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Threshold Effect of Trade on Climate Change in South Africa

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ABSTRACT

The relationship between trade and climate change is not a simple linear relationship. In this paper, using the threshold regression model, we estimated the effect of trade on climate change in South Africa. The paper applied the LM test to examine the nonlinear inference approach to test whether nonlinearity existed and if the threshold model was relevant to the study. The results show that when energy use is set as the threshold variable, the relationship between trade and climate change measured as methane is U-shaped. Also, in other models of GHG as climate change indicators, the results show that the effect of trade on climate change is not dynamic. This result supports the idea that high and low trade effects may have different impacts on climate change indicators. It is, therefore, recommended that all exporters in South Africa resort to more innovative environmental mechanisms to reduce the contribution to climate. The suggestion for future studies is to consider exports of different sectors to climate change. This approach will avoid the generalization of exporting firms as the worst emitters.

INTRODUCTION

Climate change is presently being recognized as a dominant problem in humankind leading to wide research that roots and affects the environmental degradation of the climate (Khan et al. 2022). However, not a shock that Beeson (2010) has described the atmosphere as a vital public policy issue. Around the world, several public sectors have embraced an environmental protection policy. For instance, France mandated that every registered company submit a report on how their operations may benefit or harm the environment. In most worldwide solutions to climate change, the significance of the environmental issue and the urgency of lowering greenhouse gas emissions are frequently highlighted.

Despite this, the "United Nations Framework Convention" on Climate Change 1992, the "Kyoto Protocol" 1997, the "Doha Agreement" 2012, and the "Paris Agreement" 2016 established the objectives and commitments from both developed and developing countries to reduce GHG emissions by producing and consuming less carbon. Carbon emissions are known to be the primary cause of global warming (Balogh & Jambor 2017, Friedl & Getzner 2003), while anthropogenic greenhouse gas emissions are known to be the primary cause of climate change (Appiah et al. 2019, Tang & Tan 2015).

Trade openness includes nations that purchase specific goods they are unable to produce from other nations and export goods that profit from their lower opportunity costs. Then, as part of the international exchange process, items are moved from one economy to another during manufacturing to the final point of consumption. However, increases in trade openness could lead to an increase in transport services in both countries, for instance, when importing and exporting from different nations. The correlation between trade and climate change has drawn the attention of many economists, policymakers, and members of society today. In recent literature, it is presumed that trade has profound effects on climate change. The scale impact predicts that more trade will result in increased energy consumption, which would, therefore, result in increased environmental deterioration. Free trade may have negative or positive environmental effects depending on "size, technique, and content," according to Antweiler et al. (2001).

Furthermore, economic growth brought on by commerce may have an impact on the environment. Economic expansion initially has a detrimental influence on the environment because of the extensive consequences of increased energy use. Nevertheless, in the long run, it might benefit the ecology.

African region contributed 2.5% to the international anthropogenic carbon dioxide emissions from 1980–2005 (Canadell et al. 2009). Even though "sub-Saharan Africa's" (SSA) emissions are the slightest internationally, this has been rising in the previous era. Since the significance of this hasty population upsurges in "carbon emissions" related to the contrary impacts, they are more worrying. Despite housing 14% of the world's population, the SSA has one of the fastest rates of population increase in the world and emits 7.1% of all GHGs (The Economist 2018).

A developing country, such as South Africa, is one of the major emitters of carbon emissions, accounting for 1.09% of global emissions (World Bank 2021). South Africa is currently ranked fifteenth in terms of annual carbon dioxide emissions. The country is primarily reliant on the energy sector, as coal is the main fuel used. This makes South Africa an even more intriguing place for this study. Even with South Africa's trade policy revisions, its conservation impact is being established as one that receives less attention (World Bank 2021). The issue of how this trade is affecting the environment or carbon dioxide emissions is now on the rise. This is the central question of this paper is to understand the effect of trade on climate change in South Africa.

