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Trade Openness and CO_2 Emissions: Evidence from Tunisia

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Abstract: We investigated the asymmetrical effects of trade openness on CO_2 emissions and the environmental Kuznets curve (EKC) hypothesis in Tunisia during the period 1971–2014. The integration analysis suggests a mixed order of integration and the cointegration analysis corroborates the long- and short-run relationships. The EKC was proved true with a turning point gross domestic product (GDP) of approximately 292.335 billion constant US dollars, and Tunisia was found at the first phase of EKC. Moreover, we corroborate the asymmetrical effects of trade openness on CO_2 emissions. The effects of increasing and decreasing trade openness are found to be positive and insignificant on CO_2 emissions, respectively. The pollution haven hypothesis is found to be true in Tunisia, along with negative environmental effects associated with increasing foreign trade.

Keywords: CO_2 emissions; trade openness; asymmetry; EKC

1. Introduction

Free trade is likely to have negative or positive environmental effects due to the effects of scale, technique, and composition [1]. Moreover, trade also affects the environment via economic growth. Economic growth generally has a negative environmental effect at the first phase of development due to the scale effect of increasing energy consumption. However, it could have a positive environmental effect at the later stage due to the effects of composition and/or technique. The scale effect illustrates that pollution emissions are increasing due to higher economic activities and energy consumption, which is because more emphasis is placed on economic growth rather than pollution control at the initial stage of the development process. Later in the development process, economic growth promotes an increase in the demand for a cleaner environment in order to attain a higher standard of living. For this purpose, dirty production processes are replaced with clean production processes, or with the service sector, which is termed as the composition effect. Moreover, demand for clean technology also increases at the second stage of development. As a result, the effect of technique aids positive environmental effects. In summary, increasing economic growth is responsible for environmental degradation at the earlier stages of the development process, and helps to improve the environment at the later stages. This quadratic effect is known as the environmental Kuznets curve (EKC) hypothesis [2,3]. Recent empirical studies have tested and also corroborated the existence of the EKC hypothesis [4–6].

The EKC hypothesis has been a workhorse of the environmental literature since trade liberalization became more widespread in the 1980s. Tunisia also introduced trade liberalization in the 1980s to foster economic growth [7]. This liberalization helped expand its trade with the world at large, and with geographically close trading partners of the European Union (EU). Most Tunisian exports consist of manufactured items. For example, in 2017, 77% of Tunisian exports to the EU were of manufactured items and 41.1% of imports were of energy consumption-oriented items, such as machinery and vehicles [8]. Furthermore, increasing trade openness also attracts foreign investment. According to the pollution haven hypothesis (PHH) theory, dirty industries in developed countries face more costs due to tight environmental policies, thus they shift their dirty production processes over to the developing world in order to enjoy the advantages of lax environmental policies and a cheap labor force [9]. On the other hand, the foreign firm could gain positive environmental effects through the implementation of the better and cleaner technology standards of the developed world [10].

In the energy consumption profile of Tunisia, most energy is utilized by the transport and industry sectors, and around 90% of energy consumption is from fossil fuel sources. Increasing energy demand and depletion of Tunisian oil resources have shifted its status from net oil-exporter to net oil-importer. To protect the environment, Tunisia is trying to control pollution through its National Environmental Control Agency; however, Tunisia was still ranked 58th on the Environmental Performance Index (EPI) in 2018. This shows that increasing economic growth can be responsible for environment degradation. Trade openness has the tendency to contribute to shaping the EKC hypothesis, in any country, because trade openness, generally, has a positive effect on economic growth. On the other hand, trade openness has the potential to aid positive environmental effects if it can change the development practices of countries, in their specialized industries, to that of clean production.

Trade openness is expected to have net negative environmental effects if the scale effect of trade openness is found to be dominant over the technique/composition effects; and net positive environmental effects are expected for an inverse situation. Moreover, trade openness can have asymmetrical effects on pollution emissions, as increasing trade openness does not necessarily have the same sign and magnitude of effect as that of decreasing trade openness. According to Keynes [11], the increasing trend of any macroeconomic variable turns into a negative trend suddenly and violently, whereas a downward trend does not have the same sharp shift into an upward trend. Secondly, increasing trade increases energy consumption and pollution due to the increasing income level of a country. However, decreasing trade does not necessarily reduce the energy consumption, due to the ratchet effect. The ratchet effect illustrates that when the income level decreases, consumption does not decrease in the same manner [12]. Following these arguments, the asymmetrical effects of increasing and decreasing trade openness on energy consumption and pollution emissions are expected. This fact can also be observed from Figures 1–3. The increasing trend of trade openness corresponds with the increasing trend of CO_2 emissions in the majority of the years during the period 1976–2014. However, this positive relationship does not hold in the declining periods of trade openness. In the years 1983, 1985, 1991, 1996–1999, 2002–2003, and 2013–2014, trade openness declined significantly but gross domestic product (GDP) and CO_2 emissions increased sufficiently, instead of declining.

