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TRADE OPENNESS, FINANCIAL DEVELOPMENT AND ENVIRONMENTAL POLLUTION IN SOUTH AFRICA: A TODA AND YAMAMOTO CAUSALITY APPROACH

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Abstract

This study examines the causal relationships between trade openness, financial development, and the environmental pollution in the economy of South Africa over the period (1980–2023) using the Toda-Yamamoto causality approach. The study seeks to find out whether or not there exists a causal relationship among the variables of interest. To achieve this, the study employed the pre-test analysis on the time series data to ascertain the stationarity of the data. Toda and Yamamoto causality technique was used to estimate the models to achieve the main objective of the study. Using both ADF & PP stationarity techniques indicated mixed integration orders. Empirical results from TY estimates revealed the existence of unidirectional causality from trade openness to CO_2 emissions, implying that increased foreign trade activities escalates environmental pollution in South Africa. It was also discovered that no causal link (zero causality) was found between financial development and CO_2 emissions. Policy recommendations include regulating polluting imports and promoting sustainable financial sector growth.

Key words: financial development, carbon dioxide, trade openness, Causality, Toda-Yamamoto

1 Introduction

The impact of international trade on the environment has been a subject of intense debates among international, environmental as well and health economists. Despite increasing level of trade openness and financial development in the developing countries like South Africa environmental pollution continue to rise. Existing empirical studies provide mixed and inconclusive evidence on the linkage and connectivity between trade openness, financial development and the environmental pollution. The waves of globalization which swept through the developed and developing countries alike have brought the issues of pollution havens. The empirical literature on trade and environment elicits evidence supporting reduction in environmental degradation and the adverse impact of trade on the environment, thus rendering the field ridden with mixed results Bernard and Mandal, (2016). The debates on the impact of trade on the environment are pertinent considering

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the increasing volume of trade among world nations and the changes in environmental quality. It is a belief of some scholars such as shahbaz *et al* (2017), Du *et al.* (2020) and Omri, (2015) that international trade influence environmental degradation especially in the countries with weaker regulations.

Development in the financial sector may also have an influence on the country's size of foreign trade in the sense that it provides credit facilities to the new investors in the country who can produce at an export quantity Omri *et al.* (2015). This may lead to the exportation of goods and services as well as the importation of new capital goods like machinery and other capital goods for advanced production, and may consequently contribute to the amount of carbon dioxide released in the country. In the views of Jalil and Feridun, (2011) trade openness may bring about an increase in the inflows of FDI and multinational corporations (MNCs) as well as the importation of capital goods and technologies by domestic producers. This process may lead to an increase in the domestic total energy consumption, which consequently increases the amount of CO_2 emission into the atmosphere.

This study aimed at exploring whether or not trade openness and financial sector development individually or jointly has any causal influence or impact on the environmental pollution in the country under study. Trade openness focused more on the import-export, inflow of FDI as well as the operation of multinational corporations in the country. South Africa which belongs to the sub-Sahara Africa is one of the promising developing economies in the African region. And little literatures were available on its economy especially using time series data analysis.

This research work came to realized that, many of the previous researches conducted on this same issue and country were mostly a panel data studies, additionally many of the literatures presents studies that explore the linkages of trade openness, financial development and CO2 emissions separately. This study empirically utilized time series data for the sample period of 43 years in order to test the causation among the variables of interest instead of conducting panel analysis. As one of the uniqueness of this study it examines the joint causation of the trade openness and financial development using the same model. Among the few literatures that were came across in which time series data was used mostly examined the impact using other statistics such as ARDL, VAR etc. those that investigate the causal relationship also used Granger causality approach developed by Engel & Granger (1995). This study employed Toda-Yamamoto technique of checking the causality among the variables. Hence this study contributed to the existing knowledge by adding to the literatures especially the time series based analysis using TY technique and in the economy of South Africa. The finding of this study was an extract from a comparative study which involved South Africa and its counterpart, hence another reason why the study is based on the South African economy.

