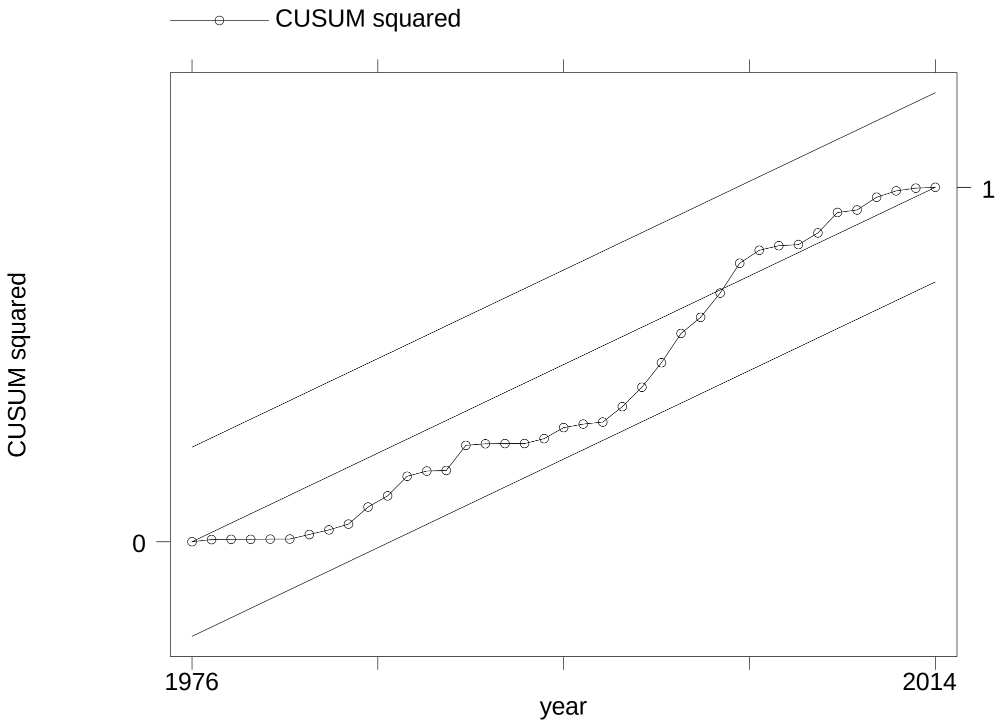

Figure 4: Model-2: CUSUM Test for stability

3.2. VAR Granger Causality/Block Exogeneity Tests

Cointegration and long-run relationships do not define the direction of the causality. Table 11 shows the results of the VAR Granger Causality/Block Exogeneity Tests. Granger causality test was applied to investigate the causal links amongst the variables; $C0_2$, exports, and GDP. This test is vital in the sense that it informs us about the direction of causality amongst the variables. There are three possible outcomes: unidirectional, bidirectional or neutral relationships. A chi-square of 10.10 for $C0_2$ emission when GDP is dependent variable implies that $C0_2$ emission is exogenous in the economic growth regression. Similarly, Energy consumption (EC) and exports have moderate chi-square statistics of 8.46 and 10.13. thus, GDP is Granger caused by these three variables. In other words, GDP is influenced by $C0_2$ emission, EC, and exports. The null of block exogeneity is refuted when GDP is taken as the dependent variable. This suggests that GDP is influenced by EC, exports and $C0_2$ emission when they are taken together. The null hypothesis of block exogeneity is also refuted when $C0_2$ emission and exports are taken as dependent variables (0.012) and (0.00). However, GDP, EC, and exports do not granger cause $C0_2$ emission. When exports are taken as the dependent variable, the chi-square statistics of 10.70 and 18.09 for GDP and EC, respectively, are significant, and the chi-square statistic of 8.15 for $C0_2$ emission is moderate. Thus, the null of block exogeneity is refuted when exports are taken as a dependent variable. In conclusion, the test reveals that GDP has a unidirectional relationship with $C0_2$ emission, EC, and a bidirectional relationship with exports. Exports have a unidirectional relationship with $C0_2$ emission and energy consumption.

