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Sustainable development and openness in oil-exporting countries: green growth and brown growth

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Abstract

What is the nexus between sustainability and openness? This study employs econometric methods to estimate a neoclassical growth model, considering brown and green growth as two pillars of sustainability, in ten oil-exporting countries during 1990–2012. Based on the results, the nexus is non-linear and U-shaped, depending on the level of openness. From the green growth viewpoint, the current relationship of sustainability with openness is negative in the sample, but it becomes positive in the higher levels of openness. From the brown growth perspective, not only the current relationship of openness with sustainability is positive, but also it can become stronger in the higher level of openness. They are proofs for the openness acting as a catalyst for sustainability in the sample. All the oil-exporting countries are suggested to open their economy wider and wider since the sustainability and openness nexus either is already positive or it becomes positive in the higher degrees of openness. So, sustainability is a flimsy pretext to discourage the openness since it is a positively effective strategy in the long-term, notwithstanding its potentially negative effects in the short-run which creates a gap.

Keywords: Sustainability, Openness, Green growth, Brown growth, Oil-exporting countries

JEL Classification: Q24, Q38, Q41

1 Introduction

What is the nexus between sustainability and openness? It has been a main question for many decades for which no clear answer has been proposed to achieve a strong consensus on (Dufrenot et al. 2010; Falvey et al. 2012; Greenaway and Morgan 1998; Greenawa et al. 1998; Grossman and Krueger 1991; Prebisch 1950; Singer 1950; Singer and Gray 1988; Talberth and Bohara 2006; Ulasan 2015; Zahonogo 2017). This can be due to the various relationships of openness with each element of sustainability (i.e., environmental quality and economic growth). Although there are a wide range of hypotheses and theories on the relationship, there is no strong consensus on the nexus of openness either with the environmental pollution or with the economic growth (Arezk et al.

2014; Grossman and Krueger 1991; Moutinho et al. 2017; Sun et al. 2017; Talberth and Bohara 2006; Zhang, et al. 2017).

Openness has four potential relationships with economic growth, as a pillar of sustainability, including neutral, positive, negative, and non-linear relationships. The last three hypotheses are presented in Fig. 1. Based on the figure, the growth hypothesis claims a positive nexus between openness and sustainability due to the increase in specification, knowledge spillover, and return to scale, resulted from the openness (Alesina et al. 2000; Almeida and Fernandes 2008; Baldwin et al. 2005; Barro and Sala-i-Martin 1997; Bond et al. 2005; Zahonog 2017). However, the depression hypothesis suggests a negative connection which might be owing to incapability in society and vitality in domestic industries (Clemens and Williamson 2001; Fagerberg 1994; Irwin 2002; Musila and Yiheyis 2015; O'Rourke 2000). In addition to the couple of linear hypotheses, many suggest non-linear relations including J-carve pattern, Laffer curve of trade, pollution haven hypothesis, and Prebisch–Singer theory (Arezki et al. 2014; Colagiuri and Morrice 2015; Costa and Santos 2013; Greenaway and Morgan 1998; Greenaway et al. 1998, 2002; Harvey et al. 2010; Shen et al. 2017; Sun et al. 2017; Zhang et al. 2017). Finally, the four hypotheses believe no nexus between openness and economic growth as a sustainability pillar (Sachs and Warner 1995; Ulasan 2015). Environmental quality, as another pillar of sustainability, has the three potential relationships with openness, as mentioned above (Grossman and Krueger 1991). These wide range of theories and hypotheses not only do not assist in the identification of the nexus between openness and sustainability, but also they make it more dubious.

This ambiguity is a problem statement for the oil-exporting countries, emerging with more focus on the issue in the future studies, as ours deals with it. The oil-exporting countries, on the one hand, are growing their economy via exporting the oil, thanks to the technological and transportational advances which lead to a considerably greater openness. The openness, on the other hand, is a channel to import the more expensive and consumptive commodities into the oil-exporting. Not only does it waste the oil income, rather than the development of infrastructure, but also it might damage the domestic industry, or rather the economic growth (Arezki et al. 2014; Harvey et al. 2010; Prebisch 1950; Singer 1950). In addition to the effects of

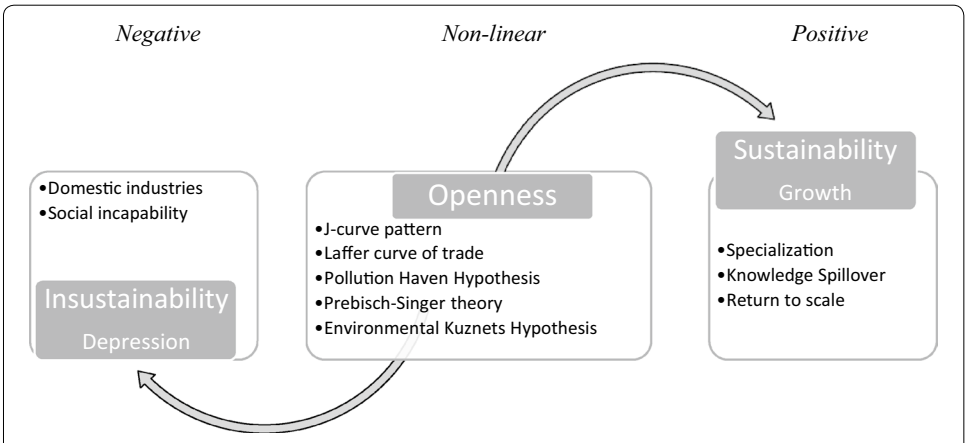

Fig. 1 Potential nexuses of openness and sustainability

openness on economic growth as a sustainability pillar, the production and exportation of oil are polluting the environment which is another pillar of the sustainability. This contradiction is proposing some questions which we investigate in the study, as mentioned below.