Firstly, our paper contributes to the existing literature by applying the novel threshold regression by Bruce & Hansen (2000). This method provides an advantage over traditional regression in the sense that the method models the phenomena depending on change points or thresholds. Threshold regression provides a simple but elegant and interpretable way to model certain kinds of nonlinear relationships between the outcome (climate change) and a predictor (trade). *Secondly*, our paper contributes by exploring the use of three measures for climate change which are methane, nitrous oxide, and greenhouse gas emissions. This approach is very critical in the sense that it will provide a more inclusive view on measures of environmental quality, and this may avoid misleading policymaking by only using one measure of climate change.

The study Is organized as follows for the remaining portions. The literature is examined in Section 2. Section 3 presents the research method. While Section 4 provides results and discussion. Section 5 presents the conclusions of the study.

PAST STUDIES

The first to offer a theoretical framework for the environmental consequences of economic openness were Grossman & Krueger (1995) and Copeland & Taylor (1994). Multiple elements influencing carbon emissions and the ways that trade can have an impact on the environment are highlighted by Antweiler et al. (2001), who further expanded on it. To classify the environmental influences, the study divides them into effects of composition, method, and scale. The degree of environmental deterioration is influenced by the structural nature of an industrialized country's output. This structural composition, therefore, has an environmental influence, which is captured by the composition effect. Because people like a clean environment and stricter environmental rules are implemented as income levels rise, the technique effect leads to greater environmental quality (Kebede 2017). While less developed countries with loose and compromised environmental standards constantly prioritize producing more products with a high pollution footprint, industrialized nations with stringent environmental controls often manufacture fewer products with a significant carbon footprint.

Numerous studies in empirical literature have investigated the relationship between trade and climate change. However, across a range of methodological frameworks and countries under examination, the outcomes of these studies are generally unclear and conflicting. The empirical study by Ibrahim & Ajide (2021a) found that trade openness raises CO_2 emissions in the G-7. Similar results were provided by Van Tran (2020), who showed that, between 1971 and 2017, 66 developing economies' environmental conditions deteriorated because of trade. In contrary Dogan and Turkekul (2016) conducted an analogous analysis in the USA to determine the relationships between carbon emissions, urbanization, economic development, trade, energy depletion, and financial expansion. The findings demonstrated that more trade helps the US environment. Furthermore, Ibrahim & Ajide (2021b) found that trade openness slows down environmental deterioration in the setting of G-20 countries using the common correlated effect mean group (CCEMG) and mean group (MG).

The literature further demonstrates in developing economies, trade facilitation (TF) as a measure of trade openness for 48 Sub-Saharan African countries from 2005 to 2014. Ibrahim and Ajide (2022) conclude that TF is environmentally friendly and raises environmental quality in the area. The work of Adams and Osei-Opoku (2020) employed a time series from 1995 to 2014 and focused on 22 Sub-Saharan African countries. The paper examined the relationship between two carbon emissions indicators and trade performance (split into imports, exports, and total commerce) as well as figures on territory-based carbon emissions. It was found that trading generally lowers emissions using the system's generalized method of moments. Appiah et al. (2022) used the Driscoll-Kraay error's regression in pooled OLS to determine the long-run coefficients. The results show that increased exports and urbanization are reported to benefit the environment of emerging countries, albeit this gain is not statistically significant. Khan & Ozturk (2021), by using the difference and system generalized method of moment models, discovered that between 2000 and 2014, 88 developing nations' CO_2 emissions increased because of trade. Similar findings were made by Ali et al. (2020), who discovered that the Organization of Islamic Cooperation countries' exposure to the global commodities market results in a significant deterioration of those countries' environmental circumstances.

The literature further shows that for developing single countries, the study by Khan et al. (2022) found that Pakista's openness to trade makes the environment's condition worse. Furthermore, the paper by Halicioglu (2009) examined the relationship between foreign trade, energy use, income, and carbon emissions in Turkey. The paper found a long-term connection between global trade and pollution emissions. Antweiler et al. (2001) investigated how pollutant concentrations are impacted by global trade in products. Findings showed that when the overall composition of national production is changed, foreign trade causes a minor marginal shift in environmental degradation. There are also empirical papers in China regarding trade and climate change. The paper by Weber et al. (2008) on trend analysis suggests that the main reason for the rise in China's CO_2 emissions is an increase in exports.

