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The Nexus between Environmental Quality, Economic Growth, and Trade Openness in Saudi Arabia (1990-2017)

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ABSTRACT

In fact, this study endeavors to explore the relationship between CO_2 emissions, trade, and economic growth using the simultaneous equation for Saudi Arabia over the period 1990-2017, using the VAR model and the impulse response functions to examine the relationship between these variables. Therefore, the obtained results showed that there is evidence of a bidirectional causality between CO_2 emissions and economic growth. Moreover, the feedback hypothesis between trade openness and CO_2 emissions is validated. Then, the retroaction hypothesis between economic growth and trade openness is identified. Furthermore, our results indicate economic growth impede environmental quality, while our empirical results have established crucial relationships that have important policy implications. However, it is mandatory for policy makers to develop economic, environmental and outside policies to promote economic growth and trade and improve the environmental quality.

Keywords: Causality, Economic Growth, CO_2 Emissions, Trade
JEL Classifications: Q56, 47, I25, B41, F31, F43, P28, O47, P33, R11

1. INTRODUCTION

Certainly, the linkage between economic growth, environmental quality, and trade openness is very complex and depends on many and different aspects, such as the size of the economy, the sectoral structure, the vintage of the technology, and the demand for environmental quality. All these factors are interconnected. Moreover, the association between per capita economic growth and the environmental quality is termed as Environmental Kuznets curve (EKC) as presented by Grossman and Krueger (1995), Panayotou (1995), Leal and Marques (2020) and Kahia et al. (2021) who suggested that economic development initially leads to the deterioration of the environment. However, after a certain level of economic growth, the society begins to improve its relationship with the environment and the level of environmental degradation. In addition, economic growth is affected by many other socio-economic factors such as the population growth, the energy use, trade openness, infrastructural development, financial sector development, the levels of corruption, etc. For example, Ozturk and Acaravci (2010); Iyke (2017) and Oloyede et al. (2021) pointed out that some of these factors, notably trade openness, play a controversial rolein economic growth. Besides, the neoclassical growth theory supports that trade openness can promote capital formation and the improvement of resource allocation efficiency, thus helping the enhancement of the economic growth quality (Grossman and Helpman, 1991). In line with this reasoning, the authors of the new growth theory, such as Romer (1986) and Robert (1988), suggested that openness of trade essentially raises the economic growth quality by accelerating technical progress and stimulating the factor productivity.

Meanwhile, more recent studies have revealed that developing countries could better exploit the existing knowledge storage of developed countries through trade. In fact, the same conclusion was revealed by the investigation of Mensi et al. (2019) who emphasized that an increase of trade can accelerate the technical progress of the advantaged industries, consequently favoring the improvement of the economic quality. In addition, trade openness significantly affects capital deepening and stimulates economic growth quality by changing the structure of the labor force. Therefore, the shared factor of the previous studies on the linear relationship between trade openness and the quality of economic growth is that most researchers assume that trade openness not only leads to economic progression but also promotes quality of economic growth which indicates that the economic activities should take environmental factors into account. On the other hand, several researchers, such as Hulten (2001), Zheng and Hu (2006) among others have attacked this area and tried to find out an indicator that measures the economic growth quality. Therefore, by taking into account the above analysis, we can think about the nexus between economic growth, trade openness, and the environmental quality. In fact, the relationship between these variables constitutes the research object of many previous studies. For example, studies that uncover a relationship between trade openness and economic growth, such as those of Hutchinson and Singh (1992), Bahmani-Oskooee and Alse (1993), Edwards (1998), Babatunde (2011), Zahonogo (2017) and Rahman et al. (2020) found mixed results. Furthermore, many other empirical studies are interested in the interconnection between economic growth and CO_2 emission. For example, Apergis and Payne (2009), Menegaki (2011), Lee (2014), Omri et al. (2015), Abdouli and Hammami (2017), and Adewuyi and Awodumi (2017) confirmed that the existence of a two-way connection between the output and carbon outflows, was studies by Lindmark (2002) for Sweden (1870-1997), Acaravci and Ozturk (2010) for Denmark and Italy (1960-2005). In addition, Can and Gozgor (2017) verified the existence of the EKC in France. Similarly, the causality links between environmental degradation and trade openness has been the subject of considerable empirical research (e.g. Jug and Mirza, 2005; Elliott and Zhou, 2013; Kahouli and Omri, 2017) who used different estimation techniques in various economic regions over diverse periods, but obtained dissimilar conclusions.

The lack of consensus as to the existence of a relationship between the variable of concern namely the economic growth, the environmental quality, and trade openness, which is the principal stimulator for conducting this work in the case of the Kingdom of Saudi Arabia to emphasize additional evidence. The model allows examining at the same time the interrelationship between economic growth, trade openness, and the CO_2 emissions. More particularly, this research uses three equations, such as a structural model, which to simultaneously examining the impact of (i) the trade openness and the CO_2 emissions on economic growth, (ii) the economic growth and CO_2 emissions on the openness of trade, and (iii) the economic growth and trade on the CO_2 emissions. Therefore, in light of these facts, the current study aims to explore the two-way connection between the variables aforementioned for Saudi Arabia. In fact, many stimulants justify the selection of this placement.

First, Saudi Arabia's economy is making exceptional leaps, especially in the non-oil sector growth, because of the programs of the Kingdom's 2030 Vision. In fact, the World Bank raised Saudi Arabia's 2023 growth forecast to 3.2% and added that the non-oil sector would be likely to have a strong recovery, which will be positively reflected on the exports. Similarly, according to the Saudi 2030 Vision, the share of non-oil exports in the non-oil GDP is to be increased from 16% to 50% and the non-oil government revenues to be increased from SAR 163 billion Saudi Rials (Sars) to trillion SARs.

Second, over the last several decades, the industrial sector has experienced a rapid growth in Saudi Arabia. In fact, the industrial value-added grew from 28.3 billion 2010 Saudi Riyals (SARs), which is the equivalent of 7.5 billion 2010 United States Dollars (USDs) in 1986, and rose to 213.4 billion 2010 SARs in 2016, which is the equivalent of 56.8 billion 2010 USDs according to Saudi Arabian Monetary Agency "SAMA," (2018). This is interpreted into a real average annual growth rate of 7%, underlining the pace of the developed industrial base in this country. Moreover, during this period, the industrial energy consumption rose at an even faster rate of almost 8% per annum (IEA, 2018). In addition, industrial activity development may improve air pollution. In this context, Saudi Arabia is one of the major emitters of carbon dioxide (CO_2) in the Middle East. By referring to BP (2019), Saudi Arabia emitted 571 million tonnes of CO_2 in 2018, or around 18 tonnes per person, which is one of the highest levels worldwide. In fact, there is a rapid and continuous growth of the domestic energy consumption, while CO_2 emissions can both strain Saudi's fiscal budget and prevents its climate change mitigation effort. During this period, industrial energy consumption rose at an even faster rate of almost 8% per annum (IEA, 2018).

Then, following the announcement of its 2030 Vision (SV 2030, 2016), Saudi Arabia started to implement critical economic, social, and environmental changes. In fact, SV2030 includes several important programs, such as the Fiscal Balance Program, the object of which is to balance the government budget by 2023 by increasing oil and non-oil revenues and improving the spending efficiency (Fiscal Balance Program, 2017-2019). The Fiscal Balance Program comprises a value-added tax, levies on expatriates, and energy price reform. In the same context, the Saudi Green Initiative works on growing Saudi Arabia's reliance on clean energy, offsetting emissions, and keeping the environment, in line with the 2030 Vision. Its goal is to improve the quality of life and defend future generations.

Finally, the last stimulant that encourages us to study international trade in the Saudi economic context is the significant share of trade openness in the GDP of this country. According to World Development Indicators (WDI) (2019), since the 1970s, the Saudi Arabian share of international trade in the GDP has exceeded 70%. In addition, the 2030 Saudi Vision highlights international trade. Indeed, it focuses on the Kingdom's well-established trading relationships with its fellow members of the GCC, other Arab countries, and further afield with foreign markets. Therefore, the solidification of the current economic ties and the creation of new business partnerships is an obvious priority. However, within the wider objective there isgreat regional focus, which brought together a series of advanced schemes.

As consequence, by integratingthe various stimulants discussed above and the three links aforementioned, this paper makes novel contributions as it aims at examining three-way linkages between economic growth, trade openness, and CO_2 emissions for the case of Saudi Arabia. To the best of our knowledge, none of the empirical previous studies has investigated the three-way linkages between the concerned variables by using simultaneous-equation modeling with a growth framework mainly in Saudi Arabia. Thus, it is worthwhile to examine the economic growth-trade-environmental quality relationship of a country, like Saudi Arabia, where the economic sector bears distinct characteristics, especially in the context of the 2030 Saudi Vision, which is a strategic framework which is intended to reduce Saudi Arabia's dependence on oil, diversify its economy, and develop public service sectors such as health, education, infrastructure, recreation, and tourism.

2. LITERATURE REVIEW

Several empirical studies have supported the assertion of the existence of a relationship between economic growth and CO_2 emissions, trade, and economic growth even though the literature evidence is mixed. Thus, this paper reviews the literature under three subsections. The first strand of literature focuses on reviewing the existing literature between economic growth and CO_2 emissions then, the second emphasizes the existing literature on trade openness and environmental degradation and finally, the third strand focuses on reviewing the existing studies on economic growth and trade openness.