The main objective of the study is to estimate the relationship between openness and sustainability in the oil-exporting countries. It is achievable with answering three questions: the first one is, what is the nexus between openness and brown economic growth (including merely the economic perspective) in the oil-exporting countries; the second one is, what is the nexus between openness and green economic growth (growth including economic, social and, environmental considerations) in the oil-exporting countries; and third one is, how wide is the gap between growth and sustainability. Answering these questions provide vital clues to the strategical question of whether the oil-exporting countries have been successful in compensating the depreciation in their natural capital by the well worthwhile investment. In case of a positive response, their policy-makers should pursue their current strategies; otherwise, they are advised to restructure the economic, social, and environmental policies to make them consistent with the sustainability framework.

The novelty of the study is to employ both the green economic growth and brown economic growth simultaneously for the measurement of the relationship between openness and sustainability, which has three key pillars including economic, social, and environmental one. Based on Fig. 2, the GDP focuses solely on the economy pillar of sustainability, ignorance of the environmental issues, namely brown GDP while the green GDP (environmentally adjusted GDP) embraces not only the economic items, but also the social and environmental ones (Talberth and Bohara 2006; Wang et al. 2011). In this study, we take the advantage of both brown GDP and green GDP while no previous study has such a simultaneity, despite numerous previous researches.

2 Literature review

There are various ideas on the nexus between openness and sustainability. Many researchers are supporting a positive relationship while many are claiming a negative one. Notwithstanding the mentioned couple-of-view-points, a third group is viewing the nexus from a broader standpoint to compromise the conflicting view-points by accepting a non-linear relationship between trade, for openness, and growth, for sustainability. Growth index (GDP) rather than green GDP, many argue that, is subject to

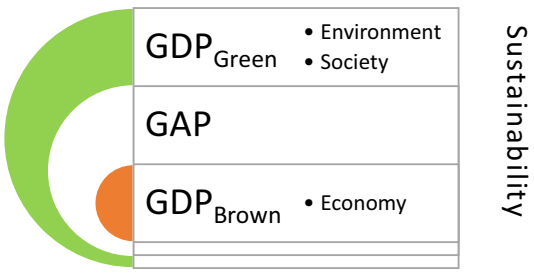

Fig. 2 Brown GDP versus green GDP

limitations upon the measurement of the sustainable development, leading to different results and then conflicting perspectives on the openness and sustainability.

On the one hand, trade and growth suggest a positive relationship in numerous researches (Alesina et al. 2000; Almeida and Fernandes 2008; Baldwin et al. 2005; Barro and Sala-i-Martin 1997; Bond et al. 2005; Guncavdi and Ulengin 2012; Zahonogo 2017). They provide a wide range of explanations for the nexus. One of them is specification due to the Adam Smith`s belief in the role of trade, as an openness proxy, on specification which leads to economic growth, as he entitled the first chapter of his famous book, "Wealth of Nations", as "Of The Division of Labour" (Smith 1776). Like Adam Smith, the comparative advantage theory of Ricardo explains how trade leads to specification and economic growth through comparative advantage theory (Ricardo 1817). In addition to the specification, trade causes the diffusion of technology and knowledge spillover as the Solow residuals, leading to economic growth (Romer 1996). Moreover, the recent researches add other growth contributors such as foreign direct investment and return to scale increment as a result of trade, supporting the positive connection of trade and growth (Alesina et al. 2000; Bond et al. 2005; Zahonogo 2017).

On the other hand, trade and growth show a negative relationship in many researches (Clemens and Williamson 2001; Irwin 2002; Musila and Yiheyis 2015; O'Rourke 2000) They offer various explanations for the reverse nexus such as insufficiency in R&D and human capital, hampering the technology adoption in the countries with inappropriate institutional-settings such as financial and bureaucratic systems which are impervious culturally, socially, politically, etc. (Fagerberg 1994; Zahonog 2017). Another is the domestic industries. They, clearly, might be threatened by opening the borders to the international trade which leads to the more competitive markets, paving the way for boosting the more competitive industries in other countries. Whether has the openness the various effects on the different countries, times or, conditions?

Furthermore, many researchers, considering both the above-mentioned views, claim that the nexus can be both positive and negative in changing circumstances which propose several theories and hypotheses supporting non-linear relationships between trade, as a proxy for openness, and growth, as a proxy for sustainability, such as (A) "Laffer curve of trade" (Zahonogo 2017); (B) "Environmental Kuznets Hypothesis" (Grossman and Krueger 1991); (C) "J-curve pattern" (Falvey et al. 2012; Greenaway et al. 1997, 1998, 2002; Jelassi et al. 2017); (D) "Pollution Haven Hypothesis" (Zhang et al. 2017); and (E) "Prebisch–Singer theory" (Arezk et al. 2014; Harvey, et al. 2010).

A. *J-curve pattern* it establishes a J-curve nexus for trade and growth, considering short- and long-run time-periods. In short-run, this nexus is negative due to the delay in shifting the resources. It slowly occurs after which the trade liberalization-promoting policies are implemented, leading to a lag for the trade–growth relationship. Moreover, a crisis involving a decline in income can, albeit slowly, facilitate trade liberalization which, in turn, is a prerequisite to secure loans of the international financial institutions (the World Bank and IMF) (Falvey et al. 2012; Lora 1998). Another prerequisite is devaluation. The IMF-supported structural plans generally embark on devaluation (Singh 2010). It, at first, immediately worsens the trade balance, already conducted, since the imports seem more expensive in nominal value and that of

the exports do cheaper. So the higher the trade is, the lower the growth becomes in short-run. Later, the exported products, however, become more competitive in price and the imported ones do cheaper, leading to a reversal as the devaluation improves the trade balance and, in turn, the economic growth (Oskooee et al. 2016). In addition, the resources have, finally, shifted to the efficient allocation and the loans are received in long-run, accelerating the growth in this time-period. So the higher the trade is, the higher the growth becomes in long-run. This reversal, in short- and long-terms, forms a J-curve for the trade–growth nexus (Falvey et al. 2012; Greenaway and Morgan 1998; Greenaway et al. 1998, 2002; Jelassi et al. 2017). In addition to the economic growth, the openness shows relationship with other pillars of sustainability such as environment.