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2 Literature Review

2.1 Empirical Literature Review

There were plethora of works done on the relationship between trade openness, financial development and environmental pollution. In this section some of the works were reviewed and presented. One of the popular studies by Nasir, *et al.* (2021) investigates the linkage among environmental degradation, trade liberalisation, economic growth and urbanization within the framework of the EKC hypothesis in the case of Australia using time series data analysis covering the period 1980-2014. Empirical evidence indicated a significant positive impact of trade openness, financial development, and economic growth on carbon dioxide emissions in the Australian case. Also, short-term bidirectional causality prevails between financial development, energy consumption and trade openness with CO_2 emission. Biala and Adegoke, (2024) in their study on Nigeria found that trade openness and FDI inflows contributed positively and significantly to the environmental degradation in Nigeria most especially in CO2 emissions as well as natural resources depletion. Wasti & Zaidi, (2020) empirically examined the relationship among trade liberalisation, CO_2 emission, energy consumption and economic growth in the case of Kuwait. Using time series data between 1971 and 2017 and the use of the ARDL bound test method, the empirical evidence revealed the existence of a long-run impact of trade openness and energy consumption on CO_2 emission in the Kuwait economy during the period under study. Causality test result indicates a unidirectional causality from trade openness to CO_2 emission and from energy demand to CO_2 emission as well. As a component of trade openness Zayyana and Kwara, (2024) finds that foreign direct investment FDI inflows significantly contribute to the environmental degradation in Nigeria where they call for stringent policy should be laid down to force foreign investors to align with the environmental sustainability policies. In the same vain Bial et al. (2024) using threshold regression analysis to test the EKC in Nigeria, discovered that trade openness which represent economic integration facilitate economic growth and technological exchange which also lead to carbon dioxide emission via energy intensive production as well as importing polluting technologies.

Dou, *et al.* (2021), Chen, *et al.* (2019) & Ziaei. (2015) discovered a positive linkage of CO2 emission and trade openness and its associates in their respective study places. However Du, *et al.* (2020) investigates whether international trade increases CO_2 emission or otherwise in the case of 116 selected countries. Empirical results revealed that there is a non-linear relationship between trade openness and CO_2 emissions. They divided the analysis based on the income level and made these conclusions: at a very high income level, trade openness tends to have a positive impact on reducing CO_2 emissions, while at the middle and low income levels; the effect of trade openness on CO_2 emissions tends to be negative.

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Jijian, *et al.*, (2021) in their recent effort, they studied the impact of international trade and foreign direct investment in some 62 selected BRI countries using panel data analysis. The empirical findings revealed a positive link between imports and carbon dioxide emissions, while on the contrary, exports revealed an inverse relationship with carbon dioxide emissions. While FDI inflows reveals a positive but, insignificant, impact on the consumption-based carbon dioxide emissions. Pata & Caglar, (2021) investigate the impact of trade openness, energy consumption, globalisation and economic growth on the environmental pollution in China using time series data analysis. Recently invented augmented ARDL with structural breaks was used to analyse the main aim. Empirical results indicate that the EKC hypothesis did not hold in the case of China, and specifically, trade openness and globalization had a positive effect on the release of carbon dioxide in the case of China. Finally, the results suggest that globalization, trade openness both drive environmental pollution in the world's most polluted country, which is China. Wu, *et al.*, (2021) empirically investigate the influence of bilateral trade on the CO_2 emission in some selected Belt and Road Initiative (BRI), One of the finding indicate that import intensity tend to promote CO_2 emission while export intensity tends to reduce CO_2 emission in the BRI countries. Jalil & Feridun, (2011) discovered that financial development and energy consumption may reduce carbon emissions. This indicates that financial progress and energy usage have not compromised environmental quality. In the same vain however in their study on Nigeria Zayyana and Halliru (2023) by utilizing threshold analysis technique found the negative connection of financial development and environmental pollution and it implied that FND helps to improve environmental quality. On the contrast Akinpelumi et al. (2024), and Chinedu A. et al. (2024) using NARDL approach and concluded that FND have contributed positively to the environmental pollution in Nigeria and West Africa respectively. Shahbaz *et al.* (2015) examined the relationship between globalization, namely financial development, utilising annual time series data from India over a span of 42 years. Employing cointegration methodology of Bayer & Hanck , (2013), to examine the long-term relationship. The long-term findings indicate that the swift advancement of globalization has resulted in heightened energy demand and consequently increased CO2 emissions in India. Abdelkader *et al.* (2020), Shahbaz et al. (2013), and Shrezal, (2020). Found a causal linkage running from financial development to CO2 emissions at various studies.