Furthermore, Chinese researchers examined the relationship between trade exports and carbon emissions (Xuemin 2009). The analysis revealed a two-way causal relationship between trade exports and CO_2 emissions, leading to the conclusion that exports had a significant impact on China's emissions level. Toda and Yamamot's causality test and the vector autoregression approach were both used by Michieka et al. (2013) to investigate the relationship between CO_2 emission, coal use, and export commerce in China for the period 1970 to 2010. The findings revealed that there is a cointegration between exports and carbon emissions. Jalil & Mahmud (2009) have established the long-term connections between environmental degradation, energy consumption, income, and international commerce in China. The paper used time series data for the years 1975 to 2005. Their research paper shows that trade opening has been beneficial but is classed as having a statistically modest effect. The analysis demonstrates that trade liberalization has improved China's environment, yet it is deemed to have a statistically minor impact. In the South African context, an empirical study by Udeagha & Ngepah (2019, 2022) demonstrates that access to global markets for goods causes the environment to deteriorate over time in South Africa. The author'' analysis also reveals a strong link between CO_2 emissions and trade openness.

According to the literature above, numerous empirical studies have been conducted to examine trade and climate change in industrialized and developing countries. There have been inconsistent results from earlier empirical studies on the relationship between trade and climate change, ranging from the assertion that rising trade leads to rising concerns about climate change. Empirical research has produced uneven and typically mixed results. All these earlier studies, such as Jalil & Mahmud (2009), Xuemin (2009), and Udeagha & Ngepah (2019), only used one measure of climate change as opposed to different measures analytically and for policy. Our paper gives estimation results for both, which also aids in testing the reliability of our findings. Different from these previous studies, this study investigates trade and climate change in South Africa.

MATERIALS AND METHODS

The study adopts and modifies the model used by Michieka et al. (2013) to explore the impact of trade on climate change in South Africa. The econometric model takes on the following form:

$$CC_t = \alpha_0 + \alpha_1 URP_t + \alpha_2 EPT_t + \theta_t \qquad \ldots(1)$$

Where CC_t accounts for climate change, in which for this study is measured using various indicators such as Met_t which is the methane, Nit_t to describe nitrous oxide and Nit_t greenhouse gas emissions. These indicators serve as the dependent variables for each variation of equations to be considered. The independent variables to be considered are EU energy use, URP, which is the urban population, and EPT is the export of goods to measure the trade component of the study. The empirical literature is widely suggesting that there may be a non-linear relationship between trade and climate change. Hence, according to Bruce & Hansen (2000), the current study develops an econometric model with a single threshold model and is as follows:

$$CC_t = \alpha_0^1 + \alpha_1^1 URP_t + \alpha_2^1 EPT_t + \theta_t,\ if\ q_t \leq \gamma > \alpha_0^2 + \alpha_1^2 URP_t + \alpha_2^2 EPT_t + \theta_t,\ if\ q_t > \gamma \qquad \ldots(2)$$

Where q_t is the threshold variable used to split the sample into regimes, for the current study, is EU_t energy use and the parameter value is unknown. This type of estimation strategy allows the role of nuclear energy to differ depending on whether the carbon emissions are below or above some unknown level of gamma. In this model, GDP acts as a sample-splitting or threshold variable. The effect of nuclear energy on carbon emissions is designated β_1^1 and β_2^1 for low carbon emissions or β_1^2 and β_2^2 for high carbon

Table 1: Data source and description.

Abbreviation	Variable description	Data source
met	Methane emissions (kt of CO_2 equivalent)	United Nations Framework Convention on Climate Change.
Nit	Nitro oxide	IEA Statistics OECD/ IEA 2014
GHG	GHG net emissions/ removals by LUCF (Mt of CO_2 equivalent)	Climate Watch. 2020. GHG Emissions. Washington, DC: World Resources Institute
URP	Urban population	World Bank
EU	Energy use (kg of oil equivalent per capita)	IEA Statistics OECD/ IEA 2014
EXP	Exports of goods and services (% of GDP)	World Bank

emissions. On the other hand, under the hypothesis $\beta_1 = \beta_2$ the model becomes linear and reduces to (1).