B. *Environmental Kuznets hypothesis* firstly, it was proposed by Grossman and Kruger in 1991 to investigate the nexus between openness and environmental pollution; they suggest an inverted U-shaped curve. The explanation is focused on the higher technological and efficiency capacity in the richer countries (Taghvaee and Parsa 2015). The difference in capacity is generated to other factors in the next hypothesis.

C. *Laffer curve of trade* it suggests that the trade–growth nexus hinges on the levels of financial development, adoption of technology, human capital, and institutional quality. As long as they are high, the nexus works positively and, vice versa, if they are low it does negatively. It suggests a positive and negative nexus in the developed and developing countries, respectively, which is interpreted as a non-linear nexus of trade–growth in the different phases of development in a country (Ikerd 2016: Zahonogo 2017). For example, the oil-exporting countries are potentially in the danger of low level of social and technological quality, as curse hypothesis argues. This hypothesis claims that these countries are concentrating on the oil industry, leading to miss the development of the other sectors. The more open their borders, the higher the oil export, encouraging focus on oil industry stronger and stronger while the other sectors become weaker and weaker (Colagiuri and Morrice 2015; Costa and Santos 2013).

D. *Pollution haven hypothesis* the allocation of foreign direct investment is another explanation for the nexus between openness and sustainability, based on the stringency of environmental regulations. The developing countries with less-stringent regulations attract relatively larger foreign investment from the developed ones with more stringent regulations, stimulating the economic growth, development, and sustainability in the former countries. However, it vastly increases their level of pollution due to the inherently pollutant character of those investments. Clearly, they are environmentally perilous, leading to the outflow from the developed countries for escape from those stringent rules through the international borders. The more open the developing economy, the larger the inflow level of pollutant foreign investment, which, in turn, discourages the sustainability in developing countries; and vice versa in the developed countries with more stringent environmental regulations (Shen et al. 2017; Sun et al. 2017; Taghvaee et al. 2017; Zhang et al. 2017). Therefore, openness has two different effects which are conflicting not only on the environment and the economy, but also on the developed countries and the developing countries.

Oil industry is a good example for the hypothesis. This activity makes the oil-exporting countries a pollution haven for the foreign investments. It paves the way for economic growth in both the contributing countries while it degrades the environmental quality in the oil-producer one, proposing different effects not only on the various sectors, i.e., environment and economy, but also on the different countries.

E. *Prebisch–Singer hypothesis* it argues that the markets of primary commodities are demonstrating a downward trend in their equilibrium price while it is upward in the manufactured commodities with the elapse of time in long-run. The primary-commodity-based economies, like oil-exporting countries, with the decreasing price trend, regarding the hypothesis, are expected to stagnate in case of engaging in trade with the manufactured-commodity-based economies, though it boosts the economy for the latter (Arezki et al. 2014; Harvey et al. 2010; Prebisch 1950; Singer 1950) The above-mentioned example of oil-exporting countries in pollution haven hypothesis works as well for this theory. Since oil is a primary commodity for production of the other manufactured ones, its exporters might fall into the trap of this theory, notwithstanding the current income of oil sale, as the more open their economy, the more serious their deficit in balance of payments, with the elapse of time.

   The sustainability of oil-exporting countries might be threatened by increasing openness and its potential damages on environmental, economic, social, and technological elements. Although the strong sustainability perspective believes that the damages are irrecoverable especially in the environment, the supporters of weak sustainability believe that they can be avoided by investing the current oil income in the infrastructural sectors to guarantee a sufficient, secure, and permanent income in the future to compensate them.

However, many researchers believe in a neutral nexus between trade and growth, rejecting any relationships between them (Ulasan 2015). They claim that it is insignificant, even if it exists, needing a fertile ground to become considerable and effective. In other words, openness merely is insufficient to establish a connection with sustainability and the breeding ground for the establishment is achievable by stable macroeconomic policies, structural policies, and institutions (Sachs and Warner 1995).

These various results and conclusions can be rooted in the limitations of the methodologies, indices, and models in the previous studies. The GDP index, for example, has many serious limitations to cover all the aspects of sustainability and even growth concept which we replace by the green GDP in an econometric methodological framework as explained below.

3 Methodology, model, and data

In this section, we explain the methodology, tests and model of our study as well as the sequence of various tests and estimations; then we elucidate how the research questions and the studied hypotheses are related to the parameters of the models.

The model of our study is based on the neoclassical growth model, endogenous growth model, and standard Solow growth model (Mankiw et al. 1992; Othman et al. 2014; Solow 1956; Talberth and Bohara 2006), as follows:

$$Y = f(L, K, O), \tag{1}$$

where Y, L, K, and O are output, labor, capital, and openness, respectively. Following Mankiw et al. (1992), Taghvaee et al. (2016), Talberth and Bohara (2006), the function is transformed into the Cobb–Douglas form as below:

$$Y_t = A_0 K_t^{\alpha} O_t^{\beta} L_t^{1-\alpha-\beta} e^{u_t}. \tag{2}$$

To be employed in the empirical researches, the corresponding log-linear form is Eq. 3:

$$Y_t = A_0 + \alpha K_t + \beta O_t + (1-\alpha-\beta) L_t + u_t, \tag{3}$$

where A_0 is the intercept; u is residuals; t is year; and α and β are the parameters to represent the elasticities, thanks to the natural logarithm form of the variables. Now following Talberth and Bohara (2006), we insert the following proxies for output, capital, labor, and openness to form an estimable regression with a restriction. We call the linear regression as Model 1-L:

$$\begin{aligned} &\mathrm{GGDP}_{it} = C + \beta_1 \mathrm{DADR}_{it} + \beta_2 \mathrm{DGFC}_{it} + \beta_3 \mathrm{OPN}_{it} + \varepsilon_{it} \\ &\beta_1 = 1 - \beta_2 - \beta_3 \end{aligned}, \quad \text{Model 1-L}$$

where GGDP is the GDP growth as a symbol for the brown growth or merely economic growth; it is the first difference of per capita GDP in logarithmic form measured in Purchasing Power Parity (PPP) in constant 2011 international dollar. DADR is the first difference of the age dependency ratio; it is the ratio of dependents—people younger than 15 or older than 64—to the working-age population—those aged 15–64 in percentage term, as a proxy for the inactive population. DGFC is the first difference of the ratio of gross fixed capital formation to GDP in constant 2011 international dollar; OPN is the first difference of the ratio of trade value to GDP. All the data are derived from World Bank database (World Bank 2016). ε is residual series; i is country; t is year; β is are the corresponding coefficients of the independent variables. In addition to the linear variables, the squared form of openness is affixed to the explanatory variables to investigate the non-linear relationship between output and openness (Talberth and Bohara 2006). We name the non-linear regression as Model 1-N:

$$\mathrm{GGDP}_{it} = C + \beta_1 \mathrm{DADR}_{it} + \beta_2 \mathrm{DGFC}_{it} + \beta_3 \mathrm{OPN}_{it} + \beta_4 \mathrm{OPN}_{it}^2 + \varepsilon_{it} \quad \text{Model 1-N}$$