3 Methodologies

Data on all the variables were extracted from the world development indicators of World Bank. The data measurement, definition and source are given in Table 1. All the data on the variables are annual time series data.

Table 1 Variables description.

Series	Definition	Source
CO_2	Environmental pollution, carbon dioxide (CO2) metric tons per capita (annual data)	WB (2023)
TOP	Trade openness, total trade as % of GDP or trade ratio to GDP (annual data)	WB (2023)
FND	Financial development, domestic credit by banks to private sector as percentage of GDP (annual data)	WB (2023)
FDI	Foreign direct investment inflows as % of GDP in the reporting country (annual data)	WB (2023)
ENC	Energy consumptions, Kg of oil equivalent as % of GDP (annual data)	WB (20203)

Note: WB means World Bank, GDP stand for Gross Domestic Products.

3.1 Theoretical framework

Several theories were reviewed such as Environmental Kuznets Curve theory/hypothesis (EKC), Trade-induced environmental impact theories, Green Finance and technological innovation theory, Pollution haven hypothesis and Growth-mediated channel (Via EKC). However for the purpose of this work EKC is adopted as a back bone of this study. This research work is built upon EKC framework which explains the non-linear relationship among economic activities such as trade, finance and environmental quality. The EKC proposes that as an economy grows environmental degradation first increases as a result of industrialization, urbanization and pollution and thereafter decreases after certain income level in the economy as a result of demand for cleaner technologies in the society. EKC theory has an inverted U shape portraying a non-linear relationship among the variables. While EKC explains how economic growth influences environmental quality, pollution haven offer specific explanations on how trade openness affects pollution. The financial development theory explains how access to finance can either increase emission or promote green technology adoption. Jointly these theories offer a comprehensive way of analyzing the causal relationship among TOP, FND and environmental pollution.

3.2 Model Specifications

To examine the nature and direction of causality among the variables of interest, which is the fourth objective of the study, the study employed the causality test technique developed by Toda and Yamamoto (1995). This technique is employed because of the superiorities it has over the normal Granger causality test technique. The Toda-Yamamoto technique does not require any pre-testing of variables regarding their cointegration status, and it is also suitable and compatible with Vector Auto regression (VAR) method in which variables can be estimated in their levels rather

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than the first difference Aslam *et al.*, (2021). To examine the nature and direction of causality among the variables of interest, the study employed the causality test technique developed by Toda and Yamamoto (1995).

3.3 Environmental Pollution Multivariate Causality Model Specification

The model used in this study was a modified VAR model adopted from Dou, *et al.* (2021), with some suitable modifications in order to suit the variables of this study. After modifications to their model, this study specified the model as follows to suit the demand of this research work.

$$\ln CO_{2t} = \alpha_0 + \sum_{i=1}^{k} \alpha 1i \ln CO_{2t-i} + \sum_{j=k+1}^{d\max} \alpha_{2j} \ln CO_{2t-j} + \sum_{i=1}^{k} \eta_{1i} \ln TOP_{t-i}$$

$$+ \sum_{j=k+1}^{d\max} \pi_{1i} \ln TOP_{t-i} + \sum_{i=1}^{k} \pi_{1i} \ln ENC_{t-j} + \sum_{j=k+1}^{d\max} \pi_{1i} \ln ENC_{t-I} + \sum_{i=1}^{k} \pi_{1i} \ln FND_{t-j} + \sum_{j=k+1}^{d\max} \pi_{1i} \ln FND_{t-I}$$

$$+ \sum_{i=1}^{k} \pi_{1i} \ln FDI_{t-j} + \sum_{j=k+1}^{d\max} \pi_{1i} \ln FDI_{t-I} + {}_{I} + \varepsilon_{1i} \ldots\ldots\ldots\ldots (1)$$

4 Results and Discussion

4.1 Toda and Yamamoto causality tests

This section explores whether any causality exists and its nature and direction among the variables of interest, in the country of the study. In an attempt to investigate this, several methods and techniques are available, such as the Granger causality test developed by Engel Granger in (1987) and the Toda and Yamamoto causality techniques. In an attempt to examine the causality, this study adopted the causality test technique developed by Toda and Yamamoto in (1995).

