A step Towards Environmental Mitigation In South Africa: Does Trade Liberalisation Really Matter? Fresh Evidence From A Novel Dynamic ARDL Simulations Approach

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A step towards environmental mitigation in South Africa: Does trade liberalisation really matter? Fresh evidence from a novel dynamic ARDL simulations approach

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Abstract

This study revisits the trade-CO_2 emissions nexus for South Africa over the period 1960-2016. Our strategy is distinctively different from previous works in the following dimensions: we employ the recently developed novel dynamic autoregressive distributed lag (ARDL) simulations framework to examine the negative and positive changes in trade openness, technological innovation, industrial growth, energy consumption, foreign direct investment, technique effect, and scale effect on CO_2 emissions. Second, we use an innovative measure of trade openness developed by Squalli and Wilson (2011) to capture trade share in GDP as well as size of trade relative to world trade for South Africa. Third, we use the frequency domain causality (FDC) approach, the robust testing strategy suggested by Breitung & Candelon (2006) which enables us to explore permanent causality for medium, short and long-term relationships among variables under review. Fourth, we employ the second-generation econometric procedures accounting robustly the multiple structural breaks which have been considerably ignored in earlier studies. For South Africa, we find that: (i) higher trade openness is strikingly injurious to the environment in the long run, although it is environmentally friendly in the short run; (ii) the scale effect increases CO_2 emissions whereas the technique effect improves it, validating the presence of an environmental Kuznets curve (EKC) hypothesis; (iii) energy consumption, foreign direct investment and industrial value-added deteriorate environmental quality; (iv) technological innovation contributes to lower CO_2 emissions; (v) the pollution haven hypothesis (PHH) exists; (vi) InSE, InTE, InOPEN, InEC, InFDI, InTECH and InIGDP Granger-cause $InCO_2$ in the medium, long and short run suggesting that these variables are important to influence CO_2 emissions. In light of our empirical evidence, this paper suggests that the international teamwork to lessen carbon emissions is immensely critical to solve the growing trans-boundary environmental decay and other associated spillover consequences.

JEL Classifications: F18, F13, Q56; O13; F1; F41

Keywords: Trade openness; CO_2 emissions; Dynamic ARDL simulations; Energy consumption; EKC; Cointegration; Economic growth; Industrial value-added; South Africa

1. Introduction

Greenhouse gases (GHGs) emissions like carbon dioxide (CO_2) are seen as the driving factor for climate change, which happens due to internal changes within the climate system, or in the interaction between its components, or due to changes in external forces brought about by either human activities or natural factors (Udeagha & Ngepah, 2019). The notion that environmental degradation poses a threat to only the industrialised countries and not the less developed countries is no longer valid today at least in terms of consequences (Shahbaz, Tiwari & Nasir, 2013c). The accumulation of GHGs emissions in the surface of the earth is significantly affecting every nation across the world, both industrialised and less developed, notwithstanding the country who is responsible for such emissions. The tsunami in Japan, the earthquake in Haiti, the outburst of flood in Australia and Pakistan and the burn out of fire in Russia are just few major disasters witnessed in the recent past that could be attributed to the repercussions of environmental degradation (Zerbo, 2017). Such events brought about destructions to infrastructure, natural resources like agricultural land and produce, wildlife, forests, and most importantly to precious human lives.

Environmental degradation is now a global issue since every nation is exposed to such threats. The responsibility to save the world from such threats is largely dependent on nations like China, India, Russia, Brazil, OECD group and USA and who are considered the key GHGs emitters (Shahbaz, Tiwari & Nasir, 2013c). More importantly, the successful international efforts to minimise the global CO_2 emissions is substantially dependent on the commitment of these key emitters. However, problems begin for countries because CO_2 emissions are connected to energy production and energy is crucial for economic growth. In this situation, reducing CO_2 emissions would certainly reduce production, which in turn retards economic growth, thereby making these countries very reluctant to either comply or commit to programmes to minimise these emissions. Therefore, this calls for finding better approaches in which sustainable economic growth along with improved environmental quality could be attained. Therefore, trade liberalisation is among strategies which a country could be deployed to realise these.

Trade liberalisation is seen as a crucial tool that brings about economic growth in both developing and developed economies. As clearly illustrated by Udeagha & Ngepah (2020a, b), Udeagha & Ngepah (2019), Ngepah & Udeagha (2019), Ngepah & Udeagha (2018), Ngepah (2014) and Berg & Krueger (2003), it permits a full exploitation of a country's comparative advantage resulting in high returns to capital in unskilled labour-abundance countries; enables the importation of investment and intermediate goods needed to boost domestic production in developing countries and leads to openness to innovations and ideas. It brings about improved innovation resulting in greater entrepreneurship via improved market access and higher competition. Also, openness to international goods markets is a vehicle that brings about new investment, enhancing productivity and stimulating employment and real wages (Berg & Krueger (2003). The consensus reached by most studies is that the internationally active (more open) economies develop faster; consequently, they tend to be more productive than their counterparts, which simply concentrate on the production to satisfy their domestic markets. Furthermore, trade liberalisation stimulates efficiency in resource allocation leading to improved economic growth. This ultimately could lead to transformation into larger factor accumulation, knowledge spillovers and technology diffusion (Udeagha & Ngepah, 2020a, b; Das & Paul, 2011; Zahonogo, 2017). While considering the gains of trade liberalisation, its environmental impact has received a less attention.

Over the years, the environmental effect of trade liberalisation has attracted much attention, thereby generating more heat than light. Theoretical works have successfully revealed the numerous channels in which trade liberalisation influences a country's environment, empirical studies have however generated mixed findings. Antweiler et al. (2001), while drawing from Grossman and Krueger (1991; 1995)'s important works, theoretically divide the impact of trade liberalisation on the environment into composition, technique and scale effects.

Concerning the empirical works on the trade-CO_2 emissions nexus, the reported findings are mostly contradictory and largely diverse (Harbaugh et al., 2002; Rahman et al., 2017; Cherniwchan, 2017). Previous studies, which examined the impact of trade liberalisation on environmental quality were criticised with the way it defined and measured trade openness. These studies used the ratio of trade (sum of imports and exports) to GDP to measure trade openness, which orthodoxly referred to as "trade intensity (TI)". This proxy was criticised because it only focuses on the comparative position of trade performance of a country in relation to its domestic economy. In this way, it overlooks openness of a country to global trade, thus failing to precisely reflect the true effect of trade openness on the environmental quality. The use TI-based proxy penalises bigger economies like Germany, the US, France, China, Japan, South Africa and many others because they are being classified as closed economies due to their larger GDPs, whereas the poor countries such as Zimbabwe, Zambia, Venezuela, Uganda, Ghana, Nigeria, Togo and many others are grouped as open economies due to their small GDPs (Squalli and Wilson, 2011). The diverse findings and lack of empirical agreement about the trade-environment nexus are also attributed to the differences in methodological approaches and problems associated with model misspecifications.

Against this background, this paper contributes to the empirical literature on the trade-environment link in four ways: (i) It adopts an innovative measure of trade openness proposed by Squalli and Wilson (2011) capturing trade share in GDP as well as size of trade relative to the global trade. Therefore, employing the Squalli and Wilson proxy of trade openness in this study remarkably differentiates our paper from others, which predominantly used TI-based measure of trade openness. (ii) Previous studies, which examined the trade-environment nexus have widely used the simple ARDL approach proposed by Pesaran et al. (2001) and other cointegration frameworks that can only estimate and explore the long- and short-run relationships between the variables. However, this study uses the novel dynamic ARDL simulations model proposed by Jordan and Philips (2018), which overcomes the limitations of the simple ARDL approach. The novel dynamic ARDL simulations model can effectively and efficiently resolve the prevailing difficulties and result interpretations associated with the simple ARDL approach. This newly developed framework is capable of stimulating and plotting to predict graphs of (positive and negative) changes in the variables automatically and also estimate their relationships for long run and short run. (iii) It uses the frequency domain causality (FDC) approach, the robust testing strategy suggested by Breitung & Candelon (2006) which permits us to capture permanent causality for medium term, short term and long term among the variables under review. This test is also used for robustness check in this study. To the best of our knowledge, previous studies have not used this test in the trade-environment nexus especially in the context of South Africa. (iv) Lastly, it employs the second-generation econometric procedures accounting robustly for the multiple structural breaks which have been considerably ignored in earlier studies. In light of this, the paper uses the Narayan and Popp's structural break unit root test since empirical evidence shows that structural breaks are very persistent in empirical literature and many macroeconomic variables like CO_2 emissions and trade openness are affected by structural breaks.

The remainder of the paper is organised as follows. Section 2 reviews the relevant literature on trade-environment nexus. Section 3 outlines the material and methods, while section 4 discusses the results. Section 5 concludes with policy implications.

2. Literature review

The theoretical underpinning on the environmental effect of trade openness was earlier developed by Copeland & Taylor (1994) and Grossman & Krueger (1993, 1995). Antweiler et al. (2001) later amplified that. Grether & De Melo (2003) contend that international trade indirectly brings about environmental decay because it boosts economic growth and directly causes environmental degradation in less developed countries since it facilitates the inflow of trade activities from industrialised nations. Given this, Dinda (2006) highlights that the pollution-intensive industries in developed countries facing higher environmental standards have continuously migrated to developing countries. This migration consequently has resulted to increasing the pollution levels; thereby making less developed countries dirtier. This suggests that trade openness leads to worsening environmental quality. This notion is referred to as pollution haven hypothesis (PHH) and has been extensively investigated by previous studies

Theoretical study by Antweiler et al. (2001) is instrumental for highlighting the various factors influencing carbon emissions and channels through which trade openness can affect the environment. The study thus divides the environmental impacts into composition, technique and scale effects. The structural composition of a country's industrial production determines the level of environmental degradation. Composition effect therefore reflects the environmental effect of this structural composition. A country with more carbon-intensive production structure will always generate more environmental pollution compared to its counterpart whose production structure is less carbon-intensive. So, the nature of a country's industrial composition and structural arrangement determine the level of that country's environmental quality. Regarding the scale effect, this is an effect on emissions brought about by a rise in income. As income increases, it deteriorates environmental quality because of intensive production. The technique effect, on the other side, arises due to the enforcement of environmental laws, which force private sector to comply with the adoption of greener, cleaner and updated production processes improving environmental quality. The technique effect results in a better environmental quality because of people's predisposition for a clean environment as well as the enforcement of more stringent environmental standards as income increases (Kebede, 2017). In summary, Antweiler et al. (2001) stress that the overall composition effect will be determined by the magnitude of a country's openness to international trade, the resource abundance, comparative advantage and the enforcement of environmental standards. Developed countries with high environmental standards usually produce less carbon-intensive goods; however, their less developed counterparts with feeble and compromised environmental laws always specialise in production of more pollution-intensive products.