2.1. Economic Growth and CO_2 Emissions

The relationship between economic growth and CO_2 emissions has been empirically analyzedin an intensive way for more than two decades as it attracted the widespread attention of a large number of researchers. In this context, some existing studies such as inter alia, those of Holtz-Eakin and Selden, (1995) and Jalil and Feridun (2011), found evidence of the EKC hypothesis which implies that economic growth degrades the environmental quality in its initial phase, while after a certain level of growth, the environmental improvement occurs. Contrary to the conclusion of the EKC hypothesis, the study of Nemat and Bandyopadhyay (1992) points out that the environmental pollution increased in parallel with economic growth. For their part, Coondoo and Dinda (2002) studied the relationship between the income and the environment for panel data from 88 countries during the 1960/1990 period. The analysis is based on a study of income-CO_2 emission causality based on a Granger causality test, which showed that the causality relationship varies depending on the country. For example, for the country groups of Central and South America, Oceania, and Japan, causality from theincome to the CO_2 emission is obtained. For their part, Martínez-Zarzo and Bengochea-Morancho (2004) exhibited that the GDP and the CO_2 emissions were positively and negatively related in high and low-income countries, respectively.

On other hand, some other studies, such as Nemat and Bandyopadhyay (1992) found that the EKC is monotonically increasing. In fact, a plethora of research works, such as those of Chandran and Tang (2013); which have been conducted to support a U-shaped relationship, but others studies found that there is an inverted-U shaped (Jalil and Mahmud, 2009; Lean and Smyth, 2010; Saboori et al., 2012; Jiang et al., 2020, Xuejiao et al., 2021), or even an N shaped relationship (Moomaw and Unruh, 1997).

Some research added other potential determinants of CO_2 emissions such as trade openness, in order to test the pollution haven hypothesis (PHH) by Halicioglu (2009), and financial development by Ozturk and Acaravci (2013).

By referring to the above analysis, we can put forward the following hypothesis:

$H_{1.1}$: Increased economic growth leads to an environmental degradation

If various studies showed that the GDP has an effect on the environmental quality, the finding of some other studies showed the opposite conclusion. Given this, Grossman and Krueger (1995) carried out an empirical analysis involving a panel of 42 countries to examine the link between air pollution and economic growth. Their results showed that despite the global negative effects of CO_2 emissions, this study has provided a little inducement for countries to undertake exclusive actions for these emissions. Especially, the results showed an "inversed-U" shaped relationship between the per capita GDP and several air pollutants. Therefore, this result confirms the conclusion of a scenario in which industrial development firstly leads to more raw emissions; however, those emissions eventually decrease because the concomitant increase of the income raises the demand for a healthy environment. Similarly, Coondoo and Dinda's above analysis (2002) found a causality running from CO_2 emissions to the income in the developed country groups of North America and Western Europe as well as in Eastern Europe. For his part, using the Vector Error Correction Model (VECM), Ang (2008) analyzed the relationship between the output, the pollutant emissions, and energy consumption in Malaysia. The results of his study, which covered the period from 1971 to 1999, showed that pollution use is positively correlated with the output in the long run. In the same line, the research aim of Yuan et al. (2008) is to examine the direction of causality between the output growth and the energy use in China's economy at both aggregated total energy and disaggregated levels such as coal, oil, and electricity consumption. The results revealed a uni-directional causal link running from electricity and oil consumption to the GDP. As for Halicioglu (2009), he employed the cointegration procedure to examine the relationship between CO_2 emissions, energy consumption, GDP, and foreign trade in Turkey from 1960 to 2005 to provide evidence in support of the damaging effect of the environmental degradation on economic growth. The same conclusion was reached by Pao and Tsai (2010) for a panel of the BRIC countries over the period 1992-2004. In the same way, Jayanthakumaran et al. (2012) used the ARDL model to investigate the links between CO_2 emissions, energy consumption, trade, and income in the case of China and India in the 1971-2007 period. Their results revealed that the low production capacity of a country could be explained by the high level of polluting emissions. Ejuvbekpokpo (2014) explored the effects of CO_2 emissions from fossils fuels, gas fuels, liquid fuels, and solid fuels on the economic growth of Nigeria over the 1980-2012 period, using the ordinary least squares method of analysis. Results indicated that CO_2 emissions negatively affect the gross domestic product in Nigeria. In addition, it has an adverse effect on the level of gross domestic product (GDP) through the decrease of the aggregate output in the Nigerian economy. Furthermore, using a dynamic simultaneous equation in order to investigate the relationship between FDI inflows, economic growth, and CO_2 emissions for 54 countries over the period 1990-2011, Omri et al. (2014) revealed a unidirectional causality running from CO_2 emissions to economic growth. Recently, Kasperowicz (2015) for 18 EU Member Countries and Nguyen (2019) for 5 central Asian countries demonstrated that CO_2 emissions have a negative effect on economic growth. Therefore, we must reduce CO_2 emissions since they have been considered as an essential cause of the decline of economic growth. More recently, to analyze the causal link between CO_2 emissions, renewable energy consumption, economic growth, urbanization, and total population in 16 West African countries, Musah et al. (2020) used the panel data model for the period from 1990 to 2018. The results indicated that CO_2 emissions and renewable energy consumption did not have a vital effect on economic growth.

Therefore, based on the above discussion, the following hypothesis is tested:
$H_{1.2}$: CO_2 emissions dampen economic growth

Other several empirical studies have supported the assertion of the existence of a bidirectional relationship between economic growth and the environmental degradation. For instance, Coondoo and Dinda (2002) indicate that, for the country groups of Asia and Africa, the causality between CO_2 emissions and economic growth is bi-directional. Day and Graften (2003) examined the causality link between economic growth and the environment in Canada. Their results showed that the bi-directional causality between the per capita income and the measures of the environmental degradation is confirmed only in the short run. Halicioglu (2009) reported a similar finding in the case of Turkey. Chang (2010) investigated the causal relationships between CO_2 emissions, energy consumption, and economic growth based on panel data for 28 Chinese provinces over the period (1995-2007). The results of the study demonstrated the existence of a bi-directional causality running: from the GDP to the CO_2 emissions and the consumption of crude oil and coal; and from electricity consumption to the GDP. Furthermore, increased GDP growth or energy consumption stimulates CO_2 emissions. Recently, a study by Omri et al. (2015) for a panel of 12 MENA countries over the period (1990-2011) has shown the evidence of a bidirectional causality between the CO_2 emissions and economic growth. In the same context, Abdouli and Hammami (2017) studied this relationship for a panel of 17 MENA countries over the 1990-2012period, using the simultaneous-equation panel data VAR model. Their results supported that there is bidirectional causality between the CO_2 emissions and economic growth. Using a multivariate model, Acheampong (2018) demonstrated that there is a bidirectional causality between the CO_2 emissions and economic growth in the case of 116 countries during1990-2014 period. More recently, Saidi and Omri (2020) have focused on the same link between the CO_2 emissions and the GDP per capita for 15 major renewable energy-consuming countries using both the Fully Modified Ordinary Least Square (FMOLS) and the VECM estimation techniques. Their findings showed that there is a bidirectional causality between those two variables. In fact, the same result was found by Rahman et al. (2020) for the case of five South Asian countries. Therefore, our third hypothesis is formulated as follows:
$H_{1.3}$: There is a bidirectional link between economic growth and the environmental degradation

In the same context of the relationship between economic growth and pollution of the environment while one group of empirical studies exhibited insignificant or no association between them. On the same topic, Richmond and Kaufmann (2006) studied the link between the CO_2 emissions and economic growth in 36 countries over the period from 1973 to 1997 and verified the neutrality hypothesis. Their results support the idea of the absence of interdependence between economic growth and environmental efficiency. In line with this, Olusegun (2009) carried out a study about Nigeria to test the causality between the CO_2 emissions and the GDP. For this purpose, he used the timing data from 1970 to 2005 and showed that there is no correlation between the income changes and environmental pollution. On the other hand, verifying the nexus among the carbon emissions, the income, energy, and total employment in selected five OPEC countries between 1971 and 2002, was the objective of the study conducted by Sari and Soytas (2009). In fact, using the ARDL approach, they showed that none of the countries needs to sacrifice economic growth for the sake of reducing its CO_2 emission levels. For their part, Ben Jebli et al. (2014) investigated the nexus between CO_2 emissions, economic growth, renewable energy consumption the number of tourist arrivals, and trade in Central and South America from 1995 to 2010. To analyze the relationship across the variables both in the short-and the long-run, the authors used panel cointegration techniques and panel Granger causality tests. Their results support the neutrality of the hypothesis for the link between carbon emissions and economic growth. This means that there is no significant causality between environmental quality and economic growth. From 1992 to 2012, Shaari et al. (2014) empirically evaluated the relationship between foreign direct investment, economic growth, and CO_2 emission in 15 developing countries. They employed the Granger causality test based on the VECM to examine the effect connection between the variables. In fact, their findings demonstrated that there is no impact of FDI and GDP on the CO_2 emissions in the short run.

Similarly, Waheed et al. (2019) studied the connection between income, the environment, and energy usage in both single and multi-country studies. Their focus in their survey was on the coverage of countries, the modeling methodologies, the study periods as well as the empirical conclusions. Their findings postulated that the CO_2 emissions in the industrialized nations were not linked with economic growth. In addition, the main cause of high carbon emissions in the developed nations is the high energy consumption. Recently, Egbetokun et al. (2020) have analyzed the link between the environmental quality and economic growth in Nigeria to check for the existence of the EKC while taking into account the impact of the institutional quality in this relationship. The results revealed that there is an EKC only for two variables of the environmental pollution (carbon dioxide "CO_2" and suspended particulate matter "SPM"). However, the other variables such as nitrous oxide (N_2O), rainfall, temperature, and total greenhouse emission (TGH) exert an insignificant effect on economic growth. As for Tong et al. (2020), they have tested the cointegration and causality relationship between economic growth, energy consumption, and CO_2 emissions, using the bootstrap autoregressive distributed lag (ARDL) bound test. They collected their data from the E7 countries over the period from 1965 to 2017. The research results indicated no cointegration between economic growth, energy consumption, and CO_2 emissions for the People's Republic of China, Indonesia, Mexico, and Turkey. Additionally, theyshowed that environmental pollution is explained mainly by energy consumption. This problem obliges the E7 countries to develop rigorous policies on energy consumption and environmental inefficiency.