Conflicting signs of β_3 and β_4 provide evidence for a non-linear nexus between openness and growth which is consistent with one the non-linear hypotheses including J-curve pattern, Laffer curve of trade, or Prebisch–Singer hypotheses which are focusing on the economic dimension of sustainability (Arezki et al. 2014; Falvey et al. 2012; Zahonogo 2017). To investigate the environmental aspect of sustainability, or rather the strong one, we employ the genuine savings instead (Othman et al. 2014; Talberth and Bohara 2006; Nasrollahi et al. 2018). We name the linear regression as Model 2-L:

$$\begin{aligned} &\mathrm{GGS}_{it} = C + \beta_1 \mathrm{DADR}_{it} + \beta_2 \mathrm{DGFC}_{it} + \beta_3 \mathrm{OPN}_{it} + \varepsilon_{it} \\ &\beta_1 = 1 - \beta_2 - \beta_3 \end{aligned}, \quad \text{Model 2-L}$$

where GGS is the genuine savings growth as a proxy for the green growth; it is the first difference of per capita genuine savings in logarithmic form measured in Purchasing

Power Parity (PPP) in constant 2011 international dollar and derived from World Bank database (World Bank 2016). The remaining symbols were described previously. Like Model 1-N, the linear form of Model 2-N is transformed into the non-linear one with inclusion of the squared form of openness (Talberth and Bohara 2006). We name the non-linear regression as Model 2-N:

$$\mathrm{GGS}_{it} = C + \beta_1 \mathrm{DADR}_{it} + \beta_2 \mathrm{DGFC}_{it} + \beta_3 \mathrm{OPN}_{it} + \beta_4 \mathrm{OPN}_{it}^2 + \varepsilon_{it}. \quad \text{Model 2-N}$$

The examination of both the green and brown economic growth paves the way for the analysis of the openness nexus with two dimensions of sustainability, the economic and the environmental ones. The difference between the two concepts is investigated with the following regression (Talberth and Bohara 2006). We name the linear regression as Model 3-L:

$$\mathrm{GAP}_{it} = C + \beta_1 \mathrm{GCO2}_{it} + \beta_2 \mathrm{OPN}_{it} + \varepsilon_{it}, \quad \text{Model 3-L}$$

where GAP is the gap between green and brown economic growth, GCO_2 is the growth of per capita carbon dioxide emissions measured in kilo-ton and derived from World Bank database, as the index of environmental pollution (World Bank 2016); and the remaining symbols are as mentioned previously. Like Models 1-N and 2-N, we attach the squared openness to investigate the non-linear relationship of openness and the gap of green and brown economic growth (Talberth and Bohara 2006). We name the non-linear regression as Model 3-N:

$$\mathrm{GAP}_{it} = C + \beta_1 \mathrm{GCO2}_{it} + \beta_2 \mathrm{OPN}_{it} + \beta_3 \mathrm{OPN}_{it}^2 + \varepsilon_{it}. \quad \text{Model 3-N}$$

Subsequent to the estimation of the models using the software of EViews 8, we delineate the non-linear ones in the coordinates system in which the openness is the horizontal axis using the software of MATLAB 9. Next to the estimated curve, the location of each country in 2012 is represented in the coordinates system to allow the comparison of the countries with each other. Furthermore, it paves the way to find the position of each country in comparison with the estimated curve which plays a key role in the trade strategies of the country.

Prior to the estimation of the above regressions, we run the preliminary tests to check the robustness of the estimated coefficients. Firstly, we put the variables into the Levin, Lin, and Chu unit root test to assure that the estimated coefficients are not spurious. The null hypothesis implies unit root, or rather the non-stationarity of the variable, being performed in two cases: (1) without intercept and trend and (2) with intercept (Levin et al. 2002). Then we employ the F-Limer statistics, for selection between pooled and panel models, being supported by null and alternative hypotheses, respectively (Tehrani et al. 2016; Saleh et al. 2014). In case of accepting the pane model, the Hausman test is based on the Chi squared statistic to decide between fixed and random effects model whose null hypothesis suppresses the former (Georgiev and Mihaylov 2015; Greene 2011; Hausman 1978). Finally, the coefficients of the models are estimated for the sample.

The study sample is ten oil-exporting countries including Algeria, Angola, Canada, Iran, Kazakhstan, Kuwait, Norway, Russia, Saudi Arabia, and Venezuela. The studied period is 1990–2012 whose results are presented in the next section.