This section deals with the investigation of the causal relationship among the dependent variable and the explanatory variables in the models of the study. To examine the nature and direction of causality among the variables of interest, the study employed the causality test technique developed by Toda and Yamamoto (1995). This technique is employed because of the superiorities it has over the normal Granger causality test technique. The Toda-Yamamoto technique does not require any pre-testing of variables regarding their cointegration status, and it is also suitable and compatible with Vector Auto regression (VAR) method in which variables can be estimated in

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their levels rather than the first difference Aslam *et al.* (2021). This study decided to utilize the causality technique of Toda-Yamamoto. The technique is a modified and advanced version of the Granger Causality technique. The technique (TY) has been used by some recent studies, such as (Aslam, *et al.* 2021; Shahzad *et al.* 2017; & Bilas, *et al.* 2017).

4.2 Determination of Maximum Order of Cointegration

The first step in the TY approach is to test the time series data to determine the maximum order of integration (d_{max}) of the variables using the ADF, PP or KPSS stationarity tests. For ADF and PP, the null hypothesis is non-stationary, while for KPSS is one of stationarity. Table 2 and 3 presents the stationarity tests results based on Augmented Dickey-Fuller (ADF) and Philips Perron (PP) respectively. In both ADF & PP techniques null hypothesis of Non-stationary (series has a unit root) was test against the alternative hypothesis of there is no unit root (the series is stationary). Results from both estimates lead to non-rejection of null hypothesis at 1% level of significance.

Table 2 The Augmented Dickey Fuller (ADF) Unit root stationarity test result

Variables	Constant	Level of Integration	Constant with Trend	Level of Integration
ENC	-6.509985 (0.0000)***	I (1)	-6.411129 (0.0000)***	I (1)
FDI	-3.835388 (0.0055)***	I (0)	-5.427286 (0.0004)***	I (0)
FND	-7.291032 (0.0000)***	I (1)	-7.225392 (0.0000)***	I (1)
CO2	-5.355813 (0.0001)***	I (1)	-5.335320 (0.0005)***	I (1)
TOP	-6.375065 (0.0000)***	I (1)	-6.285387 (0.0000)***	I (1)

*Note: values in parentheses are P-values, while *** and ** represent 1% and 5% significance level, respectively.*

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Table 3 ***The Philip Perron (PP) stationarity test result***

Variables	Constant	Level of Integration	Constant With Trend	Level of Integration
ENC	-6.536255 (0.0000)***	I (1)	-6.434735 (0.0000)***	I (1)
FDI	-4.661108 (0.0006)***	I (0)	-5.445327 (0.0004)***	I (0)
FND	-7.613041 (0.0000)***	I (1)	-7.563618 (0.0000)***	I (1)
CO2	-5.352777 (0.0001)***	I (1)	-5.335320 (0.0005)***	I (1)
TOP	-6.825506 (0.0000)***	I (1)	-6.793404 (0.0000)***	I (1)

Note: values in parentheses are P-values, while *** and ** represent 1% and 5% significance level, respectively.

Tables 2 and 3 above presents the unit root results from both ADF and PP technics. Checking unit root property in the time series data is very crucial in order to avoid having a spurious results which may be policy misleading. The results of ADF and PP shows the mixture of stationarity, some of the variables were found to be stationary at level I(0) while others at first difference I(1) at 1% and 5% level of significance. That is to say there exists a mixture of stationarity or order of integration. One of the strength of Toda and Yamamoto causality as main tool of data analysis is that, the technique does not relied on order of integration of the variables. Hence we can proceed with the estimation.