Based on the above discourse, we can formulate the following hypothesis:

$H_{1.4}$: There is no correlation between economic growth and CO_2 emissions

2.2. Growth and Trade Openness Literature

The relationship between trade openness and economic growth is a principal factor for trade policy. As a consequence, this link has attracted widespread attention in the past decades as here has been a large amount of research in this area that articulated theoretical and empirical ways in order to test the relationships between trade-in openness and economic growth. On the other hand, Adam Smith and Ricardo's traditional models explained that trade openness would push specialization. Consequently, countries specialize in the production of goods and services that they have advantages of exporting them. On another side, countries without such advantages will import from those countries and specialize in other types of goods and services. Therefore, the resources are more optimally allocated.

Çevik et al. (2019) emphasized that the trade and growth nexus has mainly been examined with respect to four competing hypotheses where the first suggests that economic growth is founded especially on trade openness, which means that trade openness causes economic growth. In fact, three pillars justify this hypothesis; the first supports the idea that trade openness can contribute to economic growth through the foreign trade multiplier, the second pillar, which focuses on the role of exports in the relationship between trade openness and economic growth, shows that higher exports might procure the most needed foreign exchange for countries to trade in international markets and therefore, acquire the necessary resources for economic production. Then, the third pillar revealed that exports can strengthen the ties between economic growth and trade openness. In fact, export growth can help countries to expand their market share and also exploit the economies of scale, which minimizes the risks of their exposure to currency fluctuations and other market volatilities.

On the other hand, some past studies have focused on this hypothesis and found different results. In fact, from an economic point of view, economic extension is an indicator of productivity growth, which increases the ROI and ROV for investors and therefore, may change a country into a more important player in the global supply chain and a major base for global export markets. In this case, economic growth can increase the income, which will encourage local firms and consumers to increase their consumption of foreign commodities, thus increasing imports into the domestic economy. In the context of Morocco, Bouoiyour (2003) examined the linkage between trade openness and economic growth. The results showed that, in the short run, increased imports and exports caused increased GDP, but found no evidence of a growth effect due to trade openness in the long-run causality. As for Calderon et al. (2004), they confirmed the first hypothesis only for rich countries and stated that growth in poor countries is never justified by openness. Bolaky and Freund (2004) tested the relationship between international trade and income using cross-country data from 100 countries. The results highlighted that although an increase in trade increased the standard of living in the economies with greater flexibility, it does not have any effect on rigid economies. Along the same lines, Sarkar (2008) examined the relationship between openness (trade-GDP ratio) and growth on a sample of 51 countries from the South during the 1981-2002 period and found that for only 11 rich and highly trade-dependent countries a higher real growth is associated with a higher trade share. Moreover, Huchet-Bourdon et al. (2018) emphasized that countries growing their exports will grow more rapidly after attaining a certain degree of the extensive margin of exports. Recently, using a panel co-integration approach of extended neoclassical growth model for five South Asian countries from 1990 to 2017, Rahman et al. (2020) found a unidirectional causality running from trade openness to economic growth. Moreover, in 2021, Rahman affirmed that in the long run, the effect of international trade on economic growth is found to be positive and significant for a panel of BRICS and ASEAN countries. Therefore, based on the above analysis, we can formulate the following hypothesis:

$H_{2.1}$: Openness trade can promote economic growth

A second proposal suggests that trade openness has a negative effect on growth. In line with this, the aim of the study of Hye and Lau (2015) is to analyze the relationship between trade openness and economic growth in the case of India. Therefore, to achieve this objective, the authors developed a trade openness index to examine this link. The results of Granger causality test reveal that the trade openness index negatively influences economic growth in the long run. Additionally, the rolling window regression results demonstrated that the effect of the trade openness index on economic growth is not stable in the entire sample. Huchet-Bourdon et al. (2018) examined the link between trade openness and economic growth on a panel of 169 countries over the period (1988-2014), using the generalized method of moments (GMM) estimator. Their results pointed out that countries exporting higher quality products and new varieties grow more rapidly. More importantly, they revealed that openness to trade could have a negative effect on growth in countries that are specialized in low-quality products. A recent study by Fatima et al. (2020) has outlined an intriguing indirect relationship between openness on trade openness and economic growth. In fact, if the human capital accumulation is taken into account as an intervening variable, trade may have a negative impact on the GDP growth mainly when countries exhibit a low level of human capital accumulation.

From this discussion, the following hypothesis can be stated:
$H_{2.2}$: Openness trade can dampen economic growth

The third proposal confirms the simultaneous existence of the two previous hypotheses, where trade openness and economic growth variables Granger cause one another through a feedback loop that is why this hypothesis is called the feedback hypothesis. Several empirical studies have supported this hypothesis (inter alia, Din, 2004 and Konya, 2006).

For a panel of eight developing Asian countries, Ekanayake (1999) has studied the causal relationship between trade openness and economic growth and found evidence of a bidirectional causality between economic growth and export for seven of them. Using the general method of moments (GMM) estimation, Gries and Redlin (2012) analyzed the relationship among openness in trade and economic growth for 158 countries from 1970 to 2009. Those effects uncovered a positive causal linkage going from trade openness to growth in the long run. Omri et al. (2015) examined the relationship between financial development, CO_2 emissions, trade, and economic growth for a panel of 12 MENA countries over the period 1990-2011. The authors concluded that economic growth and trade openness are interrelated, indicating that there is a bidirectional causality between trade and growth. Rahman and Mamun (2016) investigated the relationship between trade openness and economic growth in the Australia countries. They found evidence of a bidirectional causality between international trade and economic growth. Khalid and Ali (2017) investigated the relationship between trade openness and long-run economic growth in the Chinese case, over the sample period 1960-2015, utilizing the ARDL model and the Granger Causality tests. Actually, they found a bidirectional causality between international trade and economic growth. The study results of Rahman et al. (2017) on the major developed and developing countries are in conformity with the results of Rahman and Mamun' research (2016) mentioned above. Recently, the finding of Rahman et al. (2020) has found the same results for the case of South Asia. Therefore, based on this analysis, we can put forward the following hypothesis.

$H_{2.3}$: There is a bi-directional causality between economic growth and trade openness

The fourth proposal is the neutrality hypothesis, which supports that there is no causal link between trade openness and economic growth. Sarkar (2008), in the same study analyzed before, deepened his study by examining this relationship for the time series of individual country's experiences. The results show that the majority of the countries covered in the sample, including the East Asian countries experienced no positive long-term relationship between openness and growth during the 1961-2002 period. Babatunde (2011) suggested that trade openness does not have much impact on economic growth. In fact, Eriș and Ulașan (2013) explored the trade-growth relationship in a cross-sectional study during 1960-2000. According to their results; they did not find any evidence of a direct and robust linkage between trade openness and long-term economic growth. Burange et al. (2019) highlighted that no causal relationship was evident between trade and GDP for Brazil and Russia. Additionally, Oloyede et al. (2021) employed the Pooled OLS, Fixed and Random Effects techniques of estimation, and the Durbin-Wu Hausman test for data of Africa's regional economic communities (RECs), focusing on the Economic Community of West African States (ECOWAS) and Southern African Development Community (SADC) to analyzes the relationship among trade openness and macroeconomic outlook. The results showed a positive but insignificant nexus between the economic growth rate and trade openness in both the combined simulated ECOWAS and SADC and the individual REC. By referring to the above discourse, we formulated the following hypothesis.

$H_{2.4}$: There is no association between economic growth and trade openness.

2.3. Trade Openness and CO_2 Emission Literature

Currently, global CO_2 emissions have been linked to different economic activities. Therefore, thinking in the trade-emission nexus continues to be a pertinent issue of our time. Thus, there are several studies on trade to openness-emissions nexus, but they found contradictory results. In fact, trade openness affects the environment quality in two mechanisms. The first mechanism is related to the PHH which was verified when pollution-intensive firms discover refuge in locations with lax environmental rules; largely their actions usually increase emissions of CO_2, and various studies agree with this hypothesis. For example, Omri et al. (2015) showed that trade openness has a positive and significant effect on CO_2 emissions. In fact, the study of Cai et al. (2018) aims at testing the PHH in the case of China which consists in calculating CO_2 emissions embodied in imports and exports. The results indicate that China serves as a host for 22-advanced countries' pollution; however, it has turned 19 developing countries into pollution havens. Then, the PHH can be analyzed by the effect of IDE on the environment, which is the work objective of Liu et al. (2018). In fact, they examined the spatial effect of foreign direct investment on pollution in some Chinese cities. The authors concluded that the PHH is verified in selected Chinese cities.

Conversely, when the host country benefits from the knowledge of spillovers from trade, which are favorable to the environment, it promotes environmental quality, which is the conclusion of the second mechanism. Moghadam and Dehbashian (2017) analyzed this link for Iran and concluded that a better increase in trade openness reduces the damage to the environment in Iran. According to Zhang et al. (2019), this is known as the pollution halo effect. Recently, Essandoh et al. (2020) have tried to test the effect of trade on CO_2 emissions in 52 advanced and unindustrialized nations from 1991 to 2014. They documented that trade decreases CO_2 emissions in these regions. Moreover, the investigation came to a conclusion also that knowledge spillover from trade reduces CO_2 emissions between countries, which might benefit from this spillover when absorption capabilities are developed via human capital and other means to channel it into the economy. Then, the composition stage is where traded commodities or resources are re-assigned. Regarding the technical effect, trade openness generally leads to an environment without pollution due to developed production processes with modern technologies and efficient energy use that mostly come along with trade among countries. Consequently, based on the previous review of the various studies, the following hypothesis can be advanced:

$H_{3.1}$: Trade openness can cause either environmental pollution or environmental efficiency

Multivariate research studies have channeled their focus on the impact of environmental regulations on trade liberalization. Jug and Mirza (2005) carried out an empirical analysis involving 12 importing countries and 19 exporting countries in Eastern and Western Europe between 1990 and 2014 to study the effect of environmental abatement costs on trade flows. Results revealed that when depicting a pure cost effect, more stringent environmental regulations had a reducing effect on exports, which is important in the case where the exporting countries are Central and Eastern European, compared to the EU15. Tomoyuki and Managi (2016) have tried to analyze the bond between environment-related efficiency and export performance according to the recent international trade theory for 41 importing countries and 22 exporting countries during the 1995-2009 period using CDK's model. The authors deduced that environmental efficiency has a smaller impact on export performance in relatively less footloose industries besides, the impact of the efficiency is found to depend on the industrial characteristics. Similarly, a study by Kahouli and Omri (2017) about 14 home countries and 39 host countries from six regions between 1990 and 2011, used the gravity models to analyze the impacts of the environmental quality on international trade and Foreign Direct Investment. The study finding showed a negative and significant link between environmental degradation and trade only for the static estimation.