Table 11: VEC Granger Causality/Block Exogeneity Wald Tests

Dependent Variable: GDP			
Excluded	Chi-sq	Df	Prob.
$C0_2$	10.099	4	0.039
EC	8.4632	4	0.076
EXPORTS	10.127	2	0.006
ALL	48.158	9	0.000
Dependent Variable: $C0_2$			
Excluded	Chi-sq	Df	Prob.
GDP	4.5306	4	0.339
EC	7.1457	4	0.128
EXPORTS	.	0	.
ALL	19.498	8	0.012
Dependent Variable: EXPORTS			
Excluded	Chi-sq	Df	Prob.
GDP	10.702	4	0.030
$C0_2$	8.1455	4	0.086
EC	18.091	4	0.001
ALL	157.41	12	0.000

4. Policy implications

Various policy implications that can be drawn from this paper are: A long-run unidirectional relationship exists amongst economic growth (GDP), energy consumption (EC), and $C0_2$ emission. There also exists a short-run impact between the variables. This implies that short-run accumulation of $C0_2$ emission and energy used due to the production of goods and services would accumulate to the long-term negative effect hence leading to environmental degradation. Thus, policies should be implemented to control carbon dioxide emission, and as a result, our environment will be free from pollution, and millions of people can protect themselves from the effect of natural disasters. The government should also implement environmental and energy policies that can lead to more rapid decarbonization of the electricity sectors. This may include renewables and also the adoption of the state-of-the-art technologies for new coal power plants as well as the construction of more hydro-power. A bidirectional relationship also exists amongst GDP and exports. This implies that growth in export volumes was another critical factor in increasing China economic growth. However, too much growth in export volume may lead to an increase in exported carbon dioxide emission. Since China has large production capacity, this advantage could be directed towards the production of environmental goods. For instance, the production and export of more wind, solar, and electric vehicles with the lowest cost and greater global diffusion.

5. Conclusions

This paper analyzed the association between $C0_2$ emission, energy consumption, exports, and economic growth.

The study used annual data extracted from the World Development Indicator of the World Bank. The data covered the period starting from 1971-2014. For the empirical analysis, the study used the Augmented Dicky Fuller and Philip and Perron unit root test to check the unit root among the data. After the stationary was observed, then the ARDL model was applied to estimate the long-run and short-run relationships amongst the variables. Results from the model test results show that there exists a long-run and short-run relationship among variables in model one and model two. Furthermore, it is noted in model one that $C0_2$ emission and exports accelerate economic growth, whereas energy consumption has an inverse impact on economic growth. In model two, economic growth and energy consumption has a positive impact on $C0_2$ emission, whereas exports have a significant adverse effect. Model one and two are comparable as they exhibit the same trend among variables, whereas model three does not hold a long and short-run relationship. To judge the stability of the models, the serial correlation test was applied, and the obtained results rule out any correlation in the models or any existing heteroscedasticity. Also, the Jarque-Bera test indicates that residuals are normally distributed. Finally, the CUSUM test were also performed to observed the stability of the model. To check the directions of causality, the Granger Causality test has been applied, and the results show an existing bi-directional causality between exports and economic growth. It shows a unidirectional causality running from energy consumption and $C0_2$ emission to economic growth. It also shows a unidirectional relationship running from energy consumption, $C0_2$ emission to exports.