4 Results

This section presents the results of the study tests and estimations for ten oil-exporting countries within 1990–2012. The results of the preliminary tests are provided in Tables 1, 2, and 3 for the resulted statistics of unit root test, F-Limer test, and Hausman test, respectively; and those of model estimations are in Tables 4, 5, and 6 for the

Table 1 Unit root test results

	Statistics	Prob.	Intercept and trend	Integration degree
GGDP	− 6.4044	0.00	NIT	I(0)
GGS	− 12.2360	0.00	NIT	I(0)
GGAP	− 11.9830	0.00	NIT	I(0)
DADR	− 3.0494	0.00	NIT	I(0)
DGFC	− 7.6113	0.00	I	I(0)
GCO2	11.6515	0.00	NIT	I(0)
DOPN	− 11.4521	0.00	I	I(0)
$DOPN^2$	− 13.5479	0.00	I	I(0)

NIT no trend and intercept, *I* intercept

Table 2 F-Limer statistic for the panel-pooled model dilemma

	Freedom degree	Statistics	Prob.	Accepted model
Model 1-L	F (9,201)	686	0.00	Panel
	Chi^2 (9)	740	0.00	Panel
Model 1-N	F (9,200)	673	0.00	Panel
	Chi^2 (9)	737	0.00	Panel
Model 2-L	F (9,173)	39	0.00	Panel
	Chi^2 (9)	206	0.00	Panel
Model 2-N	F (9,172)	37	0.00	Panel
	Chi^2 (9)	203	0.00	Panel
Model 3-L	F (9,157)	30	0.00	Panel
	Chi^2 (9)	171	0.00	Panel
Model 3-N	F (9,156)	30	0.00	Panel
	Chi^2 (9)	171	0.00	Panel

Table 3 Hausman test results

	Freedom degree	Statistics	Prob.	Accepted model
Model 1—linear	Chi^2 (3)	5.3355	0.14	Random effects
Model 1—non-linear	Chi^2 (4)	12.5482	0.01	Fixed effects
Model 2—linear	Chi^2 (3)	9.4336	0.02	Fixed effects
Model 2—non-linear	Chi^2 (4)	7.8668	0.09	Random effects
Model 3—linear	Chi^2 (2)	10.7182	0.00	Fixed effects
Model 3—non-linear	Chi^2 (3)	12.3287	0.00	Fixed effects

Table 4 Resulted coefficients and statistics of Model 1-L and Model 1-N

	Linear model			Non-linear model		
	Coefficient	**Statistic**	**Prob.**	**Coefficient**	**Statistic**	**Prob.**
DADR	− 0.0434	− 18.731	0.00	− 0.0058	8.5251	0.00
DGFC	− 0.0569	− 6.6926	0.00	0.0091	4.2462	0.00
OPN	0.0050	2.8535	0.00	− 0.0104	− 4.0608	0.00
OPN^2	–	–	–	0.0001	3.8431	0.00
C	12.3239	48.3415	0.00	8.6998	61.3566	0.00
Adj. R^2	0.68			0.99		
F	151.0643	0.00		2505.908	0.00	
DW.	1.82			1.77		

Table 5 Resulted coefficients and statistics of Model 2-L and Model 2-N

	Linear model			Non-linear model		
	Coefficient	**Statistic**	**Prob.**	**Coefficient**	**Statistic**	**Prob.**
DADR	− 0.4071	− 7.2634	0.00	− 0.5683	− 14.5239	0.00
DGFC	− 0.0968	1.9551	0.05	0.0364	0.3047	0.76
OPN	0.0104	0.9111	0.36	− 0.6103	− 5.3587	0.00
OPN^2	–	–	–	0.0018	2.8435	0.00
C	36.2921	9.1691	0.00	83.2785	11.4248	0.00
Adj. R^2	0.98			0.83		
F	750.5776	0.00		224.8049	0.00	
DW.	1.92			1.75		

Table 6 Resulted coefficients and statistics of Model 3-L and Model 3-N

	Linear model			Non-linear model		
	Coefficient	**Statistic**	**Prob.**	**Coefficient**	**Statistic**	**Prob.**
GCO2	3.4127	13.5616	0.00	3.1517	10.2086	0.00
OPN	0.2969	− 1.0466	0.29	0.0285	0.7446	0.45
OPN^2	–	–	–	− 0.0002	− 1.0351	0.30
C	39.3251	13.2151	0.00	34.8324	9.1175	0.00
Adj. R^2	0.99			0.99		
F	1472.340	0.00		1521.712	0.00	
DW.	1.80			1.96		

resulted coefficients and statistics of the estimating both linear and non-linear forms of the models 1, 2, and 3, respectively, which are delineated in Figs. 3, 4, and 5. However, the models variables are put into the preliminary tests which are represented in the following paragraphs.

Table 1 offers the results of the Levin, Lin, and Chu unit root test including statistics and probabilities in a couple of cases, with intercept and without intercept and trend to diagnose the integration degree. It is zero for all the variables due to the rejection of the null hypothesis of non-stationarity at the 1% statistical significance level. It is a strong

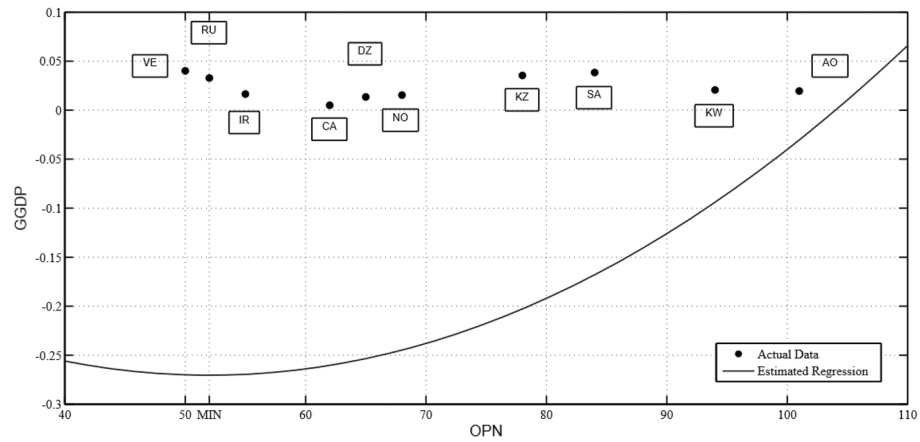

Fig. 3 GDP growth versus openness in the ten oil-exporting countries: the actual data in 2012 and the estimated curve of model 1-N