Nunez-Rocha and Turcu (2019) were interested in the economic context of 141 countries for the period 1998-2015 in order to examine the impact of the environmental laws on the trade of fuels. Their finding demonstrated that an increase of the number of laws or treaties related to energy, particularly the ones associated with energy use, decreases trade in fuel. Using the Feasible Generalized Least Squares (FGLS) and Seemingly Unrelated Regression (SUR), Xu (2000) analyzed the impact of the environmental regulation on foreign trade in China, from 1985 to 2010. The findings of the study showed that under strict environmental regulations, only the chemical industry might afford a significant loss in international trade. However, while some industries would not suffer some others would profit from the environmental regulations. In general, the study revealed that the environmental regulations boost the Chinese exports. In contrast, Dai et al. (2021) applied the gravity model and the z-score to examine the trade-environmental regulation nexus in 112 exporting countries and 53 importing countries over the period 1989-2013. Their findings revealed that the strict environmental policies harm trade. Moreover, this impact is grander in terms of the environmental goods listed in the APEC compared to the ones listed in the OECD. Consequently, by referring to the above analysis, the following hypothesis can be mentioned:

$H_{3.2}$: The environmental regulations can dampen or enhance trade liberalization

In the same context of international trade-CO_2 emission nexus, empirical studies have also found a bi-directional causality between the environmental performance and international trade.

In this view, Gu et al. (2013) studied the nexus between free trade and CO_2 emissions in China. The collected time-series data covered the 1981-2010 period. Their results showed that there is a long-term equilibrium relationship between openness in trade and environmental contamination. On the other hand, using time-series of econometric techniques covering the 1972-2009 periods, the impact of CO_2 emissions on trade openness in the Bangladesh context was studied by Rahman (2013). This inter-relationship was tested in a vector autoregressive (VAR) framework followed by Granger causality, and the impulse response function in order to identify the plausible causal relationship, the possible causal link, the direction of causality, and the probable impact of one variable on another. In fact, the outcome showed that the Granger causality analysis founds an inconclusive causal relationship between the variables. Utilizing the auto-regressive distributed lag (ARDL) bounds to test approach of the cointegration and error correction method (ECM), Farhani and Ozturk (2015) analyzed the dynamic relationship between CO_2 emissions, the real GDP, energy consumption, the financial development, trade openness, and urbanization in the Tunisian economic context, obtaining data for the period 1971-2012. Their research showed the existence of two causal long-run relationships between the variables; including the two-way relationship between CO_2 and trade.

Similarly, Sun et al. (2019) investigated the interaction between trade and environmental pollution (CO_2) through the existence of economic growth and energy usage as the main potential influential factors in this relationship using data from 49 high-emission countries in Belt and Road regions between 1991 and 2014, which were grouped according to their income (high, middle, low) and their geographical location (East Asia, Southeast Asia, Central Asia, South Asia, the Middle East/Africa, and Europe). For this reason, the authors used current panel cointegration approaches. Their results revealed a long-term causal effect between trade, economic growth, energy consumption, and environmental pollution in the Belt and Road, Europe, high-income, middle-income, and low-income panels. Recently, Rahman et al. (2020) have analyzed the link between the impact of the CO_2 emissions, the population density, and trade openness on the economic growth in South Asia, on a sample covering the 1990-2017 period. Their results exhibited a bidirectional causality between economic growth and CO_2 emissions, and also between trade openness and CO_2 emissions. Then, based on the analysis of these various previous empirical studies, we suppose that:

$H_{3.3}$: There is a two-way relationship between trade openness and environmental quality

Although a great number of researchers have hypothesized the linkage between trade openness and environmental quality, other investigations found different results. In this context, Jalil and Mahmud (2009) used time series for the period 1975-2005 to test the long-term association between the environmental pollution, consumption of energy, income, and international trade in China. The results showed that trade liberalization positively affects environmental pollution, but this impact is considered as having a statistically insignificant effect on the Chinese environment. Farhani et al. (2014) conducted a similar investigation about Tunisia over the 1971-2008 period to check whether there are nexuses between energy consumption, GDP, trade openness, and CO_2 emissions. To carry out their study, they used the autoregressive distributed lag (ARDL) model. The results indicated that an increase the per capita GDP and energy consumption will lead to the environmental damage whereas trade openness showed an insignificant connection with the CO_2 emissions. Dogan and Turkekul (2016) investigated the relationship between CO_2 emissions, energy consumption, real output (GDP), the square of the real output (GDP2), trade openness, urbanization, and financial development in the USA over the period 1960-2010 using the bounds testing for co-integration. In fact, focusing on the nexus trade-CO_2 and using the Granger causality test, the authors found that no causality is determined between CO_2 and trade openness. A study carried out by Osathanunkul et al. (2018) on Thailand examined the relationship between CO_2 emissions, income, energy consumption, trade openness, and urbanization between 1971 and 2014. The application of the ARDL co-integration technique and the use of CUSUM and CUSUMSQ tests showed that the income and energy consumption contribute to the environmental degradation, while urbanization is beneficial to the environment. However, the achieved results indicated no effect from trade opening to emissions. Wang and Zhang (2021) examined the heterogeneous effects of trade openness on CO_2 emissions using a panel of 182 countries covering 1990-2015. Using the panel cointegration test, they found no significant impact of trade openness on the CO_2 emissions in lower-middle-income countries.

$H_{3.4}$: Referring to the above analysis of empirical studies, no relationship can be found between CO_2 emissions and environmental degradation.

3. ECONOMETRIC METHOD AND DATA

3.1. Econometric Method

The purpose of this study is to examine the links between economic growth, trade in openness and the environmental quality in Saudi Arabia over the period 1990-2017. The aim of this section is to describe the econometric model, and then give a presentation of the model variables. The estimation of interactions between economic growth, trade, and environmental quality will be determined by using the vector autoregressive (VAR) model developed by Inessa and Zicchino (2006). Contrary to the conventional VAR model, this model has the advantage of being a multivariate time series model in which each dependent variable relies on its lagged variables, dependent variables, and other exogenous variable, which helps simultaneously analyze the interaction between the variables of our research.

In addition, we construct shock elasticities that are valuing corresponding to impulse response functions. We recall in this context that the impulse response function measures the importance of next-period shocks for future values of time series. They are elasticities because their measurements compute proportionate fluctuations. We show a principally close connection between the objects.

Consequently, the aim of this investigation is to use the production function approach in order to explain the interrelationship between economic growth, trade openness, and CO_2 emissions, whereas the gross domestic product depends on the endogenous variables, such as trade openness and CO_2 emissions. Moreover, the extended Cobb-Douglas production framework seems useful in this context as it helps analyze the three-way linkage between the three variables (GDP, Trade, and CO_2 emissions) which are endogenous. Therefore, it is necessary to study the interrelationships between the three variables by considering them simultaneously in one modeling framework which may help policymakers not only to build efficient economic policies but also to achieve sustainability goals.

Therefore, to try to achieve this objective, we used The Cobb-Douglas production functions, which include the capital and labor, as additional factors of production in our estimation. This function is widely used to examine the relationship between the outputs and inputs (Hall and Mairesse, 1996; Kosztowniak, 2013; Omri et al., 2014; Abdouli and Hammami, 2017 among others). Several researchers (see, inter alia Pao and Tsai, 2010 and Arouri et al., 2012) showed that the income or even the output also depends on energy consumption, which is directly related to CO_2 emissions. Using different estimation methods in various countries, a number of empirical works added openness in trade to the production function to study its effect on economic growth (Miller and Upadhyay, 2000) for the developed and developing countries; Yeboah et al. (2012) for African countries; and Dritsaki and Stamatiou (2019) for Poland). Only Dritsaki and Stamatiou (2019) found that trade openness is insignificant to economic development both in the short and long run, while the other studies concluded that trade openness promotes economic growth. Therefore, we choose to use the Cobb-Douglas type production function:

$$Y = e^{\varepsilon} AE^{\lambda} WL^{\beta}$$

It is assumed that $W = K^{\alpha} T^{\psi}$ = Capital imput

$$Y = e^{\varepsilon} AK^{\alpha} E^{\lambda} T^{\psi} L^{\beta} \qquad (1)$$

where Y is the real GDP, A is the total factor productivity, K is the capital stock, E is the energy consumption, L is the labor force, ε is the error term, α, λ, Ψ and β are the production elasticity with respect to domestic capital, energy consumption, T is the openness trade and labor force, respectively. By taking into account that energy consumption and trade openness are key inputs to promote the national outputs, this model indeed raises the standard Cobb-Douglas production function. Given the technology level at a given point in time, Zhao et al. (2011) pointed out that there is a direct linear relationship between energy consumption and CO_2 emissions, such that $E=bCO_2$. Thus, equation (1) becomes:

$$Y = b^{\lambda} e^{\varepsilon} AK^{\alpha} CO_2^{\lambda} T^{\Psi} L^{\beta} \qquad (2)$$

We divide both sides of equation (2) by the population in order to obtain all series in per capita terms. Furthermore, we assume that the production function has constant returns to scale or $\alpha+\lambda+\Psi+\beta=1$