6. Recommendations

The overall findings support that $C0_2$ emission and exports have a substantial impact on the economic growth of China. On the other hand, energy consumption and economic growth accelerate $C0_2$ emission. Therefore, the study suggests that key reforms are required to reduce carbon dioxide emissions and also conservative, strict environmental and energy policies. The government of China needs to implement environmental and energy policies that can control carbon dioxide emissions. The industrial sectors must also be encouraged to implement new technologies that can help curtail pollution. More funds should be located upon R&D programs that aim towards green energy evolutions. China, as the world-leading growing economy, has a greater production capacity for exports of goods, hence having an enormous impact on consumption emission from the products imported by other countries. Therefore, China should relocate their production towards products that help decarbonize the world. Production and exports of more wind, solar, and electric vehicles by China can not only help China mitigate emissions but also help the world as a whole through reducing its emission that comes as a result of our ever-increasing consumption. The limitation of the study is that its findings is only country specific, hence cannot be generalized for other countries since it is a time series research on a single country, China. Therefore, for a more generalized findings and conclusion, future studies should consider a cross country analysis. Additional variables such as Foreign Direct Investment (FDI) should also be considered for future studies as it might have a substantial impact on $C0_2$ emission. Energy consumption did not have a significant postive impact on economic growth as expected according to the ARDL parameters. Interestingly, the granger causality test suggest energy consumption have some significant relationship with economic growth. The different in findings maybe due to the differences in methodological background of each test. These tests serve different purposes and therefore their findings need not necessarily agree. For instance, while the estimated ARDL parameters would measure how much $C0_2$ emission depend on the explanatory variables, it does not imply causation. The Granger-causality test is performed to detect only within sample causal relationship while out of sample relationship is ignored. Additionally, the exact magnitude of the feedback relationship between the variables cannot be provided in the Granger-causality procedure. Thus, since all these models apply different methodologies in the estimation and serve different purposes, their finding could differ. Therefore, future studies should consider a more suitable models for estimation of cross-country study.

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Appendix

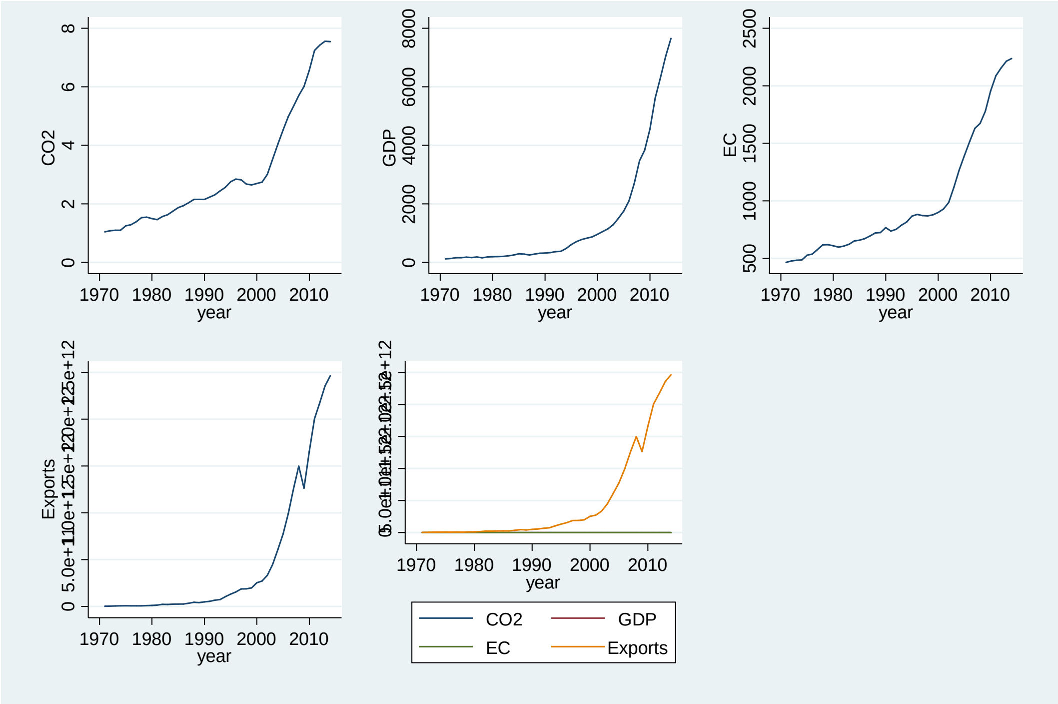

Figure 5: Time Series Plot at Level (1971-2014)