Figures 1–3 show the positive trends of CO_2 emissions and GDP in the majority of the years studied. A positive relationship could be expected from the co-movements of CO_2 emissions and GDP. However, Figure 2 shows relatively more volatility in the trade openness series (percentage of trade to GDP) in comparison to Figures 1 and 3. Furthermore, Figures 1 and 2 show that trade openness during the period 1976–2014 coincides with increasing CO_2 emissions, except for in 1987 and 1994. This further corroborates the positive relationship between them. In the same way, this positive relationship can also be observed in decreasing trade openness and decreasing CO_2 emissions in some of the years. However, relatively more evidence of a negative relationship between the two (decreasing trade openness and decreasing CO_2 emissions) can also be observed. Therefore, the direction (positive or negative) of the relationship is not certain from the trends of decreasing trade openness and decreasing CO_2 emissions.

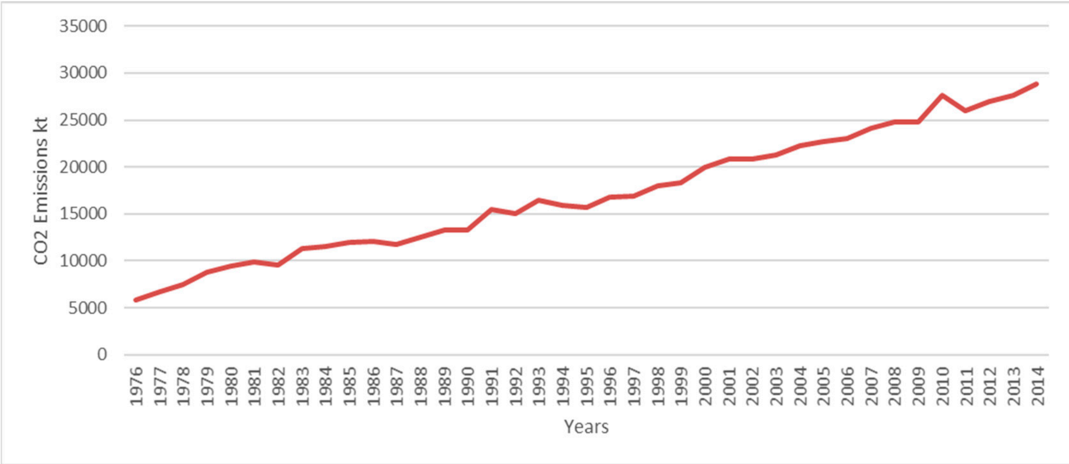

Figure 1. CO_2 emissions during 1976–2014.

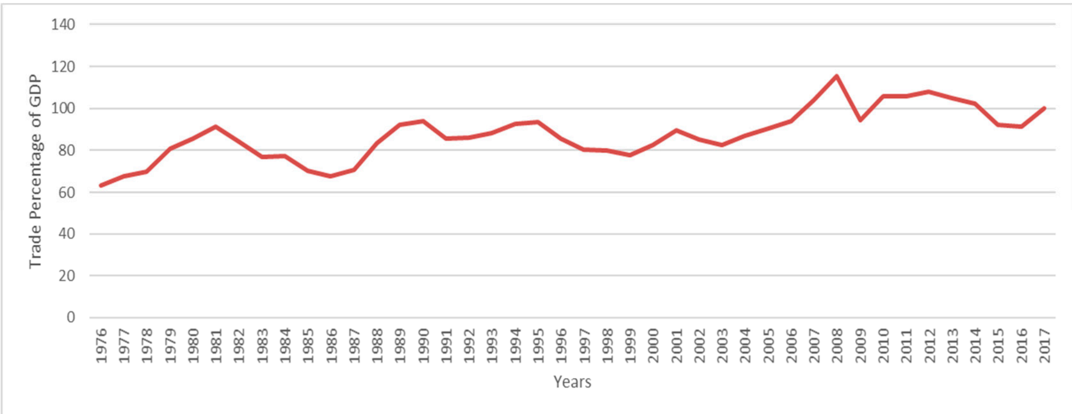

Figure 2. Trade percentage of GDP during 1976–2017.

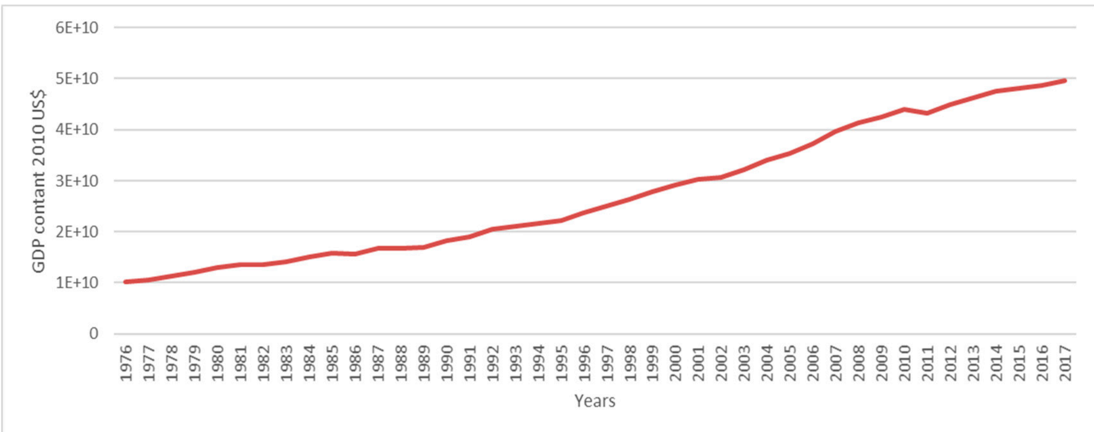

Figure 3. GDP constant 2010 US dollar during 1976–2017.