This paper employs a time series of data from 1990 to 2020 for South Africa. Depending on data availability, data for the period 1990 to 2020 is adequate for maximizing the number of collected observations to investigate the effects of trade on climate change. Table 1 depicts the list of the variables used in the study.

RESULTS AND DISCUSSION

Graphical and descriptive statistics are used to describe the basic characteristics of the data that are employed in the study. In a preliminary analysis, the study examined each variable at levels and first differences. The study explored the time series plots of variables in levels. Fig. 1, therefore, presents all the variables. It shows that Methane (Met), nitrous-oxide (Nit), greenhouse gases (GHG), exports of goods (EXP), and energy use (EU) have a random walk, whereas the urban population (URP) has an upward trend.

The descriptive statistics of the variables of the study are presented in Table 2. In South Africa, the average export of goods was around 3.21% from 1990 to 2022, whereas for the urban population, it was 17.17, and for energy use, it was 7.86. and for climate change indicators, for methane was 11.18, for Nitrogen was 2.97, and for greenhouse gases was 2.23. South Africa had a maximum greenhouse gas at 2.37%, where methane was 11.29 and 3.04 for nitrous oxide.

As the basis approach to empirical analysis, in the current paper, we primarily estimated the linear model given in equation (1). Estimation results are presented in Table 3. The table shows 3 variations of regression results, where the dependent variable climate change is measured in terms as Met_t which is the methane, Nit_t to describe nitrous oxide and Nit_t greenhouse gas emissions.

The linear model shows that the effect of trade on climate change has different effects on different measures. Specifically, results show that trade has a positive effect on climate change when it is measured as nitrous oxide and greenhouse gas emissions. Whereas trade on climate change measured as methane it shows a negative effect, but it is not statistically significant. For the control variable, urban population, the results show that when climate change is measured as methane and greenhouse gases, their trade has a positive effect, and the parameters are statistically significant. As the literature indicated, the relationship between trade on climate change can also be non-linear in nature; therefore, the current paper explores such a relationship.

Bruce & Hansen's (2000) procedure also must test whether the true relation given in equation (1) is linear or not. The LM-test statistic was applied to test the linearity of data as the null hypothesis. From the three models, it is evidenced that the models Met and GHG are significant. The LM-test statistics are calculated as 8.664 (with p-value = 0.048) and 16.593 (0.00), respectively (Table 4). Therefore, those models imply that nonlinearity was quite acceptable. For Nit as the climate change indicator, the results failed the test on non-linearity.

In detecting nonlinearity, the paper applied the LM test proposed by Bruce & Hansen (2000), which allowed the study to understand if a threshold effect existed for each of the explanatory variables. Table 5 presents test results for the threshold effects of trade on climate change with a control variable as the urban population. The table reports the three models measuring climate change as methane, Nitrogen,

Table 2: Descriptive statistics of variables.

Variable	Obs	Mean	Std. Dev.	Min	Max
Met	32	11.187	.087	11.054	11.291
Nit	32	2.97	.034	2.89	3.043
GHG	32	2.239	.076	2.118	2.37
Urp	32	17.172	.221	16.768	17.523
Eu	32	7.862	.058	7.737	7.99
Exp	32	3.213	.147	2.942	3.474