Turning to empirical literature, a good number of works have investigated the relationship between trade and the environmental quality. However, the findings of these studies are mostly contradictory and unsettled across various methodological frameworks and countries scrutinised. While some works concluded that trade openness brings about improvement in environmental quality through various channels (Aichele & Felbermayr, 2013; Zerbo, 2015; Kwakwa, Alhassan & Adu, 2018; Li, Xu & Yuan, 2015; Shahbaz, Tiwari & Nasir, 2013c; Wan, Nakada & Takarada, 2018; Dogan and Seker, 2016; Ling, Ahmed, Muhamad & Shahbaz, 2015; Hasson & Masih, 2017; Jabeen, 2015; Cherniwchan, 2017; Dogan and Turkekul, 2016; Destek, Balli & Manga, 2016; Zerbo, 2017; Roy, 2017), a few studies contended that trade openness results in worsening environmental condition (Twerefou, Appiah-Konadu & Anaman, 2015; Jamel & Maktouf, 2017; Raza & Shah, 2018; Le, Chang & Park, 2016; Balin, Akan & Altayligil, 2017; Lin, 2017; Solarin, Al-Mulali, Musah, & Ozturk, 2017; Shahbaz, Nasreen, Ahmed & Hammoudeh, 2017; Fernández-Amador, Francois, Oberdabernig & Tomberger, 2017; Kebede, 2017). On the contrary, another group of works found robust evidence that trade openness has no impact on the environment (Gale and Mendez, 1998; Oh and Bhuyan, 2018).

Empirical study by Kwakwa et al. (2018) examines the trade-environmental quality nexus in Ghana adopting the STIRPAT methodology. Authors found that higher trade openness contributes to improve Ghana's environment. Employing a two-country trade model, Wan et al. (2018)'s results show that trade openness, when supported by an environmental regulation, leads to lower CO_2 emissions. Looking at the case of North American Free Trade Agreement (NAFTA), Cherniwchan (2017) uses two major indicators of environmental quality to explore the environmental effect of NAFTA. The author shows that trade openness significantly reduces these indicators at the affected firm levels. Likewise, Roy (2017) argues that intra-industry trade as well as the overall trade intensity are beneficial to the environment, although intra-industry trade appears to have more beneficial effect. Zerbo (2017) likewise draws a similar conclusion in the case of 14 African nations that trade openness contributes immensely to boost economic growth and improves environmental condition. The author further argues that international trade enables the Sub-Saharan African countries to mitigate any form of environmental decay through the import of greener technologies. Also, trade incentive policy could be vigorously pursued to ensure that openness continues to improve the environmental quality.

In addition, for Central and Eastern European Countries (CEECs) study, Destek et al. (2016)'s findings show that a higher trade openness contributes to lower CO_2 emissions and openness is environmentally friendly for CEECs under review. Similarly, Dogan and Turkekul (2016), while confirming the presence of EKC hypothesis for the US, find that increased trade openness reduces environmental pollution. Dogan & Seker (2016) explore the various factors that influence CO_2 emissions and in particular the effect of trade openness and find that trade openness and renewable energy contribute to mitigate environmental decay.

In contrast, the empirical study by Raza and Shah (2018) reveals that trade openness worsens the environmental condition in Pakistan. Equally, Solarin et al. (2017) find that openness to international goods market has a damaging effect and contributes greatly to worsen Ghana's environmental condition. The authors, while reiterating that institutional quality contributes to improve Ghana's environment, confirmed the presence of PHH in Ghana. Also, the study by Balin et al. (2017), employing the ARDL approach over the period 1974-2013 for Turkey, reveals that higher trade openness causes rising environmental collapse. This evidence is further supported by the study of

Kebede (2017), which provides similar evidence using Ethiopian dataset over the period 1970-2014. Furthermore, Jamel & Maktouf (2017) augument the framework suggested by Kebede (2017) to examine the environmental effect of trade openness and their findings illustrate that trade openness is harmful to the environment of European countries under review. Using three indicators of environmental quality (i.e. Aerosol concentration, NO_2 and SO_2,), Lin (2017) contends that trade openness significantly contributes to increase these measures. The author's empirical findings further reveal that these measures provide stable evidence showing that international trade is detrimental to Chinese environmental quality. Shahbaz et al. (2017) show that trade openness leads to environmental dilapidation of the low-income, middle-income and high-income groups. This is further supported by the work of Le et al. (2016) that higher trade openness increases environmental decay in middle- and low- income categories, whereas it has a moderate effect on high-income category.

For South Africa's case, empirical evidence is also conflicting and largely mixed (Udeagha & Ngepah, 2019; Menyah & Wolde-Rufael, 2010; Kohler, 2013; Shahbaz, Tiwari & Nasir, 2013c; Zerbo, 2015; Zerbo, 2017; Khobai & Le Roux, 2017; Hasson & Masih, 2017; Mapapu and Phiri, 2018; Inglesi-Lotz, 2018). The recent study by Udeagha & Ngepah (2019) reveals that, in the long run, openness to international goods markets contributes to deteriorate the environment of South Africa, although there is strong evidence that trade openness can contribute to improve the country's environment in the short run. The authors' findings further reveal evidence of strong asymmetric behaviour between trade openness and CO_2 emissions. Similarly, Khobai and Le Roux (2017) find that trade openness hinders South Africa's environmental condition. On the other hand, Hasson & Masih (2017)'s findings show that international trade, through technological innovation promoting expenditures on energy research and development, lessens the overall pollutions associated with CO_2 emissions in South Africa. Zerbo (2017, 2015) draws similar conclusion arguing that South Africa's environment is supported by trade openness. Likewise, Shahbaz et al. (2013c) maintain that trade openness and financial development are both found to enhance South Africa's environmental quality, whereas increases in energy consumption and economic growth substantially contribute to worsen South Africa's environmental condition. Also, Kohler (2013) utilises South African trade and energy data to show that higher trade openness supports South Africa's environment. In contrast, empirical evidence by Mapapu & Phiri (2018) and Inglesi-Lotz (2018) shows that openness has no effect on South Africa's environmental quality.

Earlier works such as those mentioned above, which investigated the relationship between trade openness and CO_2 emissions, have one thing in common. They all proxy trade openness by utilising trade intensity (TI) and applying a simple ARDL methodology. The TI-based proxy, normally described as the ratio of trade (sum of exports and imports) to GDP, only captures the trade of a country in relation to its share of income (GDP), although it is not contrived.[1] While it is intuitively sensible, the proxy does not help to resolve the ambiguity on how trade is measured and defined. Its main shortcoming is that it reflects only one dimension focusing on the comparative position of trade performance of a country linked to its domestic economy. In other words, this proxy only focuses on the question of how enormous the income contribution of a country in international trade is. Consequently, it woefully fails to address another crucial dimension of trade openness that is how important the explicit level of trade of a country to global trade is. This suggests that the proxy is unable to truly reflect the correct idea of trade openness and accurately capture the precise environmental impact of trade. Also, the use of the proxy penalises bigger economies like Germany, the US, France, China, Japan and so many others because they are being classified as closed economies due to their larger GDPs, whereas the poor countries such as Zimbabwe, Zambia, Venezuela, Uganda, Ghana, Nigeria, Togo and many others are grouped as open economies due to their small GDPs (Squalli and Wilson, 2011). Given this, the proxy fails to reflect credibly the exact idea of trade openness because it does not capture the advantages a country enjoys while engaging enormously in global trade (Squalli and Wilson, 2011). In addition, the diverse findings and conflicting evidence on the trade-CO_2 emissions relationship are blamed on different methodologies and misspecification problems.

Against this background, this paper contributes to the empirical literature on the trade-environment link in three ways: (i) It employs an innovative measure of trade openness proposed by Squalli and Wilson (2011) capturing trade share in GDP as well as the size of trade relative to the global trade for South Africa. Therefore, employing the Squalli and Wilson proxy of trade openness in this study remarkably differentiates our paper from the previous studies, which predominantly used TI-based measure of trade openness. (ii) Previous studies, which examined the trade-environment nexus have widely used the simple ARDL approach proposed by Pesaran et al. (2001) and other cointegration frameworks that can only estimate and explore the long- and short-run relationships between the variables. However, this study uses the novel dynamic ARDL simulations model proposed by Jordan and Philips (2018), which overcomes the limitations of the simple ARDL approach. The novel dynamic ARDL simulations model can effectively and efficiently resolve the prevailing difficulties

[1] This proxy is in sharp contradiction with other measures of trade openness, which have been used by earlier works such as the arbitrary binary (1,0) measure suggested by Sachs and Warner (1995).

and result interpretations associated with the simple ARDL approach. This newly developed framework is capable of stimulating and plotting to predict graphs of (positive and negative) changes in the variables automatically and estimate their relationships for long run and short run. (iii) It uses the frequency domain causality (FDC) approach, the robust testing strategy suggested by Breitung & Candelon (2006) which permits us to capture the permanent causality for medium term, short term and long term among the variables under review. This test is also used for robustness check in this study. To the best of our knowledge, previous studies have not used this test in the trade-environment nexus especially in the context of South Africa. (iv) Lastly, it employs the second-generation econometric procedures accounting robustly for the multiple structural breaks which have been considerably ignored in earlier studies. In light of this, the paper uses the Narayan and Popp's structural break unit root test since empirical evidence shows that structural breaks are very persistent in empirical literature and many macroeconomic variables like CO_2 emissions and trade openness are affected by structural breaks.