The division by L gives:

$$\frac{Y}{L} = b^{\lambda} e^{\varepsilon} A \left(\frac{K}{L}\right)^{\alpha} \left(\frac{CO_2}{L}\right)^{\lambda} \left(\frac{T}{L}\right)^{\psi} \tag{3}$$

Eq. (3), which is transformed into a linear log as follows:

$$\log(Y) = \log(b^{\lambda} A) + \alpha \log(K) + \lambda \log(CO_2) + \psi \log(T) + \varepsilon \log(e)$$

After the Logarithmic transformation, the production function is as follows

$$\log(Y) = \log(b^{\lambda} A) + \alpha \log(K) + \lambda \log(CO_2) + \psi \log(T) + \varepsilon \tag{4}$$

We assume that *log* ($b^{\lambda} A$) = *a* the new writing of the function is:

$$\log(Y) = a + \alpha \log(K) + \lambda \log(CO_2) + \psi \log(T) + \varepsilon \tag{5}$$

The writing of Eq. (5) in growth form with a time series specification gives:

$$g(Y)_{it} = a + \alpha_{1i} g(K)_{it} + \lambda_{2i} g(CO_2)_{it} + \psi_{3i} g(T)_{it} + \mu_{it} \tag{6}$$

where i = 1,…, N denotes the country (in our study, i = 1), t is the period from 1990 to 2017, g (Y) represents the growth rate of the per capita GDP, g (K) is the growth rate of capital stock, $g\ (CO_2)$ is the growth rate of the per capita CO_2 emissions, and g (T) the growth rate of the per capita openness trade.

Our central problem is therefore to simultaneously examine the interactions between economic growth, openness trade, and environmental quality in Saudi Arabia, using the VAR model with panel data. Hence, we will estimate three VAR models with panel data, while each model is constituted of three equations.

$$g(Y)_t = \beta_0 + \sum_{J=1}^{p} \beta_{1,t} g(Y)_{t-k} + \sum_{J=1}^{p} \beta_{2,t} g(T)_{t-k} + \sum_{J=1}^{p} \beta_{3,t} g(C)_{t-k} + \sum_{t=1}^{p} \beta_{3,t} g(K)_t + \varepsilon_{1t} \tag{7}$$

$$g(T)_t = \psi_0 + \sum\nolimits_{J=1}^{p} \psi_{1,t} g(T)_{t-k} + \sum\nolimits_{J=1}^{p} \psi_{2,t} g(Y)_{t-k} + \sum\nolimits_{J=1}^{p} \psi_{3,t} g(C)_{t-k} + \sum\nolimits_{t=1}^{p} \psi_{3,t} g(FD)_t + \varepsilon_{2t} \tag{8}$$

$$g(CO_2)_t = \lambda_0 + \sum_{J=1}^{p} \lambda_{1,t} g(C)_{t-k} + \sum_{J=1}^{p} \lambda_{2,t} g(Y)_{t-k} + \sum_{J=1}^{p} \lambda_{3,t} g(T)_{t-k} + \sum_{t=1}^{p} \lambda_{3,t} g(FDI)_t + \sum_{J=1}^{p} \lambda_4 g(EN)_t + \varepsilon_{3t} \tag{9}$$

Where, g (Y), g (T), and g (C) are the growth rate of the per capita GDP, trade openness, and CO_2 emissions respectively. While g (K), g (FD), g (FDI), and g (EN) are the instrumental variables for the three equations. k designates the number of lags of the variables g (y), g (FDI), and g (C) is included as a regressor and t is the time.

Eq. (7) examines the effect of economic growth lagged by period, trade, CO_2 emissions, and capital stock (K) on economic growth (inter alia Azam et al., 2016; Belloumi and Alshehry, 2020; Rahman et al, 2020). Eq. (8) suggests that trade openness on trade lagged by period of economic growth, the environmental degradation, and the level of financial development (FD) have an impact on the openness of trade (Halicioglu, 2009; Farhani et al., 2014; Al-Mulali and Ozturk, 2015; Dogan and Turkekul, 2016) Eq. (9) indicate thatCO_2 emissions lagged by period, economic growth, trade openness, FDI stocks, and energy consumption have an impact on CO_2 emissions(Ma and Stern, 2007; Akin, 2014 and Abdouli and Hammami, 2017).

3.2. Variance Decomposition and Impulse Response

Variance decomposition is an adequate measure that deals with a dynamic stochastic process under a VAR environment. It gives information about the random shocks in the system. It decomposes the forecasting error variance for each variable into parts to determine the effect of exogeneity of the variables involved in the system over different periods.

The error terms, ε_{1t}, ε_{2t}, and ε_{3t} in equations (7), (8), and (9) respectively are recognized as innovations in the VAR terminology. The error terms in those equations can be formulated in the following way:

$$V_t = \sum_{p=0}^{\infty} \pi_{\rho} \varepsilon_{t-p} \tag{10}$$

Where Vt is the 3 × 1 column vector that holds in the variables g(Y) t, g(T)t, and g(CO_2)t and εt is the 3 × 1 column vector that takes the innovation of ε_{1t}, ε_{2t}, and ε_{3t}. Equation (10) represents a linear combination of recent and past one step ahead innovations; εt. We can rewrite the l step ahead innovations of V_t at time t–l+1 as follows:

$$V_t = \sum_{p=0}^{t-\iota} \pi_{\rho} \varepsilon_{t-p}$$

Though errors ε_{1t}, ε_{2t}, and ε_{3t} in equations (7), (8), and (9) are not serially correlated, but they can be contemporaneously correlated with these two equations. We can therefore rearrange equation (10) in the next orthogonalization form in order to avoid the possible contemporaneous correlation between equations (7), (8), and (9):

$$V_t = \sum_{p=0}^{\infty} \pi_{\rho} Z u_{t-p} = \sum_{p=0}^{\infty}{}' {}_{\rho} u_{t-p}$$

Where $\pi_{\rho}\ Z = B_{\rho}$; Z is a lower triangular matrix; u_t is the orthogonalized forecasting error term, which is $\varepsilon_t = Z_{ut}$. The i[th] and j[th] components of B_{ρ} express the impulse response of the i-[th] variable to one standard deviation shock in the j-[th] variable in p periods.

3.3. Data and Descriptive Statistics

To estimate our empirical model, we used annual time series data for the Kingdom of Saudi Arabia. All the data which were collected for the period 1990-2017, are sourced from the World Bank's WDI.

We used annual data for the per capita GDP, the per capita CO_2 emissions (CO_2), the per capita FDI stocks (FDI), the per capita capital stock (K), the per capita trade openness (T), the financial development (FD), and the per capita energy consumption (EN). The definition and the source of these variables are depicted in Table 1, while, Table 2 illustrates the summary statistics and the correlations. From this table, the GDP per capita ranges from 20.059,18US$ to 22.369,32US$; the CO_2 emissions from 21.394 metric tons per capita to 21,399 metric tons per capita while the range for openness to international trade is from 54.285 to 96.278 US$ and the one for energy consumption is from 52.587 to151.241 kg of oil equivalent the range for financial development is from 0.173 to 0.458US$, Per capita, FDI net inflows range from 1.716 to 9.247 US$, and the range for the capital stock per capita is from 2541.012 to 6124.879US$. Further, the same table shows that trade openness has the uppermost association with the GDP

Table 1: Summary of the existing empirical studies

Author (s)	Context	Type of data	Methodology	Causality direction
GDP-environment nexus				
Nemat and Bandyopadhyay (1992)	149 countries (1960-1990)	Panel	Panel regression	GDP→CO_2
Grossman and Krueger (1995)	42 countries (1979-1990)	Panel	Reduce-form approch	CO_2→GDP
Holtz-Eakin and Selden (1995)	130 countries (1951-1986)	Panel	Panel regression	GDP→CO_2
Moomaw and Unruh (1997)	16 countries (1950-1992)	Panel	Panel regression approach	GDP→CO_2
Coondoo and Dinda (2002)	88 countries (1960-1990)	Panel	Granger causality test	The developed country of North America and Western Europe and Eastern Europe: CO_2→GDP The Central and South American countries, Oceania, and Japan: GDP→CO_2 The Asia and Africa countries GDP↔CO_2
Day and Grafton (2003)	Canada (1958-1995)	Time series	OLS	GDP↔CO_2
Martínez-Zarzoso and Bengochea-Morancho, (2004)	22 OECD countries (1975-1998)	Panel	PMG	GDP→CO_2
Vollebergh et al., (2005)	24 OECD countries (1960-1997)	Panel	Panel regression	GDP≠CO_2
Richmond and Kaufmann (2006)	36 countries (1973-1997)	Panel	Cointegration	GDP≠CO_2
Ang (2008)	Malaysia (1971-1999)	Time series	VECM	GDP→CO_2
Yuan et al. (2008)	China (1965-2005)	Time series	The Johansen cointegration technique	CO_2→GDP
Jalil and Mahmud (2009)	China (1975-2005)	Time series	ARDL bounds	GDP→CO_2
Halicioglu (2009)	Turkey (1960-2005)	Time series	ARDL bounds	CO_2→GDP
Olusegun (2009)	Nigeria (1970-2005)	Time series	Co-integration analysis	GDP≠CO_2
Sari and Soytas (2009)	Five OPEC countries (1971-2002)	Time series	ARDL approach	GDP≠CO_2
Chang (2010)	28 China provinces (1995-2007)	Panel	Granger causality tests	GDP↔CO_2
Lean and Smyth (2010)	Malaysia, Singapore and Thailand (1980-2006)	Time series	DOLS	GDP≠CO_2
Pao and Tsai (2010)	BRIC countries (1992-2004) Russia (1990-2005)	Time series and panel	Granger causality tests	CO_2→GDP
Jalil and Feridun (2011)	China (1953-2006)	Time series	ARDL bounds	GDP→CO_2
Jayanthakumaran et al. (2012)	China and India 1971-2007	Time series	ARDL approach	CO_2→GDP
Saboori et al. (2012)	Malaysia (1980-2009)	Time series	Cointegration	CO_2→GDP
Chandran and Tang (2013)	Malaysia and Thailand (1971–2008)	Time series	Johansen and cointegration	CO_2→GDP