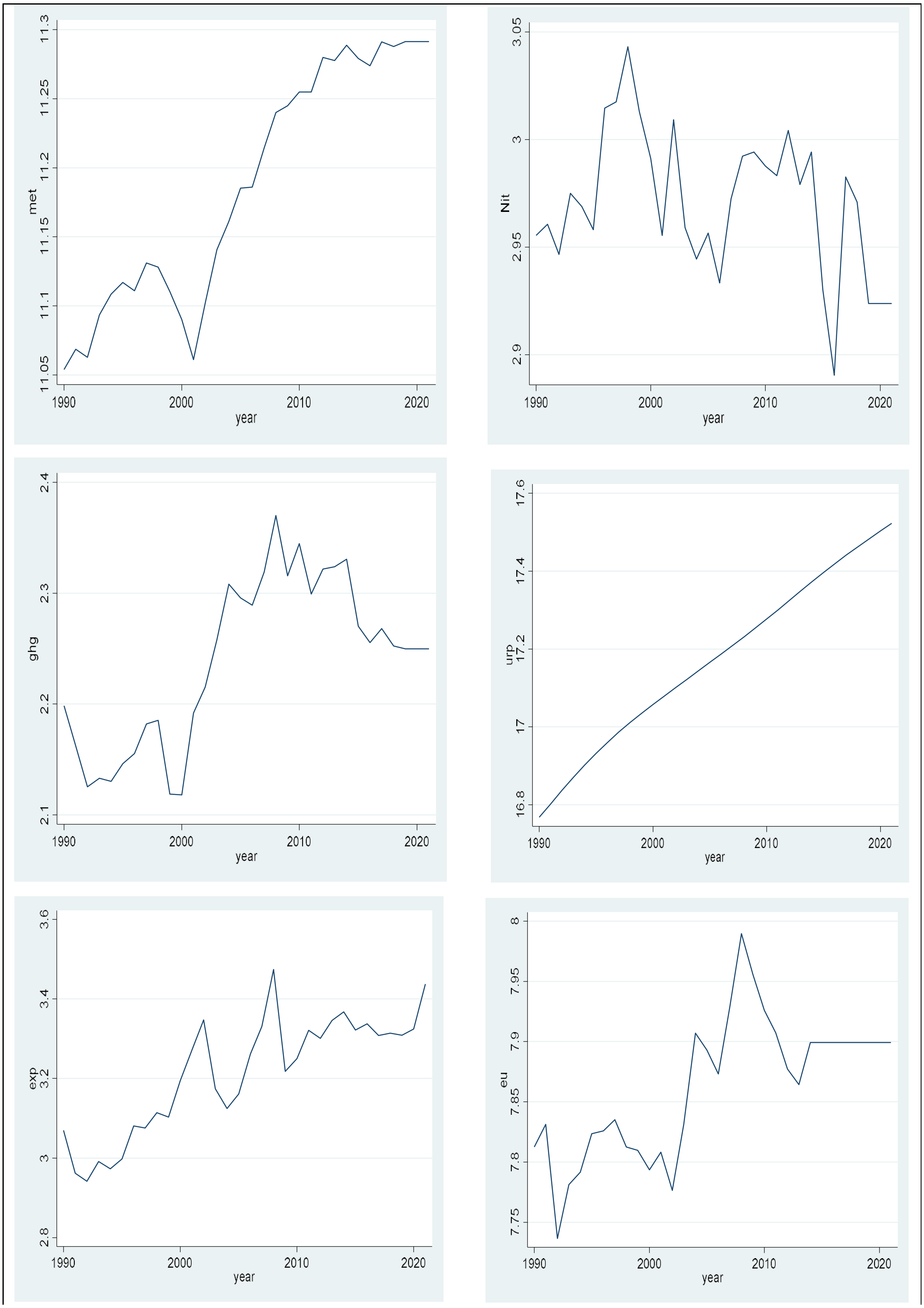

Fig 1: Line graphs for all variables of the study.

Table 3: OLS Estimation without threshold.

	Met	Nit	GHG
Intercept	4.305	4.459	0.205
	(5.732)***	(7.544)***	(0.205)
URP	0.415	-0.105	0.062
	(6.792)***	(2.560)***	(0.794)
EXP	-0.080	0.102	0.298
	(0.816)	(2.138)***	(2.504)***
R-squared	0.895	0.152	0.550

Table 4: Results of the threshold test.