3. Material and methods

This work revisits the trade-CO_2 emissions relationship for South Africa over the period 1960-2016 by using the novel dynamic ARDL simulations model capable of stimulating and plotting to predict graphs of (positive and negative) changes in the variables automatically and estimate their relationships for the long run and short run. The paper uses the second-generation econometric procedures, which take into consideration the multiple structural breaks that have been largely ignored by the previous studies. As a first step, before implementing the novel dynamic ARDL simulations model, it is important to conduct a stationarity test on the variables to ascertain their order of integration. In light of this, we employ four traditional unit root tests such as Dickey-Fuller GLS (DF-GLS), Phillips-Perron (PP), Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root tests to confirm the asymptotic behaviour and order of integration of all variables under review. This process helps to resolve the issues of spurious regressions. In the second step, the Narayan and Popp's structural break unit root test is used since empirical evidence has shown that structural breaks are very persistent in empirical literature and many macroeconomic variables like CO_2 emissions and trade openness are likely to be affected. In the third step, the estimation of long- and short-run coefficients is done by using the novel dynamic ARDL simulations model. The frequency domain causality (FDC) approach, the robust testing strategy suggested by Breitung & Candelon (2006) is further used to capture permanent causality for medium term, short term and long term among variables under review. This test is also used for robustness check in this study.

3.1 Functional form

This work follows the robust empirical approach widely used in earlier studies by adopting the usual EKC hypothesis framework to revisit the trade-CO_2 emissions nexus for South Africa. The EKC hypothesis contends that economic growth contributes immensely to deteriorate the environmental quality because during the earlier societal developmental stage, more attention was paid to achieving higher income than realising minimum environmental decay. Consequently, higher economic growth, which inevitably contributed to worsen the environmental condition was pursued vigorously at the expense of lower carbon emissions.

This reason thus intuitively explains the rationale behind the positive relationship between the scale effect (proxy for economic growth) and the environmental quality. As the society progressed, especially during the advanced industrial stage, people became more environmentally conscious, and governments introduced environmental laws aimed at improving environmental quality. Thus, during this stage of development, people's predisposition for a clean environment as well as the enforcement of more stringent environmental standards resulted in better environmental condition as income increased. This reason therefore intuitively explains the rationale behind the negative relationship between the technique effect (square of economic growth) and the environmental quality. In its standard form, following Udeagha & Breitenbach (2021), Udeagha & Ngepah (2019), Cole and Elliott (2003) and Ling et al. (2015), the standard EKC hypothesis is thus presented as follows:

$$CO_2 = F(SE, TE) \tag{1}$$

where CO_2 represents CO_2 emissions per capita (in metric tons), an environmental quality measure; SE denotes scale effect, a proxy for economic growth; and TE represents technique effect, which captures the square of economic growth. When Equation (1) is log-linearized, the following is thus obtained:

$$\text{In}CO_{2t} = \alpha + \varphi InSE_t + \beta InTE_t + \varepsilon_t \tag{2}$$

Scale effect (economic growth) deteriorates environmental quality as income increases; however, technique effect improves environmental quality due to the enforcement of environmental laws and people's predisposition for a clean environment (Cole & Elliott, 2003; Ling et al., 2015). Given this background, for EKC hypothesis to be present, the theoretical expectations require that: $\varphi > 0$ and $\beta < 0$. Following literature, as control variables in the trade-CO_2 emissions equation, we use foreign direct investment, energy consumption, technological innovation and industrial value-added. Accounting for these variables as well as trade openness, Equation (2) is thus augmented as follows:

$$\text{In}CO_{2t} = \alpha + \varphi InSE_t + \beta InTE_t + \rho InOPEN_t + \pi InEC_t + \delta InFDI_t + \tau InTECH_t + \omega InIGDP_t + U_t \quad (3)$$

where $InOPEN_t$ represents trade openness; $InEC_t$ denotes energy consumption; $InFDI_t$ captures foreign direct investment; $InTECH_t$ is technological innovation and $InIGDP_t$ denotes industrial value-added. All variables are in natural log. $\varphi, \beta, \rho, \pi, \delta\ \tau\ and\ \omega$ are the estimable coefficients capturing different elasticities whereas U_t captures the stochastic error term with standard properties.

3.2 Measuring trade openness

Following Squalli and Wilson (2011), this work uses the composite trade intensity (CTI) as a measure of trade openness to robustly account for trade share in GDP and size of trade relative to global trade. Using this way to measure trade openness enables us to effectively address the shortcomings of conventional trade intensity (TI) widely used in earlier studies. More importantly, the novel CTI contains more crucial information pertaining to a country's trade contribution share in terms of global economy, which intuitively captures TI adjusted by the share of level of trade in relation to global trade. The novelty of CTI in this work is that it mirrors trade outcome reality because it contains two dimensions of a country's ties with the rest of the world. The CTI is presented thus as follows:

$$CTI = \frac{(X+M)_i}{\frac{1}{n}\sum_{j=1}^{n}(X+M)_j} \frac{(X+M)_i}{GDP_i} \quad (4)$$

where: i reflects South Africa; j captures her trading partners. In Equation (4), the first portion represents global trade share, whereas the second segment denotes trade share of South Africa.

3.3 Variables and data sources

This paper uses yearly times series data covering the period 1960-2016. CO_2 emissions, as the proxy for environmental quality is the dependent variable. Economic growth proxied by scale effect and the square of economic growth capturing the technique effect are used to validate the presence of EKC hypothesis. Trade openness is proxied by a composite trade intensity calculated as above. The other variables controlled for, following literature, are as follows: energy consumption (EC), foreign direct investment (FDI), technological innovation (TECH) and industrial value-added to GDP (IGDP). Table 1 therefore summarises the variable definition and data sources.

[Insert Table 1 here]

3.4 Narayan and Popp's structural break unit root test

As a first step, before implementing the novel dynamic ARDL simulations model, it is important to conduct a stationarity test on the variables under review to ascertain their order of integration. Thus, this work employs Dickey-Fuller GLS (DF-GLS), Phillips-Perron (PP), Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root tests to confirm the asymptotic behaviour and order of integration of all variables under review. This process helps to resolve the issues of spurious regressions. In the second step, the Narayan and Popp's structural break unit root test is used since empirical evidence shows that structural breaks are very persistent in empirical literature and many macroeconomic variables like CO_2 emissions and trade openness are likely to be affected.

3.5 ARDL bounds testing approach

This paper employs the bounds test to examine the nexus among the variables under review for long run. The ARDL bounds testing approach, following Pesaran et al. (2001), is presented as follows:

$$\Delta InCO_{2t} = \gamma_0 + \sum_{i=1}^{n} \gamma_{1i} \Delta InCO_{2t-i} + \sum_{i=0}^{n} \gamma_{2i} \Delta InSE_{t-i} + \sum_{i=0}^{n} \gamma_{3i} \Delta InTE_{t-i} + \sum_{i=0}^{n} \gamma_{4i} \Delta OPEN_{t-i} + \sum_{i=0}^{n} \gamma_{5i} \Delta EC_{t-i} + \sum_{i=0}^{n} \gamma_{6i} \Delta InFDI_{t-i} + \sum_{i=0}^{n} \gamma_{7i} \Delta InTECH_{t-i} + \sum_{i=0}^{n} \gamma_{8i} \Delta InIGDP_{t-i} + \theta_1 InCO_{2_{t-i}} + \theta_2 InSE_{t-i} + \theta_3 InTE_{t-i} + \theta_4 InOPEN_{t-i} + \theta_5 InEC_{t-i} + \theta_6 InFDI_{t-i} + \theta_7 InTECH_{t-i} + \theta_8 InIGDP_{t-i} + \varepsilon_t \tag{5}$$

where Δ represents the first difference, $InCO_2$, InSE, InTE, InOPEN, InEC, InFDI, InTECH and InIGDP respectively. Meanwhile, t-i denotes the optimal lags selected by Schwarz's Bayesian Information Criterion (SBIC), γ and θ are the estimated coefficients for short run and long run, respectively. The ARDL model for the long- and short-run will be approximated if variables are cointegrated. The null hypothesis, which tests for long-run relationship is as follows: $(H_0: \theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = \theta_6 = \theta_7 = \theta_8 = 0)$ against the alternative hypothesis $(H_1: \theta_1 \neq \theta_2 \neq \theta_3 \neq \theta_4 \neq \theta_5 \neq \theta_6 \neq \theta_7 \neq \theta_8 \neq 0)$.