(*Contd...*)

Table 1: (*Continued*)

Author (s)	Context	Type of data	Methodology	Causality direction
Ozturk and Acaravci (2013)	Turkey (1960-2007)	Time series	ARDL bounds	$GDP \leftrightarrow CO_2$
Ben jebli et al. (2014)	Central and South America (1995-2010)	Panel	Panel cointegration techniques and panel Granger causality tests	$CO_2 \neq GDP$
Ejuvbekpokpo (2014)	Nigeria (1980-2012)	Time series	OLS	$CO_2 \rightarrow GDP$
Shaari et al. (2014)	15 developing countries (1992-2012)	Panel	Granger causality based on VECM	$GDP \neq CO_2$
Omri et al. (2014)	54 countries (1990-2011)	Panel	Dynamic simultaneous-equation	$CO_2 \rightarrow GDP$
Kasperowicz (2015)	18 EU member countries (1995-2012)	Panel	ECM estimation	$CO_2 \rightarrow GDP$
Omri et al. (2015)	12 MENA countries (1990-2011)	Panel	GMM	$GDP \leftrightarrow CO_2$
Abdouli and Hammami (2017)	17 MENA countries (1990-2012)	Panel	VAR model	$GDP \leftrightarrow CO_2$
Mohammad and King (2017)	7 countries (1960-2010)	Time series	ARDL bounds	$GDP \neq CO_2$
Nguyen (2019)	5 Central Asian countries (1998-2017)	Panel	Cointegration	$CO_2 \rightarrow GDP$
Zoundi (2017)	25 African countries (1980-2012)	Panel	MG/PMG	GDP≠
Acheampong (2018)	116 countries (1990-2014)	Panel	Multivariate model	$GDP \leftrightarrow CO_2$
Waheed et al. (2019)	single country and multi-country (different periods)	Time series+panel	Various methods	$CO_2 \neq GDP$ (industrialized nations)
Egbetokun et al. (2020)	Nigeria (1970-2017)	Time series	ARDL	$GDP \rightarrow CO_2$ GDP→SPM $N_2O \rightarrow GDP$ (insignificantnexus) TGH→GDP (insignificantnexus)
Jiang et al. (2020)	China (2006-2016)	Time series	SEM	$GDP \rightarrow CO_2$
Rahman et al. (2020)	5 South Asian countries (1990-2017)	Panel	Co-integration approach	$GDP \leftrightarrow CO_2$
Musah et al. (2020)	West African countries (1990-2018)	Panel	CCEMG and DCCEMG estimators	$CO_2 \neq GDP$
Saidi and Omri (2020)	15 MRECC (1990-2014)	Panel	FMOLS and VECM	$GDP \leftrightarrow CO_2$
Tong et al. (2020)	E7 countries (1965-2017)	Panel	ARDL bound	$GDP \neq CO_2$
Xuejiao et al. (2021)	France and Germany (1995-2015)	Time series	First and second-generation unit root testsand Pedroniand Western lund test	$GDP \rightarrow CO_2$
Trade openness, economic growth nexus				
Ekanayake (1999)	8 Asian developing countries (1960-1997)	Time series	Cointegrationand error-correction	GDP↔Trade
Bouoiyour (2003)	Morocco (169-2000)	Time series	Cointegration and granger-causality	X→GDP M→GPD (L-R) X≠GDP M≠GPD (S-R)
Din (2004)	5 LESA: India and Sri Lanka (1960-2000), Nepal (1965-2002), Bangladesh and Pakistan (1973-2002)	Time series	Granger causality	M↔GPD: Bangladesh, India and Sri Lanka (S-R) X, M↔GPD: Bangladesh and Pakistan (L-R) X, M≠GDP: India, Nepal and Sri Lanka

(*Contd...*)

Table 1: (*Continued*)

Author (s)	Context	Type of data	Methodology	Causality direction
Calderon et al. (2004)	76 countries (1970-2000)	Time series	GMM estimation	Trade→GDP: Rich countries Trade≠GDP: Poor
Konya, 2006	US and Korean economies (quarterly data, 1990-2008)	Time series	OLS, SUR, IRF, FEVD, VAR and Granger causality	X↔GPD
Bolaky and Freund (2004)	100 countries (January 2003)	Panel	Cross-country regressions in both levels and changes	Trade→GDP: Flexible economies Trade≠GDP: Rigid economies
Sarkar (2008)	51 less developed countries	Panel (1981-2002) Time series 1961-2000	BE model, FE model, and RE model	Trade→GDP for only 11 countries Trade≠GDP for the majority of the countries
Babatunde (2011)	42 SSA countries (1980-2003)	Panel	Fixed or random effect model	Trade→GDP (low effect)
Gries and Redlin (2012)	158 countries (1970-2009)	Panel	PCT, ECM and GMM estimation	GDP↔Trade
Hye and Lau (2015)	India (1971-2009)	Time series	ARDL method rolling window regression method and granger causality test	Trade→GDP
Omri et al. (2015)	12 MENA countries (1990-2011)	Panel	GMM system	GDP↔Trade
Rahman and Mamun (2016)	Australia countries (1960-2012)	Time series	ARDL bounds, granger causality and IRF	Trade↔GDP
Huchet-Bourdon et al. (2018)	169 countries (1988-2014)	Panel	GMM estimation	T→GDP
Khalid and Ali 2017	China (1960-2015)	Time series	ARDL model and Granger Causality tests	GDP↔Trade
Rahman et al. (2017)	Major developed and developing countries (1960-2013)	Panel	Granger causality test	GDP↔Trade
Fatima et al. (2018)	Developed and Developing countries (1980-2014)	Panel	GMM-centric thresholds	Trade→GDP
Çevik et al. (2019)	Turkey (1950-2014)	Time series	Granger-causal relationships	GDP↔Trade
Burange et al. (2019)	BRICS countries 1981-2013	Time series	VAR model	GDP→Trade India GDP→X China GDP→M China X and M→GDP South Africa GDP≠Trade for Brazil and Russia
Rahman et al. (2020)	5 South Asian countries (1990-2017)	Panel	Co-integrationapproach	T↔GDP
Rahman (2021)	BRICS and ASEAN countries (1990-2017)	Panel	PCT, PQRM, IRF and HPC	GDP↔Trade
Oloyede et al. (2021)	31 African countries (RECs, ECOWAS and SADC, 2006-2017)	Panel	OLS, fixed, random techniques and the Durbin-Wu Hausman test	Trade→GDP (insignificantnexus)
Trade openness-environment nexus				
Xu (2000)	China (1985-2010)	Time series	FGLS and SUR	CO_2→X
Jug and Mirza (2005)	12 importing countries and 19 exporting countries in Eastern and Western Europe (1990-2014)	Panel	GMM methodology	CO_2 (ER)→Trade
Jalil and Mahmud (2009)	China (1975-2005)	Time series	The ARDL methodology	Trade≠CO_2
Gu et al. (2013)	Chine (1981-2010)	Time series	Johansen Co-integration Test	CO_2↔Trade
Rahman (2013)	Bangladesh (1972-2009)	Time series	The VAR, Granger causality, and impulse response function	CO_2↔Trade

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Table 1: (*Continued*)

Author (s)	Context	Type of data	Methodology	Causality direction
Farhani et al. (2014)	Tunisia (1971-2008)	Time series	The co-integration approach and the ARDL model	Trade≠CO_2
Farhani and Ozturk (2015)	Tunisia (1971-2012)	Time series	ARDL bounds and ECM	CO_2↔Trade
Omri et al. (2015)	12 MENA countries (1990-2011)	Panel	GMM	Trade→CO_2
Dogan and Turkekul (2016)	USA (1960--2010)	Time series	The bounds testing for cointegrationand Granger causality test	Trade≠CO_2
Tomoyuki and Managi (2016)	41 importing countries and 22 countries	Panel	CDK' model	CO_2 (ER)→Trade
Kahouli and Omri (2017)	14 home countries and 39 host (1990-2011)	Panel	Gravity models and simultaneous-equation system	CO_2→Trade
Moghadam and Dehbashi (2017)	Iran (1970-2011)	Time series	ARDL model	Trade→CO_2
Zhang et al. (2017)	Newly industrialized countries (1997-2013)	Panel	Granger causality	Trade→CO_2
Cai et al. (2018)	China (1998-2016)	Time series	Pollution haven hypothesis validated model	X, M→CO_2
Liu et al. (2018)	285 Chine secities (2003-2014)	Panel	SLM and SEM	PHH is verified: FDI→CO_2
Osathanunkul et al. (2018)	Thailand (1971 and 2014)	Time series	ARDL cointegration technique, CUSUM, and CUSUMSQ tests	Trade≠CO_2
Nunez-Rocha and Turcu (2019)	141 countries (1998-2015)	Panel	Gravity model	CO_2 (ER)→Trade
Sun et al. (2019)	49 high-emission countries (1991-2014)	Panel	panel cointegration approaches	Trade↔CO_2
Essandoh et al. (2020)	52 developed and the developing countries (1991-2014)	Panel	PMG-ARDL model	Trade→CO_2
Rahman et al. (2020)	5 South Asian countries (1990-2017)	Panel	Co-integration approach	Trade↔CO_2
Dai et al. (2021)	112 exporter countries and 53 importer countries (1989-2013)	Panel	Gravity model and z-score	CO_2→Trade
Wang and Zhang (2021)	182 countries (1990-2015)	Panel	Panel cointegration test	Trade≠CO_2