The EKC hypothesis has been tested in the pollution literature in the case of Tunisia with mixed results regarding the relationship between income and CO_2 emissions. For instance, Shahbaz et al. [13] corroborate an inverted U-shaped relationship between income and CO_2 emissions and validated the EKC hypothesis. Conversely, Sekrafi and Sghaier [14] found a U-shaped relationship between income and CO_2 emissions. Further, Arouri [15] and Fodha and Zaghdoud [16] could not find a quadratic relationship and reported a monotonic effect of income on CO_2 emissions. A possible reason for these different results is the incorporation of an energy consumption variable in the model which generates biases in the relationship of CO_2 emissions and income [17]. As a result, we investigated the EKC hypothesis without an energy consumption variable in the model. We also tested the effect of trade openness on CO_2 emissions in both symmetry and asymmetry settings. Testing asymmetrical effects is relatively scant in the environment literature and is absent in testing the trade–environment relationship. Figures 1 and 2 illustrate the possibility of the asymmetry in the relationship of CO_2 emissions and trade openness. Using an empirical exercise, this research seeks to contribute to the literature by testing whether increasing and decreasing trade openness have symmetrical effects on CO_2 emissions.

2. Literature Review

Some pioneer studies have focused on the testing of the relationship between income and pollution emissions and claimed that trade liberalization is responsible for higher emissions due to a scale effect and can also help to reduce emissions due to composition and/or technique effects. The EKC hypothesis explains that increasing income is responsible for increasing pollution emissions at an earlier stage of growth and helps to improve the environment at later stage of growth. Trade liberalization was responsible for shaping this nonlinear relationship between income and pollution emissions [2,3]. Afterwards, the environment literature shifted the focus to the effect of trade openness on pollution emissions. Table 1 shows the relevant literature summary. Managi et al. [18] investigated the determinants of different pollution emissions for a mixed panel of the Organization of Economic Cooperation and Development (OECD) and non-OECD countries using the Ordinary Least Square (OLS), Fixed Effects (FE) and Generalized Method of Movement (GMM) methodologies. They found that trade openness has a positive effect on the all investigated emissions. Halicioglu [19] investigated the EKC hypothesis in Turkey including foreign trade in the model of CO_2 emissions per capita. He found evidence of the EKC hypothesis and also reported the positive effects of energy consumption and foreign trade on CO_2 emissions per capita. Further, Granger causality is found from energy consumption and income to CO_2 emissions per capita but not from foreign trade. Hossain [20] investigated the Granger causality for nine newly industrialized countries during the period 1971–2007. He found that trade openness is causing CO_2 emissions, economic growth and urbanization. Further, economic growth is also causing CO_2 emissions.

Table 1. Literature summary.

Authors	Region	Period	Methodology	Trade–CO_2 Emissions Relationship
Managi et al. [18]	OECD and non-OECD countries	1973–2000	OLS, FE, and GMM	Trade has positive and negative effects on CO_2 emissions in OECD and non-OECD countries, respectively.
Halicioglu [19]	Turkey	1960–2005	Cointegration and Granger causality	Foreign trade is positively affecting CO_2 emissions but not causing it.
Hossain [20]	9 newly industrialized countries	1971–2007	Granger causality	Unidirectional Granger causality from trade openness to CO_2 emissions.
Naranpanawa [21]	Sri Lanka	1960–2006	Granger causality	Unidirectional Granger causality from trade openness to CO_2 emissions.
Chebbi et al. [7]	Tunisia	1961–2005	Cointegration and Granger causality	Trade openness has direct positive effects on CO_2 emissions in the long and short term and has negative indirect effects in the long term.
Kozul-Wright and Fortunato [22]	A panel of mix countries	1990–2004	Random Effects (RE)	Trade openness positively affects CO_2 emissions.
Chang [23]	51 countries	1997–2007	Two Stage Least Square (TSLS)	Trade liberalization has positive (negative) effects on CO_2 emissions in the high(low)corrupted countries.
Shahbaz et al. [13]	Tunisia	1971–2010	Cointegration and Granger causality	Trade openness is positively affected by CO_2 emissions but not causing it.

Table 1. *Cont.*

Authors	Region	Period	Methodology	Trade–CO_2 Emissions Relationship
Al-Mulaliet al. [24]	23 European countries	1990–2013	Fully Modified OLS (FMOLS)	Negative effects of trade openness on CO_2 emissions.
Ahmed et al. [25]	4 newly industrialized countries	1970–2013	FMOLS and Granger causality	Unidirectional Granger causality from trade openness to CO_2 emissions and negative effects of trade openness on CO_2 emissions.
Hakimi and Hamdi [26]	Tunisia and Morocco	1971–2013	Cointegration and causality	Positive effect of trade liberalization on CO_2 emissions.
Shahbaz et al. [27]	105 countries	1980–2014	Causality	Trade openness is found to be harmful for the environment.
Mahmood and Alkhateeb [28]	Saudi Arabia	1970–2016	Cointegration	Trade openness has negative effects on CO_2 emissions.
Mahmood et al. [29]	Egypt	1990–2014	Cointegration	Trade openness has insignificant effects on CO_2 emissions.