Rejection or acceptance of null hypothesis depends on the value of the calculated F-statistic. If the value of calculated F-statistic is greater than the upper bound, we reject the null hypothesis and conclude that the variables are having a long-run relationship or there is evidence of cointegration. However, cointegration does not exist if the value of calculated F-statistic is less than the lower bound. In addition, if the value of the calculated F-statistic lies between lower and upper bounds, the bounds test becomes inconclusive. If the variables are having a long-run relationship, then the long-run ARDL model to be estimated is as follows:

$$\Delta InCO_{2t} = \beta_0 + \sum_{i=1}^{q} \omega_1 InCO_{2_{t-i}} + \sum_{i=1}^{q} \omega_2 InSE_{t-i} + \sum_{i=1}^{q} \omega_3 InTE_{t-1} + \sum_{i=1}^{q} \omega_4 InOPEN_{t-i}$$
$$+ \sum_{i=1}^{q} \omega_5 InEC_{t-1} + \sum_{i=1}^{q} \omega_6 InFDI_{t-1} + \sum_{i=1}^{q} \omega_7 InTECH_{t-1} + \sum_{i=1}^{q} \omega_8 InTECH_{t-1}$$
$$+ \varepsilon_t \qquad (6)$$

ω denotes the long-run variance of variables in Equation (6). In choosing the correct lags, the paper uses the SBIC. For short-run ARDL model, the error correction model used is as follows:

$$\Delta InCO_{2t} = \beta_0 + \sum_{i=1}^{q} \pi_1 \Delta InCO_{2_{t-i}} + \sum_{i=1}^{q} \pi_2 \Delta InSE_{t-i} + \sum_{i=1}^{q} \pi_3 \Delta InTE_{t-1} + \sum_{i=1}^{q} \pi_4 \Delta InOPEN_{t-i}$$
$$+ \sum_{i=1}^{q} \pi_5 \Delta InEC_{t-1} + \sum_{i=1}^{q} \pi_6 In\Delta FDI_{t-1} + \sum_{i=1}^{q} \pi_7 \Delta InTECH_{t-1} + \sum_{i=1}^{q} \pi_8 \Delta InTECH_{t-1}$$
$$+ ECT_{t-i} + \varepsilon_t \qquad (7)$$

In Equation (7), π reflects the short-run variability of the variables, whereas ECT denotes the error correction term that captures the adjustment speed of disequilibrium. The estimated coefficient for ECT ranges from -1 to 0. This work further uses the diagnostic tests for model stability. The Breusch Godfrey LM test is used to check for serial corrections; the Breusch-Pagan-Godfrey test and the ARCH test are both employed to test for heteroscedasticity; the Ramsey RESET test is used to ensure that the model is correctly specified, and the Jarque-Bera Test is used to test whether the estimated residuals are normally distributed. To check for structural stability, this paper employs the cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals (CUSUMSQ).

3.6 Dynamic autoregressive distributed lag simulations

Previous studies, which investigated the trade-CO_2 emissions nexus have widely used the simple ARDL approach proposed by Pesaran et al. (2001) and other cointegration frameworks that can only estimate and explore the short- and long-run relationships between the variables. To address the shortcomings which characterise the simple ARDL model, Jordan and Philips (2018) recently developed a novel dynamic ARDL simulations model that can effectively and efficiently resolve the prevailing difficulties and result interpretations associated with the simple ARDL approach. This newly developed framework is capable of stimulating and plotting to predict graphs of (positive and negative) changes in the variables automatically and estimate the relationships for short run and long run. The major advantage of this framework is that it can predict, stimulate and immediately plot probabilistic change forecasts on the dependent variable in one explanatory variable while holding other regressors constant. In this study, based on the multivariate normal distribution for the parameter vector, the dynamic ARDL error correction algorithm uses 1000 simulations. We employ the graphs to examine the actual change of an explanatory variable as well as its influence on the dependent variable. The novel dynamic ARDL simulations model is presented as follows:

$$\Delta InCO_{2t} = \alpha_0 + \upsilon_0 InCO_{2t-1} + \varphi_1 \Delta SE_t + \rho_1 SE_{t-1} + \varphi_2 \Delta TE_t + \rho_2 TE_{t-1} + \varphi_3 \Delta OPEN_t + \rho_3 OPEN_{t-1} + \varphi_4 \Delta EC_t + \rho_4 EC_{t-1} + \varphi_5 \Delta FDI_t + \rho_5 FDI_{t-1} + \varphi_6 \Delta TECH_t + \rho_6 TECH_{t-1} + \varphi_7 \Delta IGDP_t + \rho_7 IGDP_{t-1} + \varepsilon_t \quad (8)$$

3.7 Frequency domain causality test

Lastly, this paper uses the frequency domain causality (FDC) approach, the robust testing strategy suggested by Breitung & Candelon (2006) to explore the causal relationships among the variables under scrutiny. Unlike the traditional Granger causality approach where it is extremely impossible to predict the response variable at a particular time frequency, FDC enables that and further permits to capture permanent causality for medium term, short term and long term among the variables under examination. This test is also used for robustness check in this study.

4. Empirical results and their discussion

4.1 Summary statistics

The summary statistics of the variables used in this work are analysed and scrutinized before discussing the results. Table 2 reports the overview of statistics showing that the CO_2 emissions average value is 0.264. The technique effect (TE), the square of GDP per capita has the average mean of 60.316 greater than other variables. This is followed by foreign direct investment (FDI) which has 13.203. In addition to characterising the summary statistics, Table 2 uses kurtosis to represent the peak while the Jarque–Bera test statistics is used to check for normality of our data series. The table shows that the scale effect, trade openness, energy consumption, foreign direct investment, industrial value-added and technological innovation show a positive trend, while technique effect has a negative trend. The variance in technique effect (TE) is the highest of all the variables showing the high level of volatility in this variable. The variance in CO_2 emissions is less relative to technique effect showing that CO_2 emissions are far more stable. Also, the variations in trade openness (OPEN), scale effect

(SE) and technological innovation (TECH) are quite greater. In addition, the Jarque-Bera statistics shows that our data series are normally distributed.

[Insert Table 2 here]

4.2 Order of integration of the respective variables

Table 3 reports the results of DF-GLS, PP, ADF and KPSS showing that after first differencing all variables which are non-stationary in level become stationary at I (1). This implies that all the series under review are either I(1) or I(0) and none is I(2). The traditional unit root tests reported above do not account for structural breaks. Therefore, this work implements a testing strategy which is able to account for two structural breaks in the variables. The paper hence uses the Narayan and Popp's unit root test with two structural breaks and the results are also reported in the right-hand panel of Table 3. The empirical evidence shows that the null hypothesis of unit root cannot be rejected. Consequently, all data series are integrated of order one and prospective application for the dynamic ARDL bounds testing approach.

[Insert Table 3 here]

4.3 Lag length selection results

Table 4 reports the findings of different test criteria for lags selection. The use of HQ, AIC and SIC is documented in empirical literature as the most popular for selecting appropriate lags. In this study, SIC is used for lag selection. Based on this tool, lag one is suitable for our model. This is because the lowest value is obtained at lag one when SIC is used unlike others.

[Insert Table 4 here]

4.4 Cointegration test results

Table 5 displays the results of the cointegration test utilizing the surface-response regression suggested by Kripfganz &Schneider (2018). Since the F- and t-statistics are greater than the upper bound critical values at various significance levels, we reject the null hypothesis. Thus, our empirical evidence suggests that cointegration exists among the variables under consideration.

[Insert Table 5 here]

4.5 Diagnostic statistics tests

To ensure that our chosen model is reliable and consistent, the study therefore uses different diagnostic statistics tests and their empirical results are reported in Table 6. The empirical results suggest that the used model is well fitted having passed all the diagnostic tests. The model does not suffer from the problems of serial correlation and autocorrelation as confirmed by the Breusch Godfrey LM test. The Ramsey RESET test is used and evidence shows that the model does not suffer from misspecification. The Breusch-Pagan-Godfrey test and ARCH test are both employed to test if there is evidence of heteroscedasticity in the model. The empirical findings suggest that heteroscedasticity is moderate and not a problem. Finally, the Jarque-Bera test result shows that the model's residuals are normally distributed.

[Insert Table 6 here]

4.6 Dynamic ARDL simulations model results

The dynamic ARDL simulations model results are reported in Table 7. Our findings show that the scale effect (InSE) and technique effect (InTE) positively and negatively affect CO_2 emissions, respectively. The scale effect representing economic growth deteriorates environmental quality, whereas the technique effect has a mitigating effect on the environment. The empirical evidence therefore suggests that the EKC hypothesis holds in the case of South Africa. This empirical finding is supported by Lau et al. (2014); Shahbaz et al.(2012b); Saboori et al.(2012);Nasir & Rehman (2011); Shahbaz et al. (2015); Sadat and Alom (2016); Ling et al. (2015); Copeland and Taylor (1994); Fodha and Zaghdoud (2010); Jayanthakumaran et al. (2012) and Shahbaz et al. (2013c).

[Insert Table 7 here]

The estimated coefficient for long run on trade openness (InOPEN) is found to be statistically significant and positive suggesting that an upsurge in trade openness by 1% increases CO_2 emissions by 0.188% ceteris paribus. Our result is supported by Baek et al. (2009), who suggest that trade is injurious and has extensively contributed to worsen the environmental conditions of developing countries. Our empirical evidence suggests that South Africa's environmental quality is not supported by openness to international goods market in the long run. This is unlike the short-run results which show that trade openness can contribute immensely to improve the country's environmental quality. The detrimental effect of openness on the environmental condition of South Africa in the long run undeniably reiterates the concern against trade liberalisation. Meanwhile, the type of products forming the bulk of country's exports is part of the possible reason that could explain why trade openness impedes the environment. For instance, since the country has a comparative advantage in export and production of natural resource-intensive goods such forest products, antimony, tin, copper, manganese minerals, phosphates, vanadium, rare earth elements, natural gas, nickel, iron ore, nickel, coal, Chromium, diamond, platinum and gold, a rise in demand of these products will certainly lead to worsening South Africa's environmental condition. This is because, harvesting them continuously deteriorates the environment. The empirical results are supported by Omri et al. (2014); Feridun et al. (2006); Le et al. (2016); Solarin et al. (2017); Shahbaz et al. (2013a, c, 2014a, b).