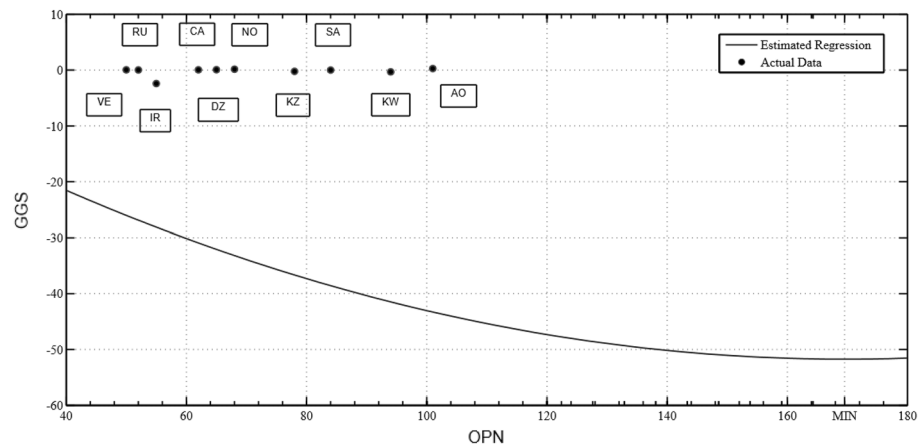

Fig. 4 Genuine saving growth versus openness in the ten oil-exporting countries: the actual data in 2012 and the estimated curve of model 2-N

evidence for easing the worry about spurious regression of the variables in either panel or pooled form.

Table 2 represents the F-Limer and Chi squared statistics to select panel or pooled model. All the statistics reject the null hypothesis of pooled model at 1% statistical significance level. It shows the distinctive characteristics of each county in the sample from economic, environment, and social perspectives, suggesting the panel model with either the fixed or random effects.

Table 3 shows the resulted statistics and probabilities of the Hausman test to determine which model follows the random effects and which follows the fixed ones. The Chi squared statistics accept the alternative hypothesis of fixed effects for Model 1-N, Model 2-L, Model 3-L, and Model 3-N, and random effects for Model 1-L and Model 2-N at 5% statistical significance. These models are regressed to estimate their coefficients and statistics.

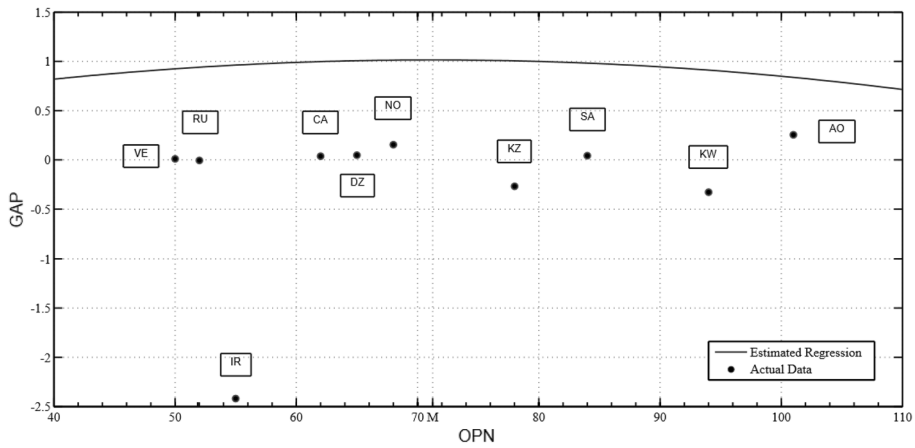

Fig. 5 Gap of brown and green growth versus openness in the ten oil-exporting countries: the actual data in 2012 and the estimated curve of model 3-N

Table 4 illustrates the coefficients and statistics of the estimation of both the linear and non-linear form of model 1 with random and fixed effects, respectively, in the panel set with GDP as the dependent variable.

The nexus between trade volume and economic sustainability (or rather the brown economic growth) is U-shaped in non-linear model and positive in the linear one. In the linear model, the GDP per capita coefficient is equal to 0.0050 which is statistically significant at 1% level. The F statistic is more than 151, which shows that the regression, as a whole, is statistically significant at 1% level and the Durbin–Watson (DW) statistic is 1.82, rejecting the autocorrelation problem, both of which support the accuracy of the model results. However, the adjusted R-squared of the model is 0.68 which is considerably less than that of the non-linear model, being equal to 0.99. The non-linear model, with more explanatory power, suggests a U-shaped connection between trade volume and economic sustainability owing to the negative and positive signs of trade volume and its squared value, respectively. This U-shaped nexus is validated with the statistical significance of F statistic of the model at 1% level, equal to 2505.908, and no autocorrelation which is shown with DW statistic, equal to 1.77. Therefore, there is ample evidence for the U-shaped nexus between openness and sustainability, which is consistent with the hypotheses implying non-linear nexus including J-curve hypothesis (based on, Falvey et al. 2012; Greenaway and Morgan 1998; Greenaway et al. 1998, 2002, Jelassi et al. 2017), Laffer trade-curve hypothesis (based on, Colagiuri and Morrice 2015; Costa and Santo 2013); and Prebisch–Singer hypothesis (based on, Arezki et al. 2014; Harvey et al. 2010; Prebisch 1950; Singer 1950).

The age dependency ratio and gross fixed capital has statistically significant coefficients at 1% level in both the models. The coefficient of the former is − 0.0434 in the linear model and − 0.0058 in the latter, showing a negative relationship between inactive population and sustainability. In addition, the gross fixed capital coefficient is − 0.0569 and 0.0091 in the linear and non-linear models, respectively, proposing conflicting relationship between growth and capital. Clearly, the positive nexus is more reliable, not only due to its consistency with the economic theories, but also due to the higher

amount of adjusted R-squared and F statistic in the non-linear model, which is delineated in the following figure.

$$\text{GGDP} = -0.0104(\text{OPN}) + 0.0001\left(\text{OPN}^2\right), \quad \text{Turning point} = 52$$

Estimated regression of model 1-N

Figure 3 displays the non-linear relationship between GDP growth and openness in the oil-exporting countries based on both the actual data in 2012 and the estimated regression of the model 1-N. On the basis of the resulted coefficients, the estimated regression of model 1-N is as above which is delineated in Fig. 3 beside the actual data in 2012. A possibly three-degree relationship is apparent in the actual data in 2012, due to the wave shape of the dots which represents the actual data. Regarding the actual data, all the countries are in the upward phase of the curve, except Venezuela which is at the end of the downward side and Russia which at the turning point, equal to 52. Although Venezuela and Russia are not located on the ascending part of the curve, they are reasonably close to it. It implies that the nexus between brown economic growth and openness is predominantly on the positive phase, notwithstanding the various amounts. Thus, the openness is currently a significantly positive contributor to the economic pillar of sustainable development. In addition, sustainable development has another pillar with which the openness relationship is estimated in the next table.