Naranpanawa [21] applied the cointegration and Granger causality test in the relationship between trade openness and CO_2 emissions in Sri Lanka during the period 1960–2006. He found that trade openness is causing CO_2 emissions, investment and economic growth. Further, he reported that economic growth is causing the investment and investment is causing trade openness. Chebbi et al. [7] investigated the triangular relationship among trade openness, CO_2 emissions and economic growth in Tunisia during 1961–2005. They reported that trade openness has direct positive effects on CO_2 emissions in the long and short term and has negative indirect effects in the long term. Using the period 1990–2004, Kozul-Wright and Fortunato [22] investigated the EKC hypothesis for a panel of countries. They found a U-shaped relationship between economic growth and CO_2 emissions. Further, trade openness has a positive effect, while institutional quality and Foreign Direct Investment (FDI) inflows have negative effects on CO_2 emissions. Chang [23] reported that trade liberalization has negative environmental effects in high corrupt countries and has pleasant environmental effects in less corrupt countries. Further, they found a U-shaped relationship between income and CO_2 emissions in less corrupt countries.

Al-Mulali et al. [24] worked on the period 1990–2013 for 23 European countries. They found that economic growth and urbanization increase CO_2 emissions, while trade openness helps to reduce CO_2 emissions. Further, they found that some sources of renewable electricity generation have positive environmental effects and the rest have insignificant effects. Ahmed et al. [25] investigated the monotonic effects of energy consumption, trade openness and income on CO_2 emissions in four newly industrialized countries during the period 1970–2013. They found a positive effect of energy consumption and negative effects of trade openness and income on the CO_2 emissions. In the Granger causality analysis, they reported a unidirectional causality from energy consumption, trade openness and economic growth to CO_2 emissions and from trade openness to energy consumption and economic growth. Hakimi and Hamdi [26] probed the determinants of CO_2 emissions in Tunisia and Morocco during 1971–2013. They found that FDI, trade openness and capital positively affected CO_2 emissions in both countries' time series and panel analyses. In the panel causal analyses, they found a bi-directional Granger causality between income and CO_2 emissions and between FDI and CO_2 emissions.

Shahbaz et al. [27] investigated the effect of trade openness on the CO_2 emissions of 105 countries from 1980 to 2014. In the time series analyses, they found that trade openness positively contributes in the CO_2 emissions of the majority of the investigated countries. However, trade openness has an insignificant effect on CO_2 emissions in the case of Tunisia. Further, the positive effects of trade openness and income on CO_2 emissions are found for the whole panel. Mahmood and Alkhateeb [28] inspected the EKC hypothesis in Saudi Arabia during the period 1970–2016. They found the existence of the EKC hypothesis and a negative effect of trade on CO_2 emissions. Mahmood et al. [29] examined the determinants of CO_2 emissions per capita and the EKC hypothesis in Egypt during the period 1990–2014. They found the EKC hypothesis in Egypt and an insignificant effect of trade openness in this case. Further, they found the positive and negative effects of energy consumption and FDI on CO_2 emissions per capita, respectively.

Ignoring trade openness, some literature explored the determinants of energy consumption and CO_2 emissions in the Tunisian economy. For example, Belloumi [30] found a long-term bidirectional Granger causality between economic growth and energy consumption and a short-term unidirectional Granger causality from energy consumption to economic growth during 1971–2004. Using the period 1971–2012, Achour and Belloumi [31] reported a short-term unidirectional Granger causality from transport energy consumption to the transport CO_2 emissions and also found many other evidences of Granger causality among transport-related energy consumption, CO_2 emissions, infrastructure and transport value added. In testing the EKC hypothesis for Tunisia, Arouri et al. [15] reported the existence of the EKC hypothesis for a panel of Middle East and North African (MENA) countries as a whole and most of individual countries as well. In the case of Tunisia, they could not find the EKC hypothesis and reported a monotonic effect of income on CO_2 emissions. In addition, Fodha and Zaghdoud [16] corroborated the existence of the EKC hypothesis in the relationship of income and SO_2 emissions in Tunisia during 1961–2004, but they could not find the EKC regarding the relationship between economic growth and CO_2 emissions. In the Granger causality analysis, they found that economic growth is causing CO_2 emissions and SO_2 emissions. Extending this research, Shahbaz et al. [13] re-examined and corroborated the EKC hypothesis in the relationship between CO_2 emissions and income in Tunisia during 1971–2010. Further, they reported that trade openness and energy consumption positively affect CO_2 emissions with low elasticity and energy consumption is causing the CO_2 emissions. Sekrafi and Sghaier [14] investigated the EKC hypothesis and found the U-shaped relationship between CO_2 emissions and economic growth. Further, they found a negative relationship between the control of corruption and CO_2 emissions. The EKC literature dealing with the Tunisian case reports different conclusions of U-shaped, inverted U-shaped and monotonic relationships between income and CO_2 emissions which is claimed due to the variation of control variables in the model. Therefore, this issue needs further attention.

Mahmood et al. [32] and Shahbaz et al. [33] have investigated and corroborated the asymmetrical effects of financial development on CO_2 emissions in the case of Saudi Arabia and Pakistan, respectively. Siddiqui et al. [34] found the asymmetrical effects of oil price on the stock markets in some Asian countries. Alkhateeb and Mahmood [35] found the asymmetrical effects of trade openness on energy consumption in Egypt. Hence, the asymmetrical effects of trade openness can also be expected on CO_2 emissions. Assuming symmetrical effects in the presence of asymmetrical effects of any variable can be considered as an omitted variable bias in the model [36]. Currently, the estimation of asymmetrical effects of trade openness on CO_2 emissions is missing in the environmental literature. Therefore, this present research represents an empirical contribution by hypothesizing the asymmetrical effects of trade openness in the Tunisian CO_2 emission model. Further, we aim to re-investigate the EKC to find the robust turning point because previous Tunisian literature exhibited contradictory results in regard to the relationship between income and CO_2 emissions.