For energy consumption (InEC), the estimated coefficients for short run and long run are statistically significant and positive suggesting that energy consumption considerably contributes to increase CO_2 emissions in South Africa. Energy use is crucial to support production and enhance economic development. Due to its substantial reliance in the country to produce goods, an increase in energy consumption increases CO_2 emissions. Our empirical evidence is supported by Ling et (2015) and Saboori & Sulaiman (2013) who observed similarly using Malaysian data. The short-run estimated coefficient on foreign direct investment (InFDI) is statistically significant and positive. However, the estimated value for long run, although positive, is not significant. Our results therefore suggest that a rise in foreign direct investment leads to worsening environmental decay in South Africa. Abdouli & Hammami (2017) draw a similar conclusion in the case of MENA countries that FDI has contributed enormously to increase CO_2 emissions and there is evidence of pollution haven hypothesis. Likewise, Omri et al. (2014) in the case of 54 countries concluded that the flow of foreign direct investment has exacerbated the level of pollutions in the affected countries.

The estimated coefficient on technological innovation is statistically significant and negative in the long run, suggesting that, by supporting efficient energy utilization and creating renewable energy sources at cheaper costs, technological innovation leads to minimum emissions in South Africa. Our finding is supported by previous studies such as Ahmed et al.(2016); Sohag et al.(2015); Yii and Greetha (2017); Chen and Lei (2018). The long-run estimated coefficient on industrial value-added (InIGDP) is found to be positive and statistically significant suggesting that industrial sector growth significantly contributes to deteriorate South Africa's environment in the long run. Our findings are supported by the results of Al Mamun et al. (2014) and Sohag et al. (2017). The error correction term (ECT) captures the speed of adjustment. The estimated coefficient is negative and statistically significant confirming that a steady long-run relationship exists among the variables under review. The ECT estimated value of -0.824 suggests that, in the long run, 82% of disequilibrium is corrected.

R-squared value shows that 78% variations in CO_2 emissions are brought about by the explanatory variables used in this work. The estimated p value of F-statistics suggests that the model is a good fit

While keeping other explanatory variables constant, the dynamic ARDL simulations automatically plot the forecasts of actual regressor change and its impact on the dependent variable. The effect of explanatory variables, that is, scale effect, technique effect, trade openness, energy consumption, foreign direct investment, technological innovation and industrial value-added, on CO_2 emissions is forecasted to increase and decrease by 10% in South Africa.

[Insert Figure 1 here]

Figure 1 shows the impulse response plot of relationship between scale effect (economic growth) and CO_2 emissions. The plot captures the transition of scale effect and its impact on CO_2 emissions. A 10% increase in scale effect denotes a positive effect of economic growth on CO_2 emissions in the short run and long run; however, a 10% decrease in scale effect implies a negative influence of economic growth on CO_2 emissions, but the impact of 10% increase is higher than 10% decrease in scale effect. This implies that an increase in scale effect (economic growth) contributes to deteriorate the environmental quality, whereas a decrease in scale effect improves the environmental condition in both the short run and long run in South Africa.

[Insert Figure 2 here]

Figure 2 illustrates the impulse response plot of technique effect and CO_2 emissions in South Africa. The technique effect graph demonstrates that a 10% increase is closely associated with a negative influence on CO_2 emissions in the long run and short run. However, a 10% decrease has a positive effect on CO_2 emissions in the long run and short run. This suggests that an increase in technique effect (square of economic growth) improves the environmental quality, but a decrease in technique effect deteriorates the environmental condition in both the short and long run in South Africa.

[Insert Figure 3 here]

Figure 3 displays the impulse response plot connecting the relationship between trade openness and CO_2 emissions. The plot shows that a 10% increase in trade openness positively influences CO_2 emissions in the long, but negatively affects it in the short run. In contrast, a 10% decrease in trade openness has a negative influence on CO_2 emissions in the long, but positive effect in the short run. This suggests that an increase in trade openness improves South Africa's environmental quality in the short run, but deteriorates it in the long run. However, a decrease in trade openness has a beneficial impact on South Africa's environment in the long, but deteriorates it in the short run.

[Insert Figure 4 here]

Figure 4 shows the impulse response plot of relationship between energy consumption and CO_2 emissions. The plot capturing the energy consumption impact on CO_2 emissions shows that a 10% increase in energy consumption has a positive impact on CO_2 emissions in the short run and long run; however, a 10% decrease in energy consumption has a negative influence on CO_2 emissions. This implies that an increase in energy consumption contributes to deteriorate the environmental quality, whereas a decrease in energy consumption improves the environmental condition in both the short run and long run in South Africa.

[Insert Figure 5 here]

Figure 5 illustrates the impulse response plot of foreign direct investment and CO_2 emissions in South Africa. The foreign direct investment graph demonstrates that a 10% increase in foreign direct investment is closely associated with a positive influence on CO_2 emissions in the long run and short run. However, a 10% decrease has a negative effect on CO_2 emissions in the long run and short run. This suggests that an increase in foreign direct investment deteriorates the environmental quality in both the short and long run in South Africa.

[Insert Figure 6 here]

In Figure 6, the impulse response plot between technological innovation and CO_2 emissions in South Africa is presented. The graph reveals that a 10% increase in technological innovation has a negative influence on CO_2 emissions in the long run and short run. However, a 10% decrease in technological innovation brings about a positive effect on CO_2 emissions in the long run and short run. This suggests that an increase in technological innovation improves South Africa's environmental quality, whereas a decrease in technological innovation deteriorates the environmental condition in both the short and long run in South Africa.

[Insert Figure 7 here]

Figure 7 presents the impulse response plot of relationship between industrial value-added and CO_2 emissions. The plot shows that a 10% increase in industrial value-added has a positive impact on CO_2 emissions in the short run and long run; however, a 10% decrease in industrial value-added has a negative influence on CO_2 emissions. This suggests that an increase in industrial value-added contributes to deteriorate the environmental quality, whereas a decrease in industrial value-added improves the environmental condition in both the short run and long run in South Africa.

[Insert Table 8 here]

This work also uses the frequency domain causality test proposed by Breitung & Candelon (2006) to explore the causality between InSE, InTE, InOPEN, InEC, InFDI, InTECH, InIGDP and $InCO_2$ in South Africa. Table 8 shows that InSE, InTE, InOPEN, InEC, InFDI, InTECH and InIGDP Granger-cause $InCO_2$ in the short, medium, and long run for frequencies $\omega_i = 0.05, \omega_i = 1.50, \omega_i = 2.50$. This implies that InSE, InTE, InOPEN, InEC, InFDI, InTECH and InIGDP significantly affect CO_2 emissions in short, medium and long term in South Africa. Our empirical evidence is compatible with the findings of Udeagha & Ngepah (2019); Al Mamun et al. (2014) and Sohag et al. (2017).

[Insert Figure 8 here]

[Insert Figure 9 here]

This study further applies the structural stability evaluation of the model to validate its robustness. To this end, the cumulative sum of recursive residuals (CUSUM), and cumulative sum of squares of recursive residual (CUSUMSQ) proposed by Pesaran and Pesaran (1997) are used. Figures 8 and 9 present a visual representation of CUSUM and CUSUMSQ. Conventionally, there is a stability of model parameters over time if plots are within a critical bound level of 5%. Based on the model trend shown in Figures 8 and 9, since CUSUM and CUSUMSQ are within the boundaries at a 5% level, we can conclude that the model parameters are stable over time.

5. Conclusions and Policy Implications

This study revisited the dynamic relationship between trade and CO_2 emissions in South Africa over the period 1960-2016 by using the recently developed novel dynamic ARDL simulations model proposed by Jordan and Philips (2018) that can estimate, stimulate and plot to predict graphs of (positive and negative) changes in the variables automatically as well as their short-and long-run relationships. Using this approach permits us to identify the positive and negative relationships between InSE, InTE, InOPEN, InEC, InFDI, InTECH, InIGDP and $InCO_2$ in South Africa, thereby overcoming the limitations of the simple ARDL approach in earlier studies. For robustness check, we used the frequency domain causality (FDC) approach, the robust testing strategy suggested by Breitung & Candelon (2006) which permits us to capture permanent causality for medium term, short term and long term among variables under consideration. This paper further contributed to empirical literature by employing an innovative measure of trade openness proposed by Squalli and Wilson (2011) capturing trade share in GDP and the size of trade relative to the global trade for South Africa. We used the Dickey-Fuller GLS (DF-GLS), Phillips-Perron (PP), Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root tests to confirm the asymptotic behaviour and order of integration of all variables under review. This process helps to resolve the issues of spurious regressions. Further, the Narayan and Popp's structural break unit root test was used since empirical evidence shows that structural breaks are very persistent in empirical literature and many macroeconomic variables like CO_2 emissions and trade openness are likely to be affected. Consequently, empirical evidence from all the tests validated that the data series were integrated into order one, that is, $I(1)$, and there is no evidence of any $I(2)$. SBIC was utilised to identify the optimal lag length. For South Africa, our empirical results revealed that the scale effect contributes to deteriorate the environmental condition, whereas the technique effect is environmentally friendly. This evidence therefore confirms the presence of EKC hypothesis for South Africa. Foreign direct investment, industry value-added and Energy consumption deteriorate environmental quality; however, technological innovation contributes to lower CO_2 emissions in South Africa. The FDC results also revealed that InSE, InTE, InOPEN, InEC, InFDI, InTECH and InIGDP Granger-cause $InCO_2$ in the medium term, long term and short term suggesting that these variables are important to influence CO_2 emissions in South Africa.

In addition, regarding the relationship between trade openness and CO_2 emissions, our empirical results showed that, in the long run, higher trade openness is highly injurious to the environment of South Africa, although it is environmentally friendly in the short run. Our empirical evidence is in line with the findings of Udeagha & Ngepah (2019) that, in the long run, trade openness contributes to deteriorate the country's environmental quality, but beneficial in the short run. These findings were further supported by Tayebi and Younespour (2012) that validated the presence of pollution haven hypothesis in case of many developing countries. The comparative advantage of South Africa in export and production of pollution-intensive products has enabled the migration of industries from developed countries to the country, thereby making the country the "havens" for the highly intensive-pollution industries of the world. Such a migration has considerably led to a shift in the pollution problems of these developed countries to South Africa and this has contributed significantly to worsen the current environmental deterioration. Added to this is the country's inefficient environmental laws and weak institutions due to corruption. Consequently, South Africa becomes dirtier as she continues to specialise in the production of dirty products, which highly contribute to deteriorate her environmental quality. Inevitably, trade openness has enabled to make South Africa to become an extremely polluted factory of the world.