Table 5 displays the resulted statistics and coefficients of the linear and non-linear mode of model 2 with fixed and random effects, respectively, in the panel set with genuine savings as the dependent variable.

The relationship of trade volume and genuine savings (or rather the green economic growth) is U-shaped in and the non-linear model and positive in the linear one. In the linear model, the coefficient of trade volume is statistically insignificant, equal to 0.0104 while both the trade volume and its squared value are statistically significant at 1% level in the non-linear model. They, respectively, are − 6.6103 and 0.0018, proving a U-shaped relationship between trade volume and sustainability which is in harmony with the pollution haven hypothesis, accepted by Shen et al. 2017; Sun et al. 2017; Zhang et al. 2017; and Environmental Kuznets Hypothesis (Taghvaee and Parsa 2015).

The age dependency rate is statistically significant at 1% level while the gross fixed capital is insignificant at 5% level in both the models. In the linear and non-linear models, the coefficient of age dependency rate is − 0.4071 and − 0.5683, respectively, accepting a negative connection of inactive population and sustainability. Not only the economic theories are consistent with it, but also the statistics of testing the model accuracy are the further evidence.

All the statistics of the model accuracy are corroborating the above-mentioned results. The adjusted *R*-squared is 0.98 and 0.83 for the linear and non-linear models, respectively, both of which show a high explanatory power of the models. Furthermore, the statistical significance of F statistic at 1% level is another evidence for the accuracy of the model as well as the Durbin–Watson statistic which is 1.92 in the linear model and 1.75 in the non-linear one, rejecting autocorrelation of the residual series. They provide preponderance of evidence for the accuracy of the mentioned results including the U-shaped nexus between openness and sustainability which is delineated in the next figure.

$$GGS = -0.6103(OPN) + 0.0018\left(OPN^2\right), \quad \text{Turning point} = 169.5277$$

Estimated regression of model 2-N

Figure 4 illustrates the non-linear relationship of green growth and openness in the oil-exporting countries based on both the actual data in 2012 and the estimated regression of the model 2-N. With regard to the resulted coefficients, the estimated regression of model 2-N is as above which is delineated in Fig. 4 as well as the actual data in 2012. Based on the actual data, all the sample countries are on the descending portion and far from the turning point (169.5277) of the curve of openness and genuine saving growth, which is in sharp contrast with that of GDP growth. It suggests that, despite the current positive nexus between openness and brown economic growth, it is negative when it comes to the green growth. In other words, opening the economy is merely forcing the economic pillar of sustainability to drive while it is impeding the green growth. Therefore, the trading and economic infrastructure in the oil-exporting countries is solely consistent with the economic pillar of sustainability, but inconsistent with the other pillars (i.e., environmental and social). It implicitly is an evidence for a great gap between the brown and green growth in these countries.

Table 6 indicates the coefficients and statistics of linear and non-linear arrangement of model 3 with fixed effects in the panel set, using the gap between GDP and genuine savings as the dependent variable. The nexus between trade volume and the gap (between brown and green economic growth) is statistically insignificant in both the models while that of CO_2 and the gap is positive and statistically significant at 1% level in both the linear and non-linear models. It implies that openness increment is ineffective on widening of the gap; instead it is the carbon dioxide emissions which are opening the gap more and more. The coefficient is 3.4127 and 3.1517 in the linear and non-linear models, respectively. These positive and statistically significant quantities assign CO_2 a major role in diverging the brown and green growth, leading to an unsustainable development. The gap versus openness is represented in the coordinates system for more interpretation.

$$GAP = 0.0285(OPN) - 0.0002\left(OPN^2\right), \quad \text{Turning point} = 71.25$$

Estimated regression of model 3-N

Figure 5 outlines the non-linear relationship of the openness and the gap between green and brown growth in the oil-exporting countries based on both the actual data in 2012 and the estimated regression of the model 3-N. The resulted regression of model 3-N is employed to delineate the curve beside the corresponding actual data in 2012 in Fig. 5. Based on Fig. 5, the estimated curve has a shallow concavity which is another evidence for the insignificancy of openness and gap nexus which is in harmony with the results in Table 6. It is in sharp contrast with the high convexity of the curves in Figs. 3 and 4. Despite the shallow convexity and insignificancy of the nexus, the actual data shows six sample countries on the ascending side of the openness and the gap curve (preceding the turning point, equal to 71.25) and four sample countries on the descending side which is in marked contrast with Figs. 3 and 4 where the sample countries congregate only on either the ascending or the descending part, respectively. This difference claims disparity of openness insignificant nexus with the gap of brown and green growth in various countries of

the study. The more open the economy, the wider the gap in Venezuela, Russia, Canada, Algeria, and Norway, whilst the more open the economy, the narrower the gap in Kazakhstan, Saudi Arabia, Kuwait, and Angola, albeit slightly. It implies that opening the economy is diverging the three pillars of sustainability in the former group, leading to the unbalanced development, which is in sharp contrast with the latter group with a relatively more converging pillars and balanced development. However, the openness plays a limited role in the gap between various pillars of sustainability.

5 Discussion

In the oil-exporting countries, openness shows various relationships with sustainability pillars in different conditions, a non-linear nexus. Currently, the more open their economy, the lower the green growth; while it shows a direct relationship with brown growth, or rather economic growth.