3. Methodology

To model the determinants of CO_2 emissions in Tunisia, we follow the standard methodology of the EKC hypothesis, in which the quadratic effect of income variable is assumed on the pollution emissions. A justification of this quadratic relation is that income has a scale effect on the pollution emissions at the first stage of development due to increasing demand for energy consumption. At the second stage of development, pollution emissions are reduced with further economic growth due to technique and/or composition effects [2,3]. The positive effect of the economic growth variable and negative effect of its square are claimed for the existence of the EKC hypothesis. Most of the studies on the EKC hypothesis incorporate energy consumption in the pollution model. However, Jaforullah and King [17] argued that energy consumption generates a systematic volatility in the estimated coefficients of the model and generates biases in the relationship of CO_2 emissions and income. Therefore, we ignore energy consumption in our model.

The EKC hypothesis has been a workhorse of the environmental literature since the implementation of trade liberalization throughout the world. Therefore, trade helps in shaping the EKC hypothesis [3]. Tunisia is a door for European countries to enter other African countries and is an attractive place for trade. When conducting environmental research on Tunisia, we cannot ignore trade openness and assume following model:

$$CO2_t = f(GDP_t, GDP_t^2, TO_t) \tag{1}$$

where

$CO2_t$ = Natural logarithm of CO_2 emissions in kilo tons;
GDP_t = Natural logarithm of gross domestic product in constant 2010 US dollar;
${GDP_t}^2$ = Square of GDP_t;
TO_t = Natural logarithm of percentage of trade (sum of exports and imports of goods and services) to the gross domestic product.

Following [18,20], TO_t is a proxy of trade openness. All the data in annual time series is sourced from the World Bank [37] and covers the period 1976–2014. The raw data is available in the supplementary material. A maximum available period of all hypothesized variables is utilized. Moreover, all variables are used after taking the natural logarithm to capture the elasticity parameters. To test the stationarity of the variables, we utilize the Ng and Perron [38] test equations:

$$\Delta y_t^d = \alpha_0 + \alpha_1 t + \alpha_2 y_{t-1}^d + \sum_{j=1}^{m} \alpha_{3j} \Delta y_{t-j}^d + \omega_t \tag{2}$$

$$MZ_a = [(y_T^d/T) - f_0]/[2\sum_{t-2}^{T} (y_T^d)^2/T^2] \tag{3}$$

$$MSB = \sqrt{\sum_{t-2}^{T} (y_T^d)^2 * T^{-2}/f_0} \tag{4}$$

$$MZ_t = MZ_a * MSB \tag{5}$$

$$MPT = [\bar{c}^2 \sum_{t-2}^{T} (y_T^d)^2/T^2 + [(1-\bar{c})/T] * (y_T^d)^2/f_0 \tag{6}$$

where

$$f_0 = \sum_{j=-(T-1)}^{T-1} \theta(j).k(j/l) \tag{7}$$

$$k = \sum_{t=2}^{T} (y_{t-1}^d)^2/T^2, \bar{c} = -13.5 \tag{8}$$

y_t^d is a de-trended series of y_t. l is the bandwidth parameter and $\theta(j)$ is the auto-covariance of the residuals. In Equation (2), the null hypothesis of unit root problem ($\alpha_2 = 0$) will be tested and its rejection will ensure the stationarity of a series (y_t). MZ_a, MSB, MZ_t and MPT are modified versions of the Z_a, Sargent–Bhargava (SB), Z_t and P_T tests, respectively, and allow for generalized least square de-trending of the data. These statistics are free of size problems [38]. Ng and Perron [38] proposed these tests to apply on the de-trended series mentioned in Equation (2). Due to the de-trending procedure and modified statistics provided in Equations (3)–(6), this test is renowned for its efficiency in a small sample case. So, it is suitable for our small sample. Afterwards, we move towards cointegration analysis to find the long-term relationship in the model. For this purpose, we utilize the Pesaran et al. [39] methodology which follows the bound testing procedure, assuming level stationary variables for the lower bound and first difference stationary variables for the upper bound. Therefore, it is efficient even in the case of a mixed order of integration. The Auto-Regressive Distributive Lag (ARDL) model of this technique for our hypothesized model of Equation (1) can be expressed as follows:

$$\begin{aligned}\Delta CO2_t = \beta_0 + \beta_1 CO2_{t-1} + \beta_2 GDP_{t-1} + \beta_3 GDP^2_{t-1} + \beta_4 TO_{t-1} + \textstyle\sum_{j=1}^{m1} \gamma_{1j} \Delta CO2_{t-j} \\ + \textstyle\sum_{j=0}^{m2} \gamma_{2j} \Delta GDP_{t-j} + \sum_{j=0}^{m3} \gamma_{3j} \Delta GDP^2_{t-i} + \sum_{j=0}^{m4} \gamma_{4j} \Delta TO_{t-j} + \psi_t\end{aligned} \tag{9}$$