In light of our empirical evidence, the following policy considerations are suggested: (i) South Africa's government and policymakers should take prompt initiatives to mandate foreign investors to use cleaner, greener and updated technologies, which can promote efficiency in the production processes and curtail CO_2 emissions in South Africa; (ii) International teamwork to improve environmental quality is immensely critical to solve the growing trans-boundary environmental decay and other associated spillover consequences. In light of this, the government should work together to build robust global teamwork with other countries with the purpose of sharing technology; (iii) The government should integrate all-inclusive environmental chapters into the country's trade agreement policies to enable a transition into low-carbon economy and greener industries, thus encouraging production of cleaner products; (iv) Lastly, trade policy reform could be supported by other developmental policies to ensure long-lasting value for reductions of carbon emissions and continuously enable the development of new technologies that can boost the country's environmental quality and protect the global environment.

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Figures

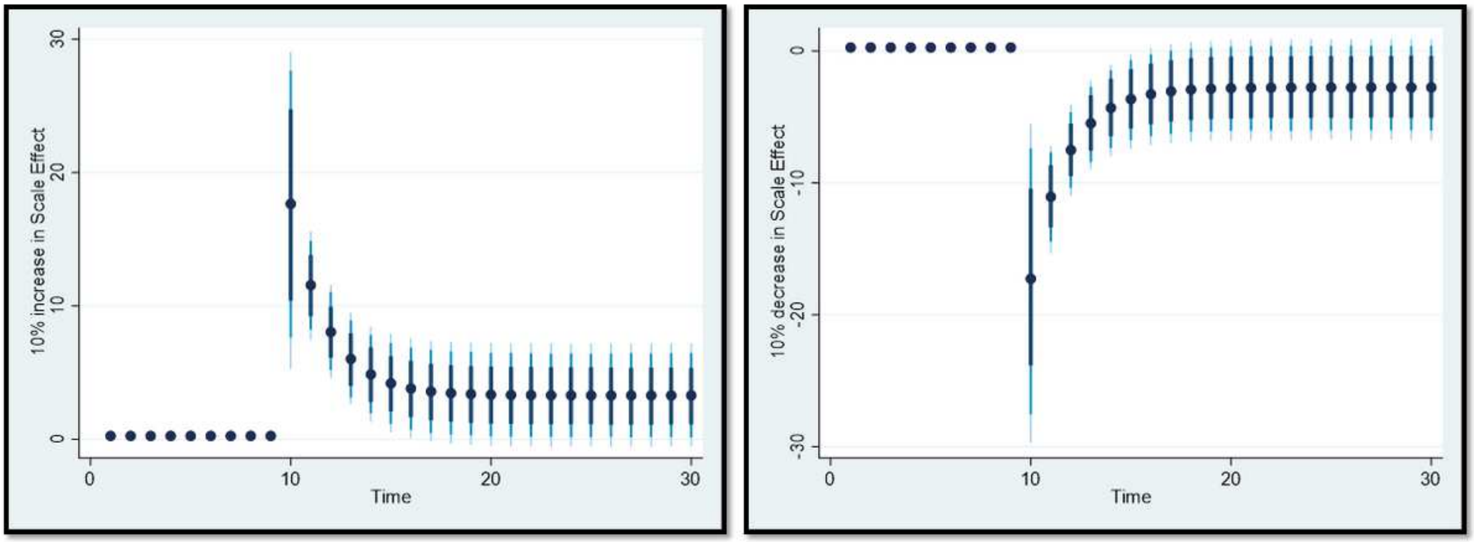

Figure 1

The Impulse Response Plot for Scale Effect (Economic Growth) and CO2 Emissions. Figure shows a 10% increase and a decrease in scale effect and its influence on CO2 emissions where dots specify average prediction value. However, the dark blue to light blue line denotes 75, 90, and 95% confidence interval, respectively.

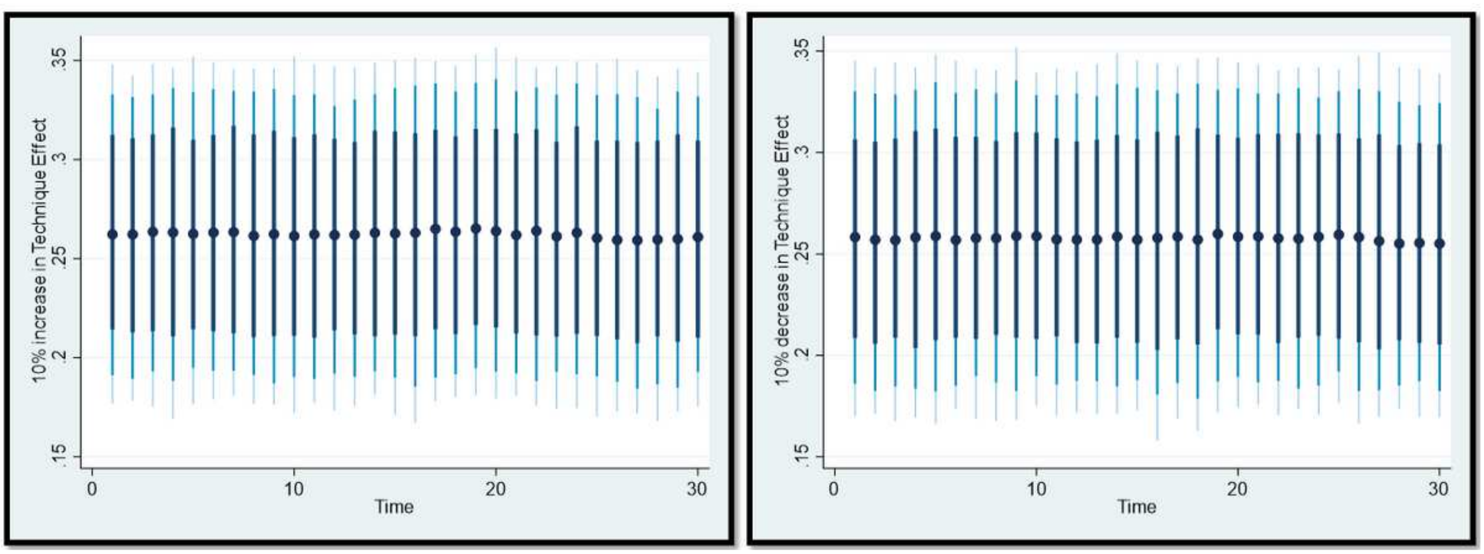

Figure 2

The Impulse Response Plot for Technique Effect and CO2 emissions. Figure shows a 10% increase and a decrease in technique effect and its influence on CO2 emissions where dots specify average prediction value. However, the dark blue to light blue line denotes 75, 90, and 95% confidence interval, respectively.

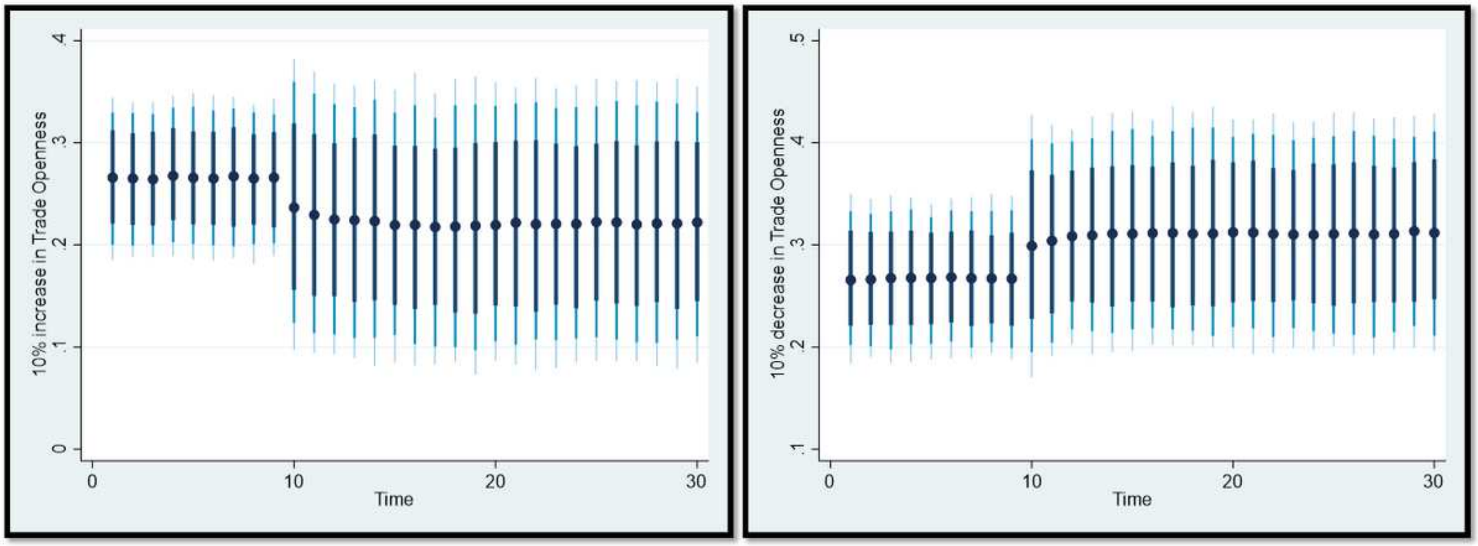

Figure 3

The Impulse Response Plot for Trade Openness and CO2 emissions. Figure shows a 10% increase and a decrease in trade openness and its influence on CO2 emissions where dots specify average prediction value. However, the dark blue to light blue line denotes 75, 90, and 95% confidence interval, respectively.