4.3 Determination of the optimal lag length (ρ)

To determine the best lag length for the models that are free from serial correlation and other problems, there is a need to utilize the optimum lag length test using the VAR framework. To do

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that, this study determines the optimum lag for the TY model to avoid assuming one lag chosen for all the models. To achieve this most notable lag selection criterion were used to obtain the optimum lag for the estimated model.

As pointed out by Musa & Maijama'a, (2020) it is more recommended to either select a lag based on the prominent criterion such as AIC and SC, or go by the lag selected by the majority of the criterion. Lag selection was conducted based on various criteria and the outcome is presented in table 4 below.

Table 4 VAR optimum lags length result: Environmental pollution model

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-848.6589	NA	4.66e+12	46.19778	46.45901	46.28987
1	-735.5011	178.6343*	8.70e+10*	42.18925*	44.01786*	42.83392*
2	-704.9290	43.55297	1.16e+11	42.32049	45.71648	43.51773
3	-678.1329	26.07189	3.03e+11	42.81799	47.78136	44.56781

*Note: *Stands for lag selected by different criteria.*

From Table 4 above, 1 lag has been selected as the optimum lag; this is because the lag (1 lag) was selected by all the five criteria for lag selection for the model. Having properly determined the optimum lag for the model, the study proceeds straight to the estimation of Toda & Yamamoto causality models.

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Table 5 *Toda and Yamamoto causality result: Environmental Pollution model*

Null hypothesis	Chi-Square ($\chi2$)	P-value	Conclusion
Carbon dioxide emission CO2 does not cause trade openness TOP	0.005683	0.9399	Unidirectional causality
Trade openness TOP does not cause carbon dioxide emissions CO2	6.241578**	0.0125	
Carbon dioxide emission CO2 does not cause energy consumption ENC.	0.140988	0.7073	Unidirectional causality
Energy consumption ENC does not cause carbon dioxide emission CO2	0.176616**	0.0437	
Carbon dioxide emission CO2 does not cause foreign direct investment FDI.	0.010282	0.9192	Zero causality
Foreign direct investment FDI does not cause carbon dioxide emission CO2	0.002033	0.9640	
Carbon dioxide emission CO2 does not cause financial development FND.	0.248265	0.6183	Zero causality
Financial development FND does not cause carbon dioxide emission CO2	1.570826	0.2101	

Note: ** represents a five percent (5%) level of significance

Table 5 presents the TY causality results for South Africa's environmental pollution model. The empirical results revealed that evidence of unidirectional causality running from trade openness TOP to CO2 emission in South Africa was discovered. Meaning that, the null hypothesis that TOP does not cause CO2 has been rejected or failed to be accepted at 5% significance level. Additionally the null hypothesis that FND does not cause CO2 emissions was failed to be rejected and is accepted. It should be noted that CO2 and TOP are the main variables of interest in the study model.

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What this result presents is that, any expansion of development in the foreign trade activities in the economy has great tendency of escalating the environmental pollution in the economy of South Africa. The economy of South Africa is sensitive to imported pollution as well as the domestic pollution induced by foreign trade. The action left to the relevant authorities to plan how to maximize gains from foreign trade and minimize the environmental pollution concurrently in South Africa

Several empirical researches discovered a similar outcome to this one of having a causality running from trade openness to environmental degradation in the form of CO2 emission in various study places utilizing varieties of methodologies. That is to say the finding is consistent with number of previous researches such as the study by Azam *et al*. (2021), where international trade brings about environmental pollution, especially in developing economies, Mutascu, (2018), Chen *et al.* (2019), Huang et al. (2019) and Du *et al.*, (2020) to mention but few have all empirically discovered a positive impact of trade openness on environmental pollution. This finding is also consistent with findings obtained by Shahbaz, et al. (2017), Wasti & Zaidi, (2020), Du, et al. (2021), Dauda et al. (2021) and Jijian et al. (2021). This result implies that any increase in the volume of trade openness may correspondingly bring an increase in environmental pollution in the country.