The estimated effects of all variables in Equation (9) are of a symmetrical nature. Considering the theoretical arguments in favor of asymmetry [11,12] and following Shin et al. [40], we divide a series of TO_t into two separate series of TOP_t and TON_t to test the asymmetrical effects of increasing and decreasing trade openness on CO_2 emissions. TOP_t and TON_t are generated by partial sums of positive and negative changes in TO_t variable, respectively, in the following way:

$$TOP_t = \sum_{i=1}^{t} \Delta TO_i^+ = \sum_{i=1}^{t} \max(\Delta TO_i, 0) \tag{10}$$

$$TON_t = \sum_{i=1}^{t} \Delta TO_i^- = \sum_{i=1}^{t} \min(\Delta TO_i, 0) \tag{11}$$

The Equations (10) and (11) are placed by the TO_t variable in the linear ARDL of Equation (9) to convert it into the non-linear ARDL:

$$\begin{aligned}\Delta CO2_t = \phi_0 + \phi_1 CO2_{t-1} + \phi_2 GDP_{t-1} + \phi_3 GDP^2_{t-1} + \phi_4 TOP_{t-1} + \phi_5 TON_{t-1} \\ + \textstyle\sum_{j=1}^{m1} \varphi_{1j} \Delta CO2_{t-j} + \sum_{j=0}^{m2} \varphi_{2j} \Delta GDP_{t-j} + \sum_{j=0}^{m3} \varphi_{3j} \Delta GDP^2_{t-i} \\ + \textstyle\sum_{j=0}^{m4} \varphi_{4j} \Delta TOP_{t-j} + \sum_{j=0}^{m5} \varphi_{5j} \Delta TON_{t-j} + \psi_t\end{aligned} \tag{12}$$

After the selection of optimum lag lengths (m_i) in Equation (12) by the Akaike Information Criterion (AIC), we apply the bound testing procedure on the null hypothesis of no cointegration, $\phi_1 = \phi_2 = \phi_3 = \phi_4 = \phi_5 = 0$. A rejection of null hypothesis confirms the existence of an alternative hypothesis of cointegration, $\phi_1 \neq \phi_2 \neq \phi_3 \neq \phi_4 \neq \phi_5 \neq 0$. After confirming cointegration, we find the long-term effects through a normalizing procedure applied on the coefficients of lagged-level variables. Further, we replace all the different variables with the error correction term (ECT_{t-1}) and the short-term effects can be discussed with the coefficients of differenced variables thereafter.

4. Results and Discussions

To test the level of integration, we apply the Ng and Perron [38] test and report the results in Table 2. The unit root results show that $CO2_t$, GDP_t, TON_t and TO_t are non-stationary at the level and TOP_t is stationary at the 10% level of significance in all MZa, MZt, MSB and MPT statistics. Further, we apply this test on the first differenced variables and find that all variables are stationary after first differencing. ΔGDP_t, ΔTON_t and TO_t are stationary at the 5% level of significance in all statistics. $\Delta CO2_t$ is stationary at the 5% level of significance in MZt and MPT and at the 10% level of significance in MZa and MSB. ΔTOP_t is stationary at the 5% level of significance in MZa, MZt and MPT and at the 10% level of significance in MSB. Overall, one independent variable of the model is level stationary and the rest are first-differenced stationary. Therefore, a mixed order of integration is corroborated. However, we proceed for non-linear ARDL cointegration, which provides efficient results even in this situation.

Table 2. Unit root analysis.

Ng–Perron Test				
Variable	**MZa**	**MZt**	**MSB**	**MPT**
$CO2_t$	−3.3901(1)	−1.1780	0.3475	24.5674
GDP_t	−9.0550(0)	−1.9570	0.2161	10.6898
TOP_t	−14.7969(1) *	−2.7146 *	0.1835 *	6.1900 *
TON_t	−13.0131(0)	−2.5504	0.1960	7.0047
TO_t	−9.7966	−2.2080	0.2253	9.3242
$\Delta CO2_t$	−17.0980(0) *	−2.9051 **	0.1699 *	5.4421 **
ΔGDP_t	−18.2471(0) **	−3.0181 **	0.1654 **	5.0085 **
ΔTOP_t	−17.1902(0) **	−2.9234 **	0.1701 *	5.3509 **
ΔTON_t	−18.4251(0) **	−3.0349 **	0.1647 **	4.9478 **
ΔTO_t	−18.1904(0) **	−3.0140 **	0.1657 **	5.0207 **

Note: *, ** and *** are showing stationarity on the 10%, 5% and 1% level of significance.

After integration analyses, we apply a cointegration procedure on both linear and nonlinear ARDL models of Equations (9) and (12), respectively. We utilize a long time period and expect the structural break. To capture the most significant break in the long-term relationship of Equations (9) and (12), we utilize the Bai and Perron [41] test and find a most significant break in the year 1983. To verify the break point of 1983, we also apply Chow test and the null hypothesis of no-break point is rejected at 1% level of significance with an estimated Wald test value of 36.9669. Therefore, the Chow test accepts the alternative hypothesis of a significant break in the year 1983. A justification for the structural break in the year 1983 in the relationships of CO_2 emissions, trade openness and income can be observed from Figures 1–3. In 1983, trade openness declined by 8.6% but CO_2 emissions increased by 18.7% in the same year and GDP also increased by 4.7%. These sharp changes reflect a negative relationship between CO_2 emissions and trade openness, which does not match with the relationship captured by the regression. Therefore, 1983 is justified as a break year in the relationship of the proposed model. Moreover, the country was facing many problems at that time, e.g., an expectation of change in political power, deficit in budget and in balance of trade, very low currency reserves, high government debt and debt cost and the removal of government subsidies on many items.