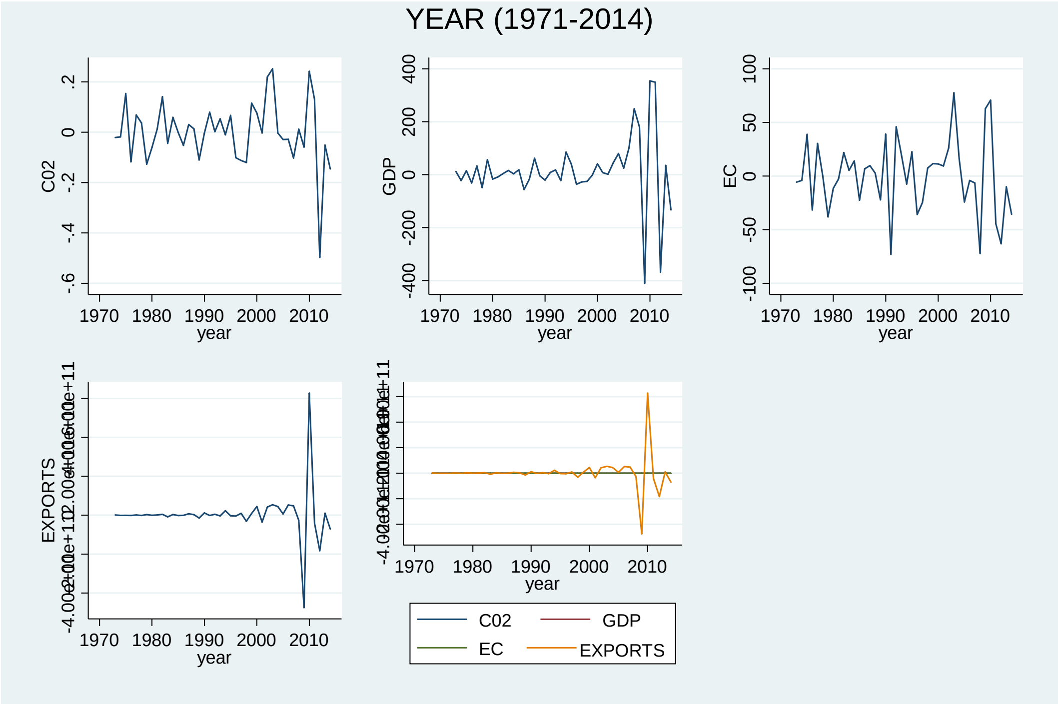

Figure 6: Time Series Plot at Stationary Level

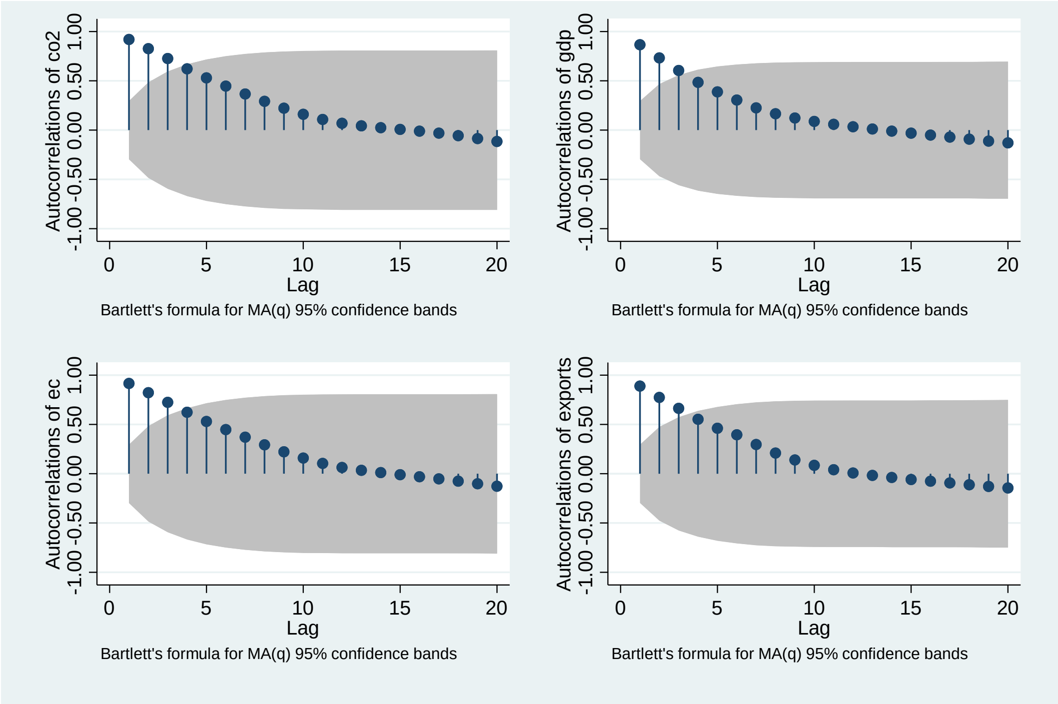