Regarding the current situation, the openness is directly correlated to the economic growth (or brown growth) as the economic pillar of sustainability in the oil-exporting countries. These countries inevitably export oil in order to raise their income level, leading to have a more open economy. On the import side, openness facilitates purchasing commodities with lower expenses as the relative advantage theory claims that the reduction, or even elimination of the tariff rates and non-tariff barriers boosts the economic growth. It is advised for the oil-exporting countries too. Furthermore, they should adopt some policies to reduce the tension in their relationships with the other countries, leading to the development in trade and economy. Finally, they should open their borders, in case of pursuing the sustainability at economic growth; but it might damage the other pillars of sustainability.

The social and environmental pillars of sustainability, as the green growth, show a negative relationship with openness in the sample countries. From the environmental point-of-view, it is not only for the growth of oil industries which is an extremely polluting sector, but also due to the expansion of transportation system which is another hazardous sector for the environment as a sustainability pillar. From the social perspective as another sustainability pillar, the negative nexus is deeply rooted in their capacity in human capital, technological adoption, financial system, etc., which is low according to the resources curse hypothesis. It is compatible with the Laffer trade hypothesis. To compensate the potential dangers of resource curse and Laffer trade hypotheses, they are suggested to develop their capacity in the non-oil sectors too; and impose the environmental regulations not only in the transportation and oil sectors, but also in the other sectors of economy. It is worth adding that the negative nexus exists solely in the current level of trade share and it reveres in the higher level of openness. So, sustainability is a flimsy pretext to discourage the openness since it is a positively effective strategy in long-term, notwithstanding its potentially negative effects in short-run which makes a gap between brown and green growth.

Openness is a minor contributor to the gap of brown and green growth, as the various dimensions of sustainability, although each dimension shows a distinctive relationship with openness, possibly widening the gap of the dimensions. The length of the gap is reliant on the other major factors which can be investigated in the future

studies, such as regulation-setting framework, taxation system (especially the environmentally related taxes), technological infrastructure, etc.

In conclusion, openness motivates the sustainability as a whole. Despite its currently negative nexus with green growth, it becomes positive in the higher levels of openness. Moreover, not only its current relationship with economic growth is positive, but also it can become stronger in the higher level of openness. They are proofs for the openness acting as a catalyst for sustainability.

6 Conclusion

This study investigates the relationship between openness and sustainability in ten oil-exporting countries within 1990–2012. This is non-linear; and it depends on the level of openness which the country has.

The estimations of models display two distinctive nexuses for each kind of growth, linear and non-linear nexus; the former is positive and the latter relies on the level of openness in which the economy is. In the lower share of openness, the more open the economy is, the lower the brown growth is while they are correlated positively in the higher level of openness, passing a certain threshold. Another threshold exits for the green growth with the same nexuses in the either side. It infers that, on the basis of the level of openness, each country might show a different nexus, but clearly it is significant. However, there is an insignificant relationship between openness and the gap of brown and green growth. Instead, openness has a significant relationship with carbon dioxide emissions in that model. The results of these models' estimations are depicted in figures.

Three distinctive figures represent the estimated non-linear regressions in mathematical coordinates beside the actual data in 2012. Almost all the sample countries congregate on the right-hand side of the openness–brown growth nexus after the threshold, showing a positive relationship whilst they assemble in the left-hand side in the openness–green growth curve, implying a negative nexus. Notwithstanding the different locations of the countries in each curve, undoubtedly, all of them find a positive relationship between sustainability and openness in the higher levels of openness after outpacing a certain threshold. It suggests the oil-exporting countries to open their borders more and more to boost both the brown and green growth. Both brown and green growth shows a nexus with openness whose curves are highly convex, but the nexus of openness–gap of brown and green growth is slightly convex, confirming the insignificant relationship of openness–gap which is resulted in the model estimation.

Finally based on the model estimation, interpretations, and discussions, all the oil-exporting countries are suggested to open their economy wider and wider since the openness and sustainability find a positive nexus in the higher degrees of openness. A suggestion for future study is to investigate the nexus with more degrees as the actual data in the openness–brown growth shows a three degree one. Furthermore, the nexus of sustainability dimensions can be investigated with other socio-economic factors such as financial development.

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All the data, employed in this study, are available via contacting and requesting the corresponding author.

Competing interests
The authors declare that they have no competing interests.

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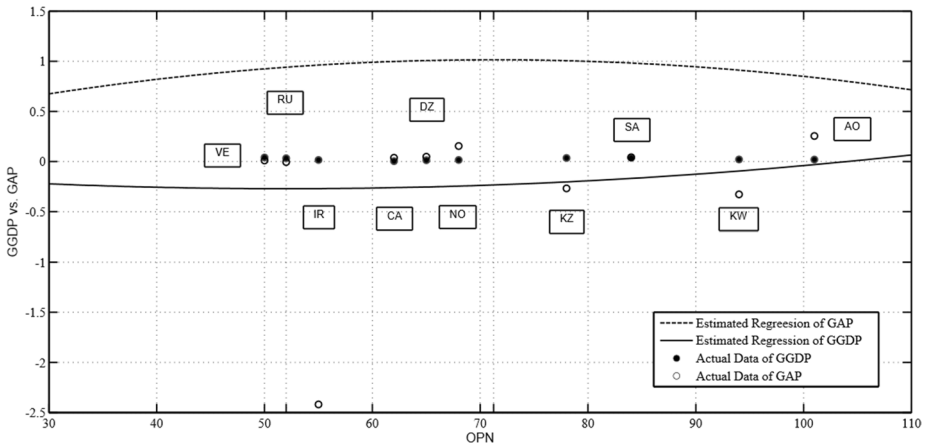
Appendices

Appendix 1: Openness versus GDP growth and the gap of brown and green growth in the ten oil-exporting countries: the actual data in 2012 and the estimated curves of model 1-N and 3-N



This merged figure provides us with a big map to make a broader comparison of each country with another in different ranges of openness and the specified thresholds. It paves the way to have more comprehensive standpoint for policy-making.

Appendix 2: Abbreviation of the sample countries

Country	Abbreviation
Algeria	DZ
Angola	AO
Canada	CA
Iran	IR
Kazakhstan	KZ
Kuwait	KW
Norway	NO
Russia	RU
Saudi Arabia	SA
Venezuela	VE

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