Table 3 shows the results of both linear and non-linear ARDL after the incorporation of a dummy variable $D1983_t$ of break year. The F-values of both the linear and non-linear ARDL are greater than the upper critical of Kripfganz and Schneider [42], which confirms the presence of cointegration in both models. The critical bound F-values of [42] are utilized due to our small sample size. The critical values of Pesaran et al. [39] are only useful and efficient for large sample sizes. Whereas, Kripfganz and Schneider [42] provide the efficient critical F-values for all sample sizes including a small sample size. Therefore, these F-values are efficient in our case. The Cumulative Sum (CUSUM) and CUSUM square (CUSUMsq) tests of parameters' stability in Figure 4 and diagnostic tests in Table 3 confirm the robustness of both linear and non-linear ARDL estimates.

Table 3. Auto-Regressive Distributive Lag (ARDL) and non-linear ARDL models.

Variable	**ARDL- Parameter**	**Nonlinear ARDL- Parameter**
Lags	(1, 2, 2, 0, 0)	(1, 2, 2, 0, 0, 0)
	Long Term	
GDP_t	7.1541 (0.0117)	7.2392 (0.0140)
GDP_t^2	−0.1325 (0.0230)	−0.1371 (0.0237)
TO_t	0.1334 (0.0385)	
TOP_t		0.1871 (0.0319)
TON_t		−0.0149 (0.9251)
Wald Test		5.2151 (0.0312)
$D1983_t$	0.1240 (0.0005)	0.1024 (0.0126)
Intercept	−86.3059 (0.0114)	−85.2367 (0.0160)
	Short Term	
ΔGDP_t	10.1065 (0.4629)	5.4973 (0.7010)
ΔGDP_{t-1}	36.9981 (0.0088)	31.9498 (0.0291)
ΔGDP_t^2	−0.2003 (0.4888)	−0.1030 (0.7324)
ΔGDP_{t-1}^2	−0.7667 (0.0096)	−0.6588 (0.0322)
ΔTO_t	0.1272 (0.0473)	
ΔTOP_t		0.1709 (0.0270)
ΔTON_t		−0.0136 (0.9247)
Wald Test		3.9467 (0.0470)
$D1983_t$	0.2121 (0.0000)	0.1966 (0.0001)
ECT_{t-1}	−0.9533 (0.0000)	−0.9132 (0.0000)
	Diagnostics	
Bound Test Critical Bound F-values At 1% 2.852−3.957 At 5% 2.261−3.264	F-value =8.1306	F-value =7.1944
F-Hetro	0.0521 (0.8208)	0.0856 (0.7716)
F-Serial	1.9719 (0.1611)	2.0259 (0.1396)
F-RESET	0.5087 (0.4823)	0.1416 (0.7100)
χ^2-Normality	0.8008 (0.6700)	0.7709 (0.6802)

Note: () shows the probability values.