Lastly, for South Africa, another evidence of zero causality between CO_2 and financial development FND was observed. Meaning that the two hypotheses that CO_2 does not cause FND and that FND does not cause CO_2 both failed to be rejected at a five per cent significance level. Meaning that in South Africa there is evidence of zero causality between CO2 and FND. This result implies that FND has no influence or contribution in explaining variation or change in the level of CO_2 in South Africa. In these countries further FND has not been achieved at the expense of the environmental quality. A policy aimed at lowering the level of CO_2 emission in the countries should bother with other measures such as utilizing more renewable energy resources, pollution abatement technologies and acceptable stringent environmental policies instead of focusing on the level of FND to curb the problem.

Diagnostic Tests

Table 6 below presents the estimated results for the Toda-Yamamoto diagnostic tests for South Africa's environmental pollution model. The model is free from the serial correlation of the variables in the model as the null hypothesis of there is no serial correlation failed to be rejected based on the Breusch-Godfrey serial correlation LM test. In the same vein using Breusch-Pagan-Godfrey test for heteroskedasticity was conducted. The empirical result confirmed that the null hypothesis that there is no heteroskedasticity failed to be rejected and hence concluded that the model is free from the heteroskedasticity issue. Based on the Jarque-Bera normality test, it was discovered that the stochastic error is normally distributed and concluded that the residuals are

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normally distributed. Using Ramsey's RESET test it was confirmed that, the model's function and specifications are perfect. It can be concluded that none of the assumptions of CLRM is violated in the models and hence the model is perfect to be used for making valid conclusions and inferences.

Table 6 Diagnostic Test results

	Tests	F-statistic	Obs*R-squared
(A)	**Serial Correlation Test**	0.380189 (0.6871)	0.996451 (0.6076)
(B)	**Heteroskedasticity Test**	2.242541 (0.0574)	13.11012 (0.0695)
(C)	**Normality Test**	76.48292 (0.000000)	Not Applicable
(D)	**Ramsey RESET Test**	1.760879 (0.1945)	Not Applicable
(E)	**Stability Test**	Stable	

Note: A: Lagrange Multiplier test of residual serial correlation
B: Based on regression of squared residuals on squared fitted values
C: Based on the test of skewness and kurtosis of the residuals
D: Ramsey's RESET test using a square of the fitted value
E: based on plots of CUSUM and CUSUMQ
Figures in parenthesis represent probability values

5 Summary, Conclusion and Recommendations

This study investigates the causal relationship between trade openness, financial development and environmental pollution, in South Africa between the periods 1980 and 2023. Pre estimation tests such as unit root test and post estimation diagnostic tests were made. Various optimum lag length selection tests were conducted using VAR technique to have a best lag for the model. Toda and Yamamoto causality technique was used as a main statistical method of data analysis.

Based on the empirical evidences obtained this study discovered the existence of a unidirectional causality from trade openness to environmental pollution in the study country at 5% significance level.. The implication of this result is that, any further expansion in trade openness activities may increase environmental degradations in the form of CO2 emission. This finding emphasized the need for policy makers to integrate the environmental considerations in to trade and economic policies. Specifically, environmental regulations should be strengthened and to ensure that the expansion of trade does not occur at the expense of ecological sustainability. Policies promoting the adoption of clean and energy-efficient technologies as well as incentives for green production should be implemented.

With regards to financial development and pollution, the study concluded that there is absence of any causation between financial development and environmental pollution. Meaning that; financial development is not among the factors that contribute to the environmental degradations in South Africa.

The study further recommended that; foreign trade policy should be design and implemented which discourages the importation of pollution ridden facilities. Stringent pollution measures should be imposed on the polluting sectors. Where necessary incentive should also be used or given to those importers who import less polluting facilities and to the domestic producers as well. On the other wing, since it has been discovered financial development is not contributing to environmental pollute, hence the study recommend that, while financial sector expansion is taking place other measures of reducing pollution should be imposed and ensured by the authorities.

As in most of the scientific studies of this nature this study encountered some challenges. Such constraints include that of up to date data covering up to 2024. Additionally there is constraint regarding the number of pages required to report this finding in more elaborate form. There is need for sponsorship to expand the size of the work. For further and future researches on this same issue there is need to upgrade the time span of the study to up to 2025 and see what may likely be the situation. Alternative methods should be employed such as VAR and Granger causality and panel causality techniques.

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