Figure 7: Correlogram at Level (1971-2014)

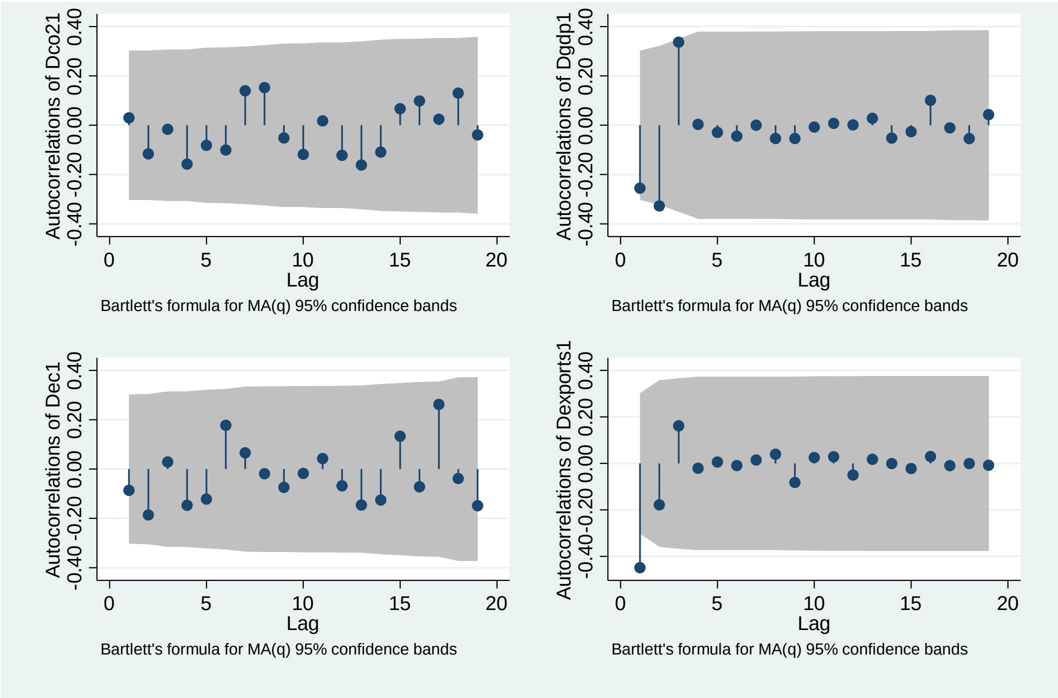

Figure 8: Correlogran1 at First Difference