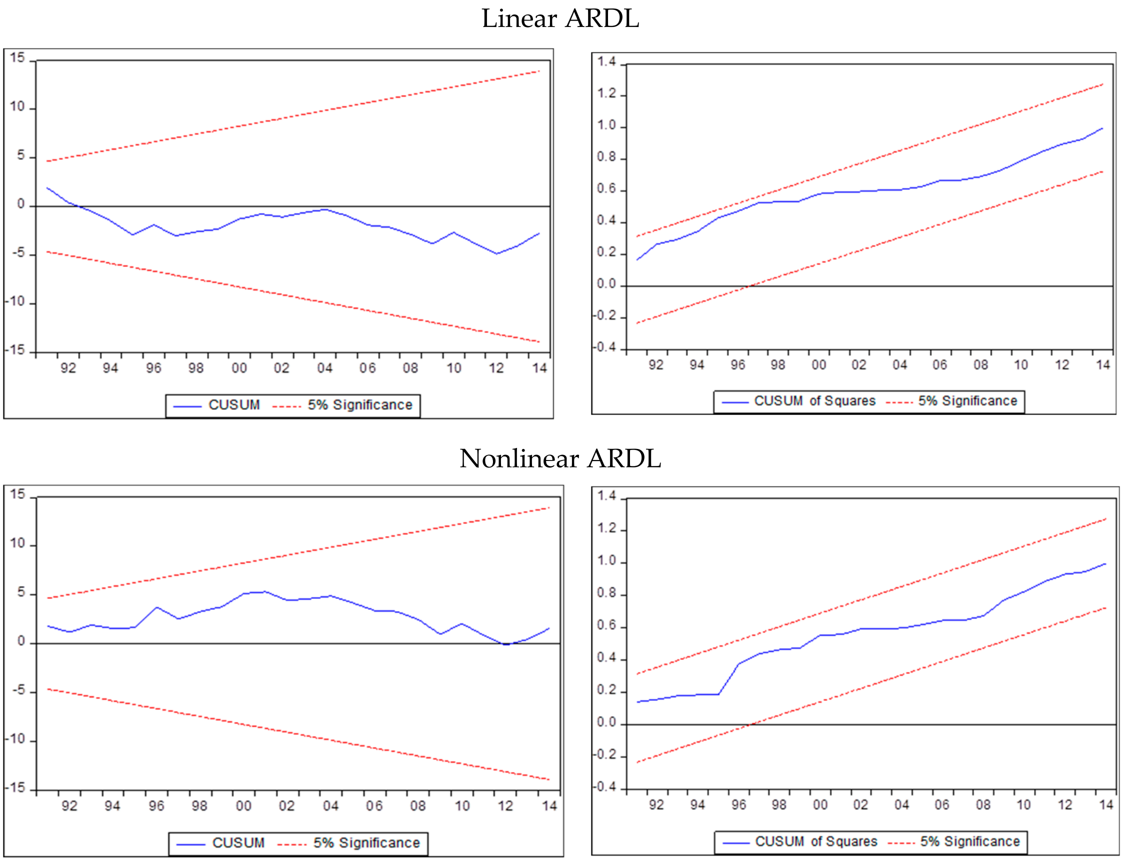

Figure 4. CUSUM and CUSUMsq tests.

We found the positive coefficients of GDP_t and negative coefficients of GDP_t^2 in the long-term estimates of both models. Hence, the EKC hypothesis was corroborated in the Tunisian case and this finding matches with the result of Shahbaz et al. [13] but contradicts the findings of [14–16]. Considering the superiority of the non-linear ARDL model, we estimate the turning point of this inverted U-shaped relationship at a GDP of approximately 292.335 billion constant US dollars which has not been achieved yet. Therefore, we claim that Tunisia is at the first stage of the inverted U-shaped relationship and increasing economic growth over the investigated period is harmful for the environment.

The results of trade openness show that TO_t has a positive effect on CO_2 emissions in the linear ARDL model. In the non-linear ARDL model, increasing trade openness (TOP_t) has a positive effect and decreasing trade openness has an insignificant effect. The elasticity of TOP_t confirms that a 1% increase in TOP_t increases CO_2 emissions by approximately 0.19%. The negative environmental effect of increasing trade openness suggests that increasing trade openness is promoting the dirty exporting industry with a high level of pollution. This evidence is also corroborated with the fact that 77% of Tunisian exports are of a manufacturing nature. On the other hand, increasing trade openness is also increasing the demand for emissions-oriented imports. Hence, a negative environmental effect of increasing trade openness has corroborated the existence of PHH in Tunisia. To verify the asymmetry, we applied the Wald test on the H_0 of the symmetrical effect of trade openness and this test rejected the H_0. Hence, the asymmetrical effects of increasing and decreasing trade openness are verified. Moreover, the asymmetrical effects of increasing and decreasing trade openness on CO_2 emissions can also be observed from Figures 1 and 2. Figures 1 and 2 show that increasing trade openness and increasing CO_2 emissions have co-movement in the same direction. Hence, these figures show a positive relation as per the findings of the nonlinear ARDL estimates. However, a relationship of decreasing trade openness and decreasing CO_2 emissions is not clear in Figures 1 and 2. This unclear relationship is corroborated by the estimated insignificant coefficient of TON_t.

The short-term estimates are also reported in Table 3. The negative coefficients of ECT_{t-1} corroborate the short-term relationships in both models. These coefficients also show the speed of convergence from short-term disequilibrium to the long-term equilibrium in the approximately twelve and a half months in the linear ARDL model and in the approximately thirteen months in the nonlinear ARDL model. The positive (negative) coefficients of ΔGDP_{t-1} ($\Delta GDP_{t-1}{}^2$) confirm the existence of the EKC hypothesis with a one-year lag in both models. Trade openness has a positive and significant effect on CO_2 emissions in the linear ARDL model. In the nonlinear ARDL model, ΔTOP_t has a positive and significant effect on CO_2 emissions and the effect of ΔTON_t is found to be insignificant. The null hypothesis of the symmetrical effects of trade openness has been tested by the Wald test and asymmetry has also been proved in the short term.

5. Conclusions

In this research, we tested the effects of trade openness and income on CO_2 emissions in Tunisia using a maximum available annual series during the period 1976–2014. Further, we hypothesized the asymmetrical effects of trade openness in the nonlinear ARDL model along with testing the EKC hypothesis and also estimated the linear ARDL model for comparison. We performed the cointegration test on the models after testing the stationarity of the variables and incorporation of one unknown structural break in the analysis. In the stationarity analysis, we found a mixed order of integration and the most significant structural break was found in 1983. Then, we validated the evidence of cointegration in both linear and non-linear ARDL models through bound testing procedure. In both models, we corroborated the EKC hypothesis with positive and negative effects of income and its square variable. Considering the superiority of the nonlinear ARDL model, we confirm that Tunisia is at the first stage of the EKC with an estimated turning point GDP of approximately 292.335 billion constant US dollar. Therefore, the increasing economic growth of Tunisia is harmful for the environment in Tunisia during the investigated period. Further, we find that trade openness has positive effects on CO_2 emissions in the linear ARDL model and has asymmetrical effects in the nonlinear ARDL model. The increasing Tunisian trade openness is found responsible for increasing CO_2 emissions in Tunisia and the effect of decreasing trade openness is estimated as insignificant.

Supplementary Materials: All utilized data is available online at http://www.mdpi.com/2071-1050/11/12/3295/s1, Data.xlxs

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