	Met	Nit	GHG
LM-test for no threshold:	8.664	4.630	16.593
Bootstrap P-Value:	0.048**	0.611	0.000***

and greenhouse gases. It is important to mention that the nitrogen model is not significant for threshold analysis but is just presented for observation purposes.

From the model of Met, the results show that when energy use is set as the threshold variable, the relationship between trade and climate change measured as methane is U-shaped. It shows that when energy use is above 7.83, trade has a positive effect on climate change. This implies that a 1% increase in trade will result from a positive effect on climate change (methane) with a 0.208% change. Also, the results show that when energy use is below 7.83, trade has a negative effect on climate change, measured as methane.

This implies a 1% increase in trade, which will result negative effect on climate change with 0.104% change. For the control variable, urban population, it shows that in both regimes, urban population has a positive effect on climate change, and the effect is statistically significant. For the GHG model, the results show that trade has a positive effect on climate change in both regimes. It shows that when energy use is below 7.83, trade has a positive effect on climate change measured as greenhouse gases. This implies that a 1% increase in trade will result from a positive effect on climate change (greenhouse gases) with a 0.231% change. Also, the results show that when energy use is above 7.83, trade has a positive effect on climate change measured as greenhouse gases. This implies a 1% increase in trade, which will result from a positive effect on climate change with a 0.224% change. For the GHG model, it can be concluded that the effect of trade on climate change is not dynamic.

Fig. 2 presents the normalized likelihood value using the likelihood ratio sequence for all the models estimated in this paper. The Likelihood Sequence (LS) parameter of □ is the value that minimizes these graphs at 7.83%. The 95% critical value line is plotted with a confidence interval of asymptotic

Table 5: Threshold regression results.

	Met	Nit	GHG
Threshold	7.835	7.835	7.835
Intercept_0	6.502	-0.364	2.475
	(8.993)***	(-0.342)	(0.942)
URP_0	0.308	0.206	-0.060
	(6.039)***	(0.287)	(-0.348)
EXP_0	-0.208	-0.051	0.231
	(-3.250)***	(-0.698)	(2.242)***
Intercept_1	6.080	5.186	6.553
	(17.421)***	(7.113)***	(11.125)***
URP_1	0.278	-0.145	-0.288
	(13.900)***	(-3.222)***	(-8.470)***
EXP_1	0.104	0.087	0.224
	(3.058)***	(0.165)	(5.209)***

95%, which crosses the dotted line. These findings suggest that there is support for two regime sampling for Met and GHG models only.

CONCLUSION

The climate change influence from trade has been strongly argued over the recent years. This paper aimed to investigate the threshold impact of trade on climate change for the period 1990 to 2022. Our paper used the methodology developed by Bruce & Hansen (2000), which allows the data to endogenously split the sample into two regimes. The current paper made an argument that it is best to measure climate change in different ways to avoid misspecification. The study applied different measures such as methane (Met), nitrous oxide (Nit), and greenhouse gases (GHG) as indicators of climate change in South Africa. The paper used energy use as the threshold variable. Therefore, three models were estimated, and climate change was proxied as Met, Nit, and GHG as the dependent variables.

The paper tested in all models of climate change indicators whether nonlinearity exists and if the threshold model is appropriate in each case. It was found that only two models passed the test of non-linearity which is the Met model and GHG model. The results show that when energy use is set as the threshold variable, the relationship between trade and climate change measured as methane is U-shaped. Also, in other models of GHG as climate change indicators, the results show that the effect of trade on climate change is positive in all regimes. This result supports the idea that high and low trade effects may have different impacts on climate change indicators, especially when climate change is measured as Methane.