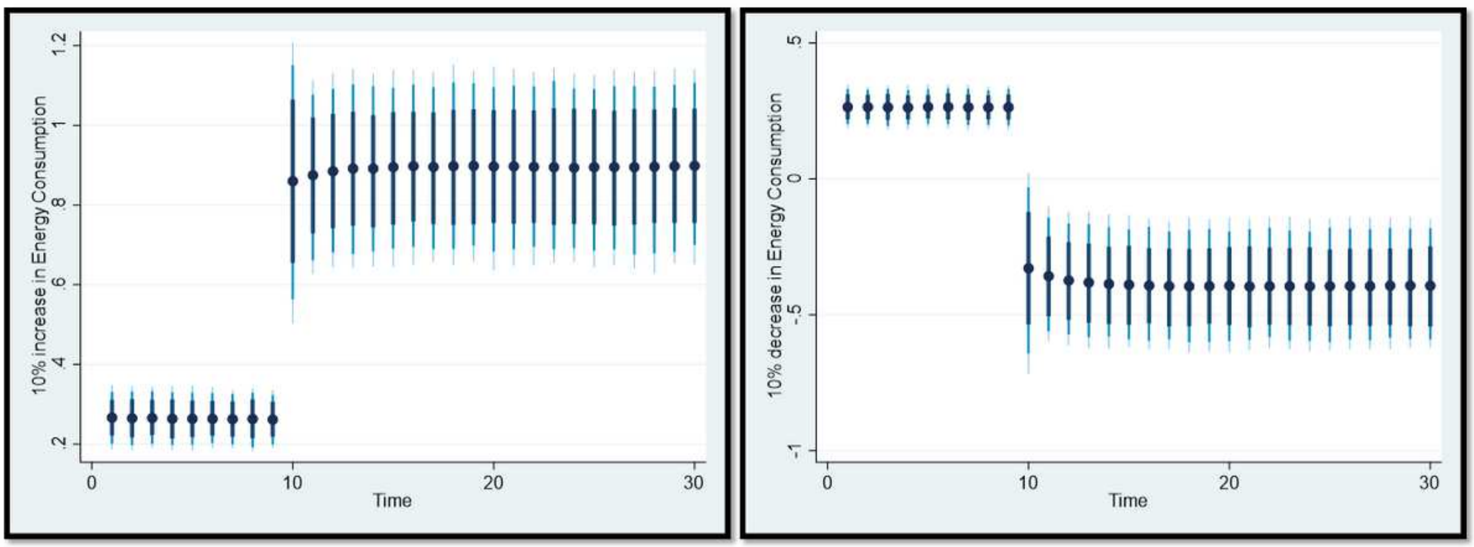

Figure 4

The Impulse Response Plot for Energy Consumption and CO2 emissions. Figure shows a 10% increase and a decrease in energy consumption and its influence on CO2 emissions where dots specify average prediction value. However, the dark blue to light blue line denotes 75, 90, and 95% confidence interval, respectively.

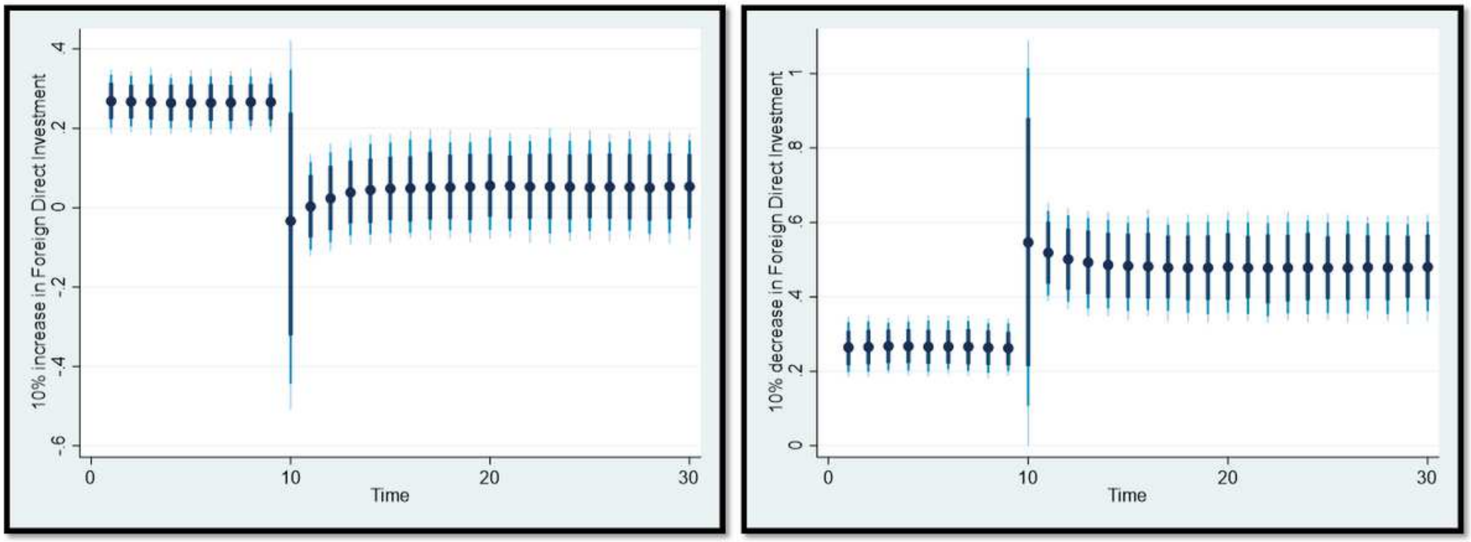

Figure 5

The Impulse Response Plot for Foreign Direct Investment and CO2 emissions. Figure shows a 10% increase and a decrease in foreign direct investment and its influence on CO2 emissions where dots specify average prediction value. However, the dark blue to light blue line denotes 75, 90, and 95% confidence interval, respectively.

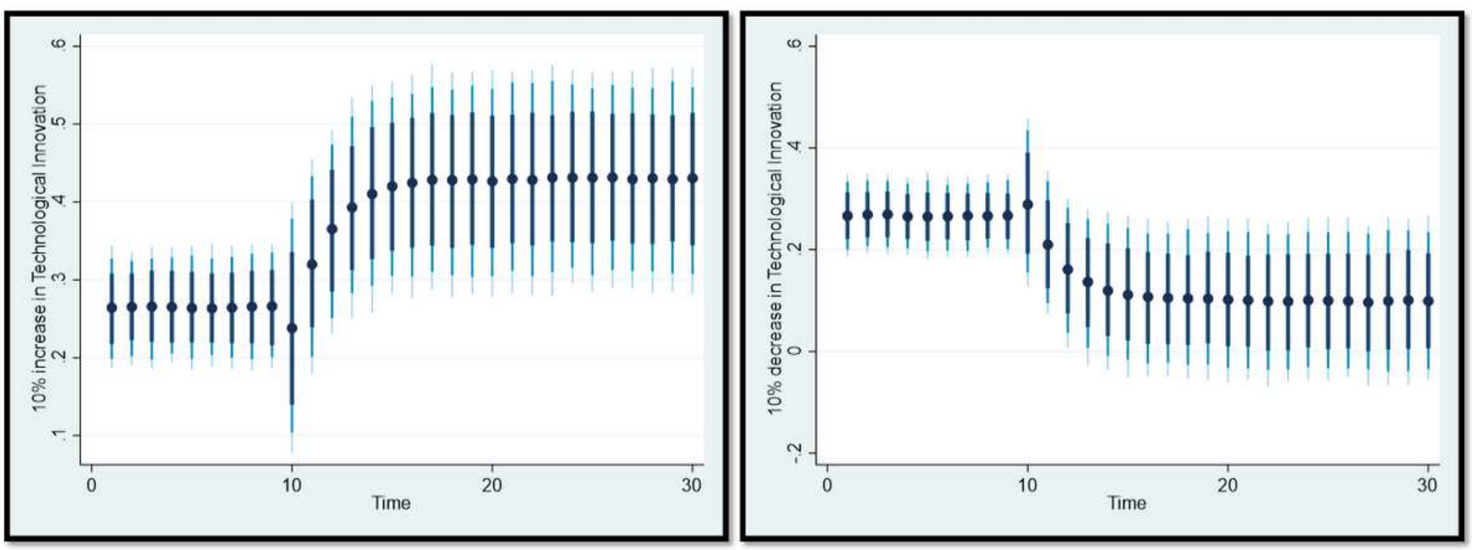

Figure 6

The Impulse Response Plot for Technological Innovation and CO2 emissions. Figure shows a 10% increase and a decrease in technological innovation and its influence on CO2 emissions where dots specify average prediction value. However, the dark blue to light blue line denotes 75, 90, and 95% confidence interval, respectively.