PMG: Pooled mean group, GMM: Generalized method of moments, PQRM: Panel quantile regression method, IRF: Impulse response function, HPC: Heterogeneous panel causality, ECM: Panel error-correction models, FEVD: Forecast error variation decomposition, VAR: Vector autoregressive model, FGLS: Feasible generalized least squares, SUR: Seemingly unrelated regression, SLM: Spatial lag model, SEM: Spatial error model, CCEMG: Common Correlated effects mean group, DCCEMG: Dynamic Common Correlated Effects Mean Group ARDL: Autoregressive distributed lag, MG: Mean group, FMOLS: Fully modified ordinary least square, VECM: Vector error correction model, L-R: Long-RUN, S-R: Short run, PCT: Panel co-integration test, IRF: Impulse response function, OLS: Ordinary least square, RECs: Regional economic communities, ECOWAS: Economic Community of West African States, SADC: Southern African Development Community, BE: Between-effects, FE: Fixed effect, RE: Random-effect, CDK: Cloud development kit, CUSUM: Cumulative sums, CUSUMSQ: CUSUM of squares, CO_2: Carbon dioxide, N_2O: Nitrous oxide, PHH: Pollution haven hypothesis, FDI: Foreign direct investment, MRECC: Major renewable energy-consuming countries, BRICS: Is the acronym denoting the emerging national economies of Brazil (B), Russia (R), India (I), China (C) and South Africa (S), ASEAN: Association of Southeast Asian Nations, LESA: Largest economies of the South Asian, SSA: Sub Saharan Africa, U.S: United States, GDP: Gross domestic product

Table 2: The variables, description and sources of data

Variables	Description	Source
GDP per capita (Y)	GDP per capita (constant 2010 US$)	WDI
CO_2 emissions (C)	CO_2 emissions (metric tons per capita)	WDI
Trade openness (T)	Per capita total export plus import (constant US$)	Calculated using data from WDI
EN	Energy use (kg of oil equivalent) per $1000 GDP (constant 2011 PPP)	WDI
FD	Per capita domestic credit provided by financial sector (constant US$)	Calculated using data from WDI
FDI	Per capita FDI net inflows (constant US $)	Calculated using data from WDI
Capital stock (K)	Is the gross fixed capital formation. It is measured in per capita	WDI

WDI: World development indicators, EN: Energy consumption, FD: Financial development, FDI: Foreign direct investment, GDP: Gross domestic product, CO_2: Carbon dioxide per capita; however, the lowest is for Foreign Direct Investment, while all the other variables, excepting CO_2 (EN, FD, FDI, and K) are positively correlation with the GDP, meaning that an increase of those variables promotes economic growth. Energy consumption has the highest association with the CO_2 emissions per capita, while the lowest is for financial development. As for energy consumption, financial development, and foreign direct investment, they are positively correlated with trade, though the result showed that there is a negative correlation between the capital stock and openness to international trade. Moreover, we noticea strong correlation between financial development and capital stock (0.901).

4. RESULTS AND DISCUSSIONS

4.1. The Estimation of the VAR Model

4.1.1. The unit root test results

We started the empirical study by checking the stationary of the time-series data using some unit root tests, namely the ADF test and the PP test and if necessary, we test the cointegration among the series. The characteristics of the time-series data enabled us to select either the level series or the first-difference series in the estimation of the vector autoregression (VAR) model for the causality test. However, all the variables are transformed into a growth form. Based on the results in Table 3, we can conclude that all growth form models are stationary in level and integrated of order zero, I (0).

4.1.2. Model selection criteria

In our study, we have multivariables, GDP, T, and CO_2 in the VAR (p) model to take into account the interactions among their p-lag variables. The VAR (p) model implies the estimation of the system of equations (Konya, 2004; Hsiao and Hsiao, 2006; and Abdouli and Hammami, 2017). The optimal lag order k of the VAR system is chosen by the Akaike information criterion (AIC), Hannan-Quinn information criterion (HQ), Schwarz Criterion (SC), and Final Prediction Error (FPE) are presented in Table 5. Toda and Yamamoto (1995) pointed out that the maximum order of integration for the economic series is at most two (dmax = 2). As demonstrated in Table 4, we use dmax = 1.

4.1.3. The VAR model's results

Table 6 reports the results concerning the interaction between economic growth, openness in trade, and the environmental quality in Saudi Arabia over the period 1990-2017 using the VAR model. It must be note there that model 1 is based on Eq. (7). In addition, model 2 is based on Eq. (8) while Model 3 is based on Eq. (9). Beginning with the results of model 1, which present the factors affecting economic growth, the results showed that economic growth lagged by one period promotes economic growth to the threshold of 10%. This means that an increase of the initial economic growth by 10% causes an increase of economic growth by 0.886%. This result confirms the findings of Abdouli and Hammami (2017), who found a positive contribution of economic growth lagged by one period in the case of 17 MENA countries over the period 1990-2012 using the simultaneous-equation panel data VAR model. In addition, the sign of trade openness lagged by one period is positive and statistically significant, meaning that an increase in trade lagged by a period stimulates economic growth. This result is consistent with hypothesis $H_{2.1}$. This finding is in line with the observation of Umer (2014) who examines the impact of trade openness on the economic growth of Pakistan by employing an autoregressive distributed lag (ARDL) approach over the period 1960-2011. From Table 4, it appears that economic growth is a negative function of environmental degradation lagged by period. In fact, the effect of CO_2 emissions lagged by a period on economic growth is negative and statistically significant. This suggests that economic growth in Saudi Arabia is elastic with respect to environmental quality, and a 10% increase of CO_2 emissions in the last period and a decrease of economic growth within a range of 0.096%; which means that the highest level of lagged pollution emissions might lead to the decline of the production capacity of a country. This result supported the hypothesis $H_{1.2}$. This result confirms those shown by Wang et al. (2011) in the case of China and Bozkurt and Akan (2014) for Turkey and Omri and Ben Mabrouk (2020) in the case of 20 selected MENA economies. The obtained results also indicated that the coefficient of the capital stock is positive but insignificant meaning that the capital stock does not affect the GDP per capita.

The empirical results relating to Eq. (8) are also presented in Table 4. The finding indicated that, at the 5% level, openness in trade lagged by period has a positive and significant effect on trade openness. This implies that a 5% increase in trade lagged by a period of increased openness of trade by 0.152%. Additionally, while economic growth lagged by a period exerts a negative and significant effect on trade at 10% level, CO_2 emission

Table 3: Summary statistics and correlations (1990-2017)

Variables	GDP	CO_2	Trade	EN	FD	FDI	K
Mean	18.75643	17.256	78.625	117.341	0.455	1.254	4328.344
SD	14.26921	3.105	11.23	13.23	0.134	2.078	245.184
Minimim	20.05918	11.987	54.285	52.587	0.173	1.716	2541.012
Maximim	22.36932	21.394	96.278	151.241	0.458	9.247	6124.879
GDP	1						
CO_2	−0.429	1					
Trade	0.583	0.348	1				
EN	0.254	0.648	0.340	1			
FD	0.420	−0.148	0.360	0.496	1		
FDI	0.235	0.204	0.402	0.316	0.453	1	
K	0.265	0.424	−0.963	0.602	0.901	0.236	1

SD, CV (SD-to-mean ratio). SD: Standard deviation, CV: Coefficients of variation, EN: Energy consumption, FD: Financial development, FDI: Foreign direct investment, GDP: Gross domestic product, CO_2: Carbon dioxide lagged by one period exerts a significant positive impact on trade at 10% significance level, suggests that economic growth decreased trade by 1.023%. By contrast, CO_2 emissions increase international trade by 0.071which confirms the hypothesis $H_{3.2}$ (CO_2 emissions dampen trade). These findings contradict the empirical finding of George and Tao (2002) when they studied the link between economic growth and openness to international trade on the international level, mainly in the United States and Canada. We also found that at a 5% level of significance, a unit increase of the gross fixed capital formation per capita reduces trade openness by approximately 1.874%. This is contrary to Adhikary's (2011) finding, implying that higher levels of gross capital formation enhance openness to international trade. Finally, the result shows that the level of financial development has a positive and significant impact on trade at 1% level. The magnitude of 0.198 indicates that a 1% increase of domestic credit to the private sector increases trade openness in Arabia Saudi by around 0.2%. This indicates that an increase of the financial development tends to increase the level of openness in trade. Our results are similar to those obtained by Omri et al. (2015), and Caporale et al. (2020).

Regarding the estimation of Eq9 in Table 4, it is clear that a 5% increase in the GDP percapita lagged by period increases CO_2 emission by around 0.85%. This suggests that economic growth in Saudi Arabia does send negative signals to the environmental quality, implying that an increase in economic growth tends to increase the environmental degradation, which supports the hypothesis $H_{1.1}$. Our result then, confirms those of (Omri, 2013). Furthermore, our result indicates that the coefficient of trade lagged by one period is positive and significant, which means that it positively affects the carbon emission intensity at 5%. This result reflects the scale effect of trade openness as it boosts economic growth in Saudi Arabia, thereby increasing the intensity of carbon emissions. This result confirms the hypothesis 3.1 (trade can cause environmental pollution). However, our result contradicts the findings of Abid (2017), which indicated that trade openness improves the environmental quality in the EU region but it is in line with his results in the case of the MENA countries. Then, the estimated coefficient of CO_2 emission lagged by period is positive and statistically significant at 5%; hence, the magnitude implies that a 5% increase of the CO_2 emission of the previous period increases the environmental degradation of the current period by around 0.471%. On the other hand, FDI has a significant impact on trade openness at a 1% level. This implies that trade is elastic with respect to FDI, and a 1% increase of the FDI rate increases the level of openness of trade in the range of 0.2%. Our results also show that energy consumption exerts an insignificant positive effect on trade openness.