Policy implication from this study is the importance of policymakers' approach to the idea of climate change. Policy design must be specific to a particular indicator in the fight

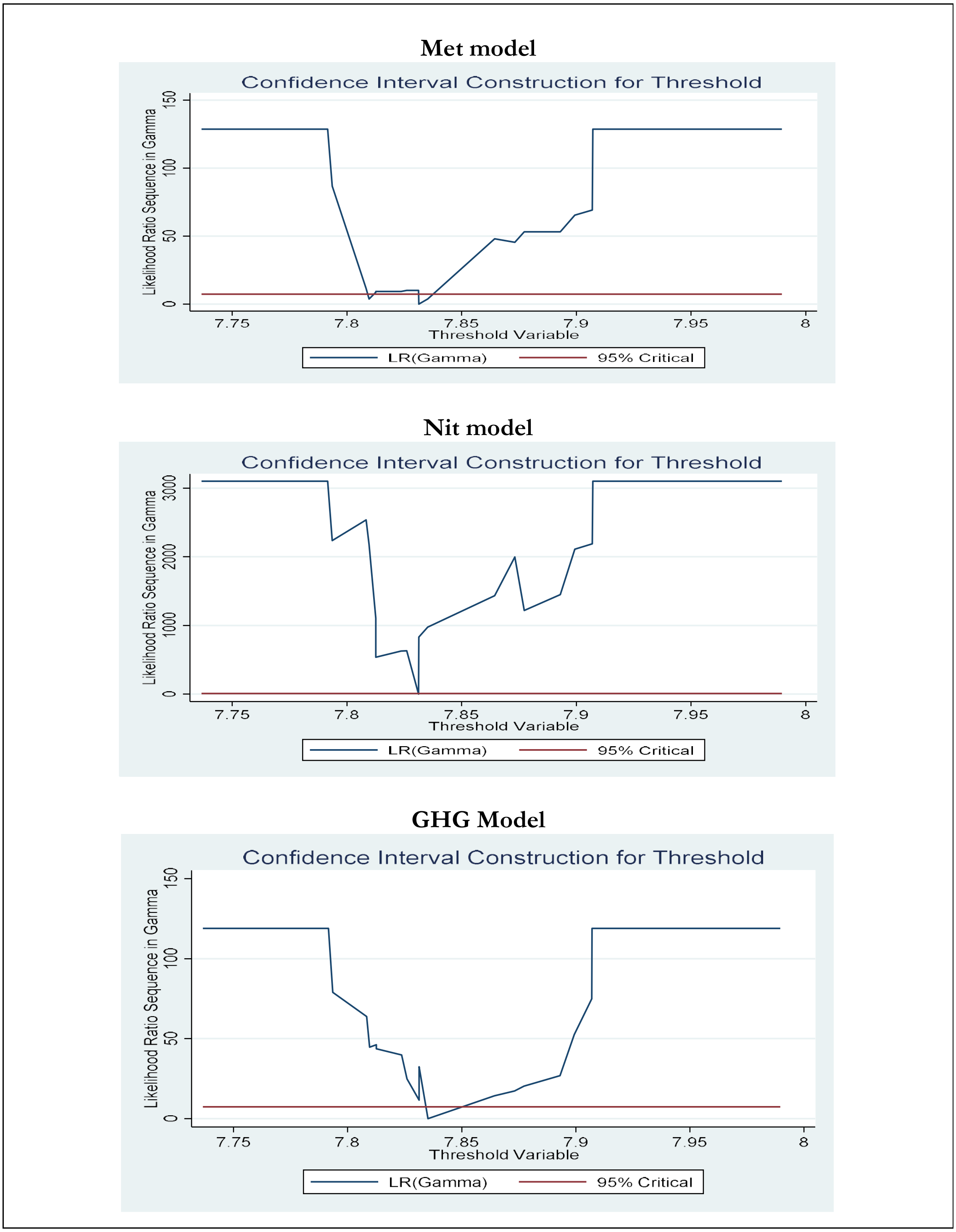

Fig. 2: Confidence interval construction for the threshold levels.

to mitigate climate change. Also, the result of this study implies that after a certain level (threshold) of energy use, exports seem to deteriorate the environment. It is, therefore, recommended that all exporters in South Africa resort to more innovative environmental mechanisms to reduce the contribution to climate. The suggestion for future studies is to consider exports of different sectors to climate change, and this approach will avoid the generalization of exporting firms as the worst emitters.

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