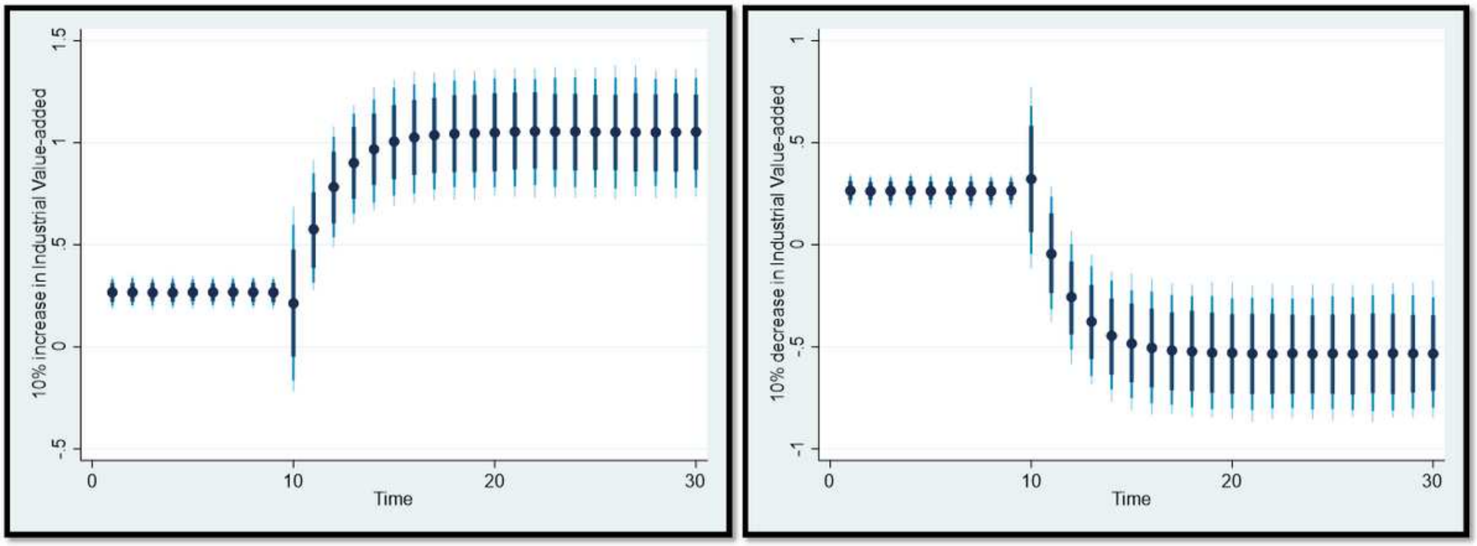

Figure 7

The Impulse Response Plot for Industrial Value-added and CO2 emissions. Figure shows a 10% increase and a decrease in industrial value-added and its influence on CO2 emissions where dots specify average prediction value. However, the dark blue to light blue line denotes 75, 90, and 95% confidence interval, respectively.

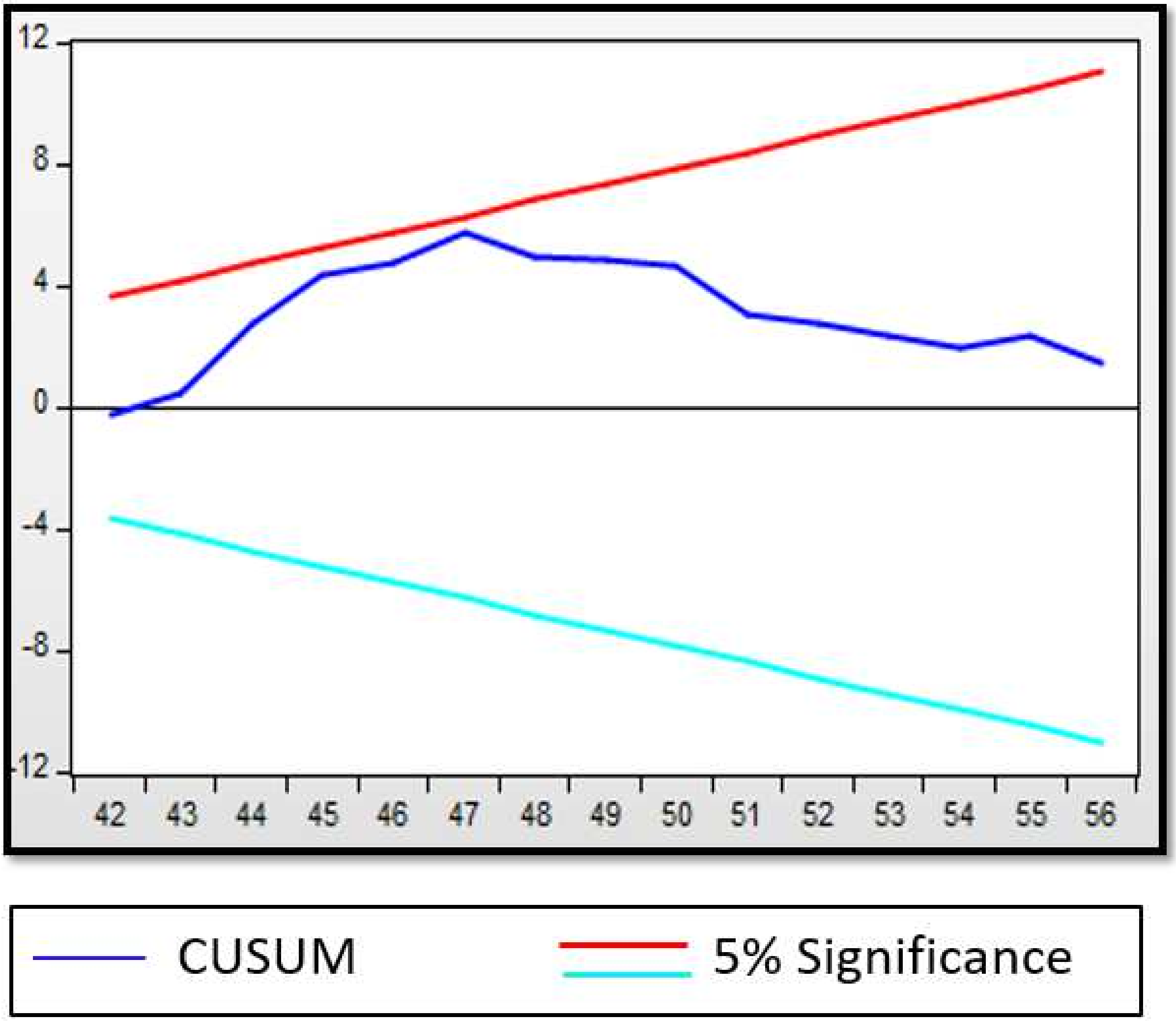

Figure 8

Plot of Cumulative Sum of Recursive Residuals (CUSUM)

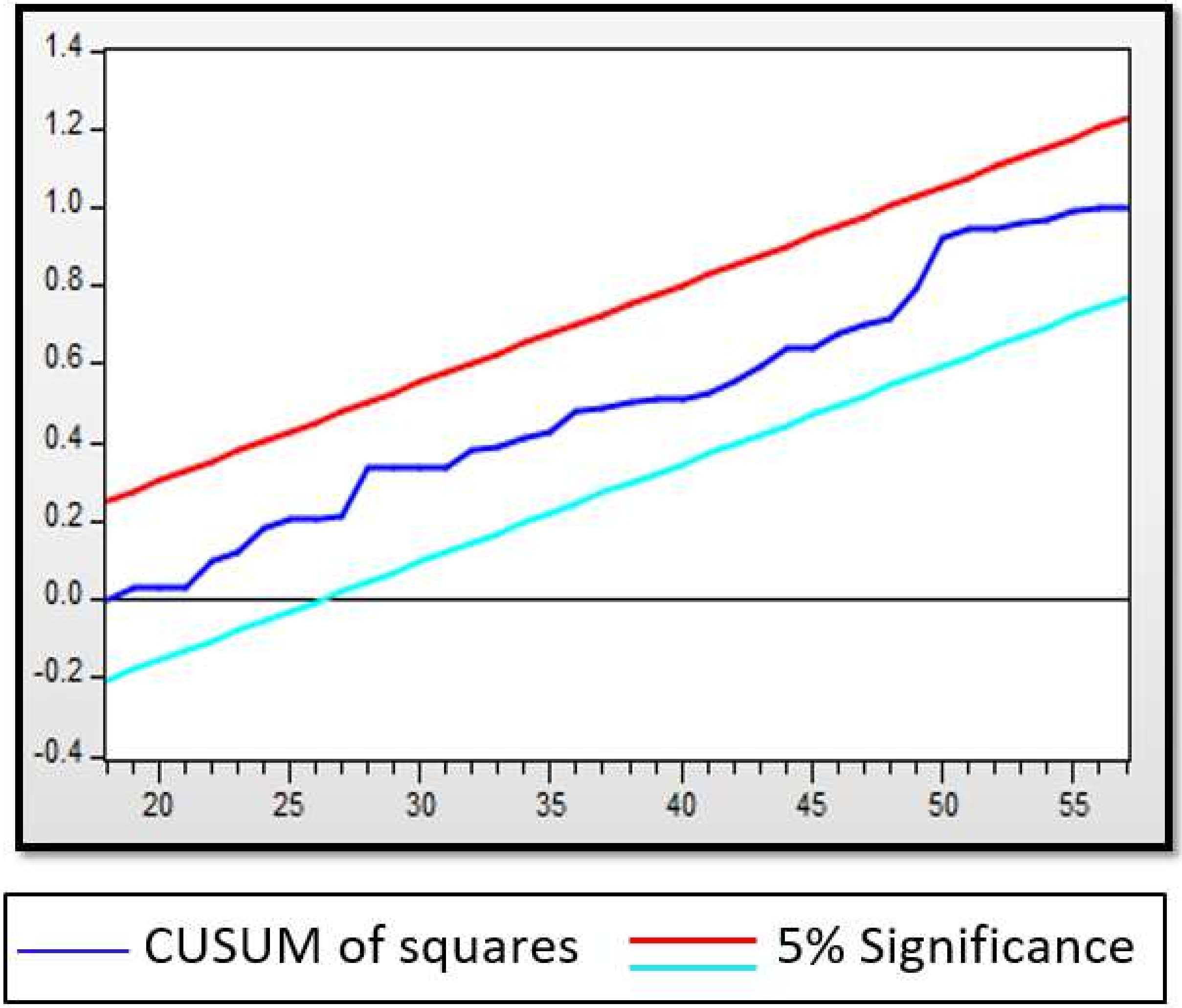

Figure 9

Plot of Cumulative Sum of Squares of Recursive Residuals (CUSUMSQ)

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Dataset.xlsx