Table 4: Results of unit root tests

Variables	ADF level		PP level		Integretion level
	T-statistics	P	T-statistics	P	
g (GDP)	−5.596*	0.0001	−5.687*	0.0001	I (0)
g (CO_2)	−6.427*	0.0000	−6.478*	0.0000	I (0)
g (Trade)	−4.126*	0.0038	−4.061*	0.0044	I (0)
g (EN)	−8.320*	0.0000	−8.153*	0.0000	I (0)
g (FD)	−5.286*	0.0002	−6.228*	0.0000	I (0)
g (FDI)	−7.893*	0.0000	−8.130*	0.0000	I (0)
g (K)	−5.928*	0.0000	−6.110*	0.0000	I (0)

*indicate significance at 1%. ADF: Augmented Dickey-Fuller, PP: Phillips-Perron, EN: Energy consumption, FD: Financial development, FDI: Foreign direct investment, GDP: Gross domestic product,
CO_2: Carbon dioxide

4.1.4. Variance decomposition analysis results

Table 7 provides the results of variance decomposition for 1-year to 10 years. This table highlights the variance decomposition in calculating and analyzing the influence of random shocks of the GDP upon itself, trade, and CO_2 emission. The results indicate that an 87.03% portion of economic growth is contributed by its own innovative shocks and one standard deviation shock in trade liberalization, which explains economic growth by 11.09% however, the results of the CO_2 emission contribution to economic growth are as informative as expected; They support that economic growth is minimal i.e. 1.88%.

As shown in Table 7, trade openness is explained by economic growth to the extent of 20.06%. On the other hand, the fluctuation of trade is accounted by the trade itself with 79.31%; while the contribution of CO_2 emission to explain trade openness is 0.61%.

The results depicted in Table 7 also suggest also that the share of economic growth to CO_2 emission is approximately 22.15% and 14.01% due to trade openness. The innovative shocks stem in CO_2 emissions explained by 63.83%.

4.1.5. The results of impulse response analysis

The results of the impulse response analysis for a time horizon of 10 years to one standard deviation shock in CO_2 emission, and trade on economic growth are given in Figures 1a and b: The responses from a positive shock of international trade openness to economic growth are given in Figure 1a. The response are negative in the 1st year, and after that, they become positive and gradually increase until the 5th year then, they diminish for the remaining years but they remain >0. Figure 1b depicts the responses of the economic growth inflow with one standard deviation shock to the CO_2 emission. It is clear that the responses generated from a shock of CO_2 emission to economic growth decrease during the first 3 years and continue to decrease slowly for the rest of the period but they remain above zero. Figure 1c and d present the results of the impulse response analysis for a time horizon of 10 years to one standard deviation shock in CO_2 emission, and GDP on trade. The results of the impulse response analysis between openness on trade and economic growth, alternatively with one standard deviation shock, are shown in Figure 1e. Then the responses from a positive shock of trade openness to economic growth are insignificant in the first 3 years, however, after that, they gradually decrease until the 7th year. Subsequently, although they have an upward movement, they stay below zero. The impact of CO_2 emission shock on trade openness is illustrated in Figure 1f. For the 1st year, its impact is insignificant, and then positively fluctuates between year 2 and 5 but loses its effect between year 6 and 8 after that it becomes negative.

The results of the impulse response analysis for a time horizon of 10 years to one standard deviation shock in GDP and trade on CO_2 emission are illustrated in Figures 1e and f: In fact, Figure 1e traces the reactions of structural shocks of economic growth on

Table 5: Lag selection criteria

Lag	Log L	LR	FPE	AIC	SC	HQ
0	103.2907	NA	1.88e-12	−7.132644	−6.796686	−7.032746
1	229.6726	177.8708*	6.94e-15*	−12.86464*	−10.17697*	−12.06545*

AIC: Akaike information criterion, HQ: Hannan-Quinn information criterion, SC: Schwarz Criterion, FPE: Final prediction error

Table 6: Results of the VAR estimation

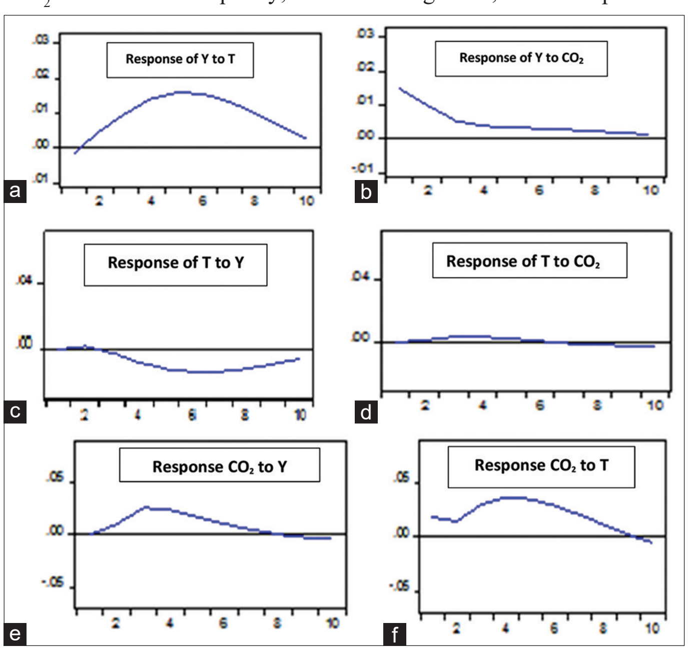
Variables	Model 1: DV: Y		Model 2: DV: T		Model 3: DV: C	
	Coefficent	Probablity	Coefficent	Probablity	Coefficent	Probablity
Y(−1)	0.886***	0.084	−1.023***	0.042	0.847**	0.048
Trade(−1)	0.514**	0.071	0.152**	0.045	3.726**	0.027
C(−1)	−0.096***	0.086	0.071***	0.529	0.471**	0.039
K	0.221	0.702	−1.874**	0.059		
FD			0.198*	0.003		
FDI					0.192*	0.000
EN					0.628	0.379
cst	−1.874	1.059	57.234	70.257	−28.601	15.024

*1% significant level, **5% significant level, ***10% significant level. DV: Dependent variable, EN: Energy consumption, FD: Financial development, FDI: Foreign direct investment, VAR: Vector autoregressive model

Table 7: Variance decomposition analysis results

Periods	Y explained by			Trade explained by			C explained by		
	Y	Trade	C	Trade	Y	C	C	Trade	Y
1	100.00	0.00	0.00	76.62	23.37	0.00	64.84	16.05	19.08
2	86.29	11.31	2.39	76.69	23.01	0.27	64.13	15.52	20.24
3	86.73	10.55	2.71	76.51	22.89	0.56	67.25	15.16	17.57
4	85.93	10.21	3.86	77.31	22.18	0.48	67.21	13.54	18.80
5	84.55	12.32	3.13	77.83	21.68	0.42	67.24	13.73	19.01
6	84.34	13.31	2.35	78.36	21.16	0.46	64.14	15.08	20.77
7	84.06	13.99	1.95	78.39	21.14	0.44	66.68	15.20	18.02
8	88.67	09.24	2.09	78.50	20.88	0.42	65.12	15.72	19.14
9	88.85	10.10	1.05	78.68	20.65	0.47	65.67	15.23	19.09
10	87.03	11.09	1.88	79.31	20.06	0.61	63.83	14.01	22.15

Figure 1: (a-f) Impulse-response function graphics relationship between environmental quality, economic growth, and trade openness CO_2: Environmental quality; Y: Economic growth; T: Trade openness



the environment quality. The responses from a positive shock of CDP on CO_2 emissions have an upward movement up to the 3rd year then gradually decrease until they become below zero from the 7th year. Actually, the impulse response analysis presented in Figure 1f gives a quantitative idea about the responsiveness of the CO_2 emission in the VAR system when a shock is put to trade in openness for 10 years in the future. During the first 2 years, the responses generated from a shock of CO_2 emission to trade are low then they gradually increase up to the 4th year and afterwards, from the end of the 20th year they decrease again and become negative.

5. CONCLUSION AND POLICY IMPLICATION

To conclude, we can say that this article examined the three-way linkages between environmental degradation, trade openness, and economic growth, using the VAR models in time series, to apply the simultaneous-equation models to the case of Saudi Arabia.

In sum, the empirical results of this study can be summarized as follows. First of all, there is a bi-directional causal relationship between economic growth and the environment in Saudi Arabia, which validate the hypothesis $H_{1.3}$. However, the growth of the GDP leads to the environmental degradation, which decreases the economic growth through its effect on human health. Therefore, the main policy implications which are very crucial for Saudi Arabia to encourage producers, require the use of the new technologies in the production process and apply strict environmental standards to reduce global warming thus, improving the quality of the environment. Therefore, this results seems to be consistent with the finding of Abdouli et al. (2018) for the BRICTS countries. In addition, regarding the negative effect of CO_2 emissions on the GDP per capita, it is obligatory and mandatory for this country to find new techniques and other phenomena to reduce pollution without affecting economic growth because the environmental aspect is a determining factor in ensuring sustainable development. Furthermore, the GDP growth is negatively influenced by the increase of waste produced by companies, which affects the productivity of the workers because of its effect on human health. Indeed, investors should be encouraged to recycle the waste, which reduces pollution and promotes economic growth at the same time.

Then, the feedback hypothesis between trade and CO_2 emissions implies that the environmental degradation and trade are determined in common and affected at the same time. This result confirmed the hypothesis $H_{3.3}$. In fact, the positive bidirectional causal relationship between CO_2 emissions and trade openness implies that Saudi Arabia encourages trade without respecting the quality of the environment, which would lead to the deterioration of the environment. In this case, we surmise that the government of this country is not interested in the "environmental quality," besides sending a positive signal to encourage trade. So, it is crucial for the policymakers to respect the environmental regulation in order to improve the environmental quality.

Finally, the retroaction hypothesis between economic growth and trade openness implies that the latter promotes economic growth, but the latter reduces international trade, which supported the hypothesis $H_{2.3}$. However important policy implications showed that this country has good economic policies but bad foreign ones to improve its foreign trade. In fact, this is not specific to Saudi Arabia, but it also concerns the countries where trade openness is still relatively weak to implement forward-looking trade liberalization policies. In fact, this result is in contrast with the findings of Rahman (2021) for the BRICS countries.

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