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RESEARCH ARTICLE

The environmental aspects of agriculture, merchandize, share, and export value-added calibrations in Turkey

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Abstract
The intricacy associated with policy design for environmental sustainability has necessitated a reconsideration of the output and environmental degradation relationship. Like many economies across the globe, the sector contributions to environmental woe are likely contingent on the respective economic performance of the sectors. From this perspective, this study examines the environmental effects of the contributions of agriculture value-added, merchandize value-added, export value-added, and share value-added over the period 1991–2019. By employing a combination of econometric techniques, the result revealed that agriculture value-added and export value-added mitigate environmental hazards, while a 1% increase in total energy utilization, merchandize value-added, and share value-added induce carbon emission by about 0.6%, 0.02%, and 0.001%. Moreover, the environmental Kuznets curve (EKC) hypothesis is validated for agriculture value-added and carbon emission nexus. However, there is a significant U-shaped relationship between carbon emission and economic contributions from the merchandize value-added, export value-added, and share value-added, thus suggesting that the EKC hypothesis is not valid. The study suggests that Turkey's agricultural sector is possibly living to the expectation of adopting and incorporating environmental sustainability practices. On the other hand, sustainable environmental policies related to other sectors of the economy are proffered in consonance with the indicated result from the study.

Keywords Value-added · Economic sectors · Carbon emission · Environmental sustainability · Turkey

Introduction

Environmental degradation becomes one of the most important subjects today due to global warming and climate change. To overcome this problem, the majority of the countries signed the Paris Agreement in which countries are required to decrease their national emissions by setting nationally determined contributions. This means that countries are encouraged to reprioritize their sustainable economic drive by promoting the economic policies that boost the income of a country while avoiding causing harm to the environment. This relation is explained by the environmental Kuznets curve (EKC) hypothesis. According to EKC, the relation between income and environmental degradation is an inverse U-shaped (Grossman and Krueger 1995). At first, as income increases, environmental degradation increases as well until a turning point is attained. After that point, environmental condition is expected to revive. To avert the adverse effect of economic development arising from energy utilization (Adedoyin et al. 2021a), the sectoral aspects of the economy in most developed countries are increasingly adopting environmentally friendly practices (Aldieri et al. 2019; Aldieri and Vinci 2020; Cop et al. 2020; Çop et al. 2020).

Previous studies extensively discussed this relation and investigated the validity of EKC by employing varying indicators and testing it for either a single country or group of countries. In this study, we will examine the aforementioned relationship for Turkey. Some previous studies examined the validity of EKC for Turkey but they provided mixed results. Gürlük and Karaer (2004), Saatçi and Dumrul (2011), Bölük and Mert (2015), Çetin and Yüksel (2018), and Çetin et al.

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(2020) supported the EKC, while Başar and Temurlenk (2007) and Omay (2013) found an N-shaped relation. Moreover, Akbostancı et al. (2009) and Malik (2021) concluded that EKC is not applicable for Turkey. Additionally, all of the aforementioned studies analyzed the income-environmental quality relationship with the aggregate level of GDP, while the current study is set out to employ the value-added components of the economy.

However, the objective of this paper is to examine EKC at disaggregated levels of GDP for Turkey from 1991 to 2019. We analyze the specific effects of agriculture value-added, merchandize value-added, export value-added, and share value-added on the CO_2 emission by controlling for the renewable and non-renewable energy utilization. Since the previous studies found a mixed result for supporting the EKC hypothesis, we believe that this difference comes from the aggregate level of GDP since each sector does not equally influence environmental degradation. In addition, each sector may have different turning points, thus resulting in an inconclusive result. For instance, Sohag et al. (2019), Moutinho et al. (2020), and Murshed et al. (2020) analyzed the sectoral EKC hypothesis for OPEC countries but they exhibited mixed results. Additionally, Moutinho et al. (2017) and Ramos et al. (2018) investigated sectoral EKC for Portugal and the former found an N-shaped association while the latter suggested both N-shaped and inverse U-shaped patterns. For our part, this study expands the EKC literature by examining the nexus between carbon emission and the contributions of agriculture value-added, merchandize value-added, export value-added, and share value-added, especially for the case of Turkey.

In the remaining parts of the study, the sections are arranged as follows. A detailed illustration of the extant study is displayed in the "Literature highlight" section (2), while the methodological approach and the description of the dataset are presented in the "Data" section (3). The results of the investigation and the conclusion are detailed in the "Findings and discussion" section (4) and "Concluding remark and policy" sections (5), respectively.

Literature highlight

Previous studies on the EKC hypothesis mainly focus on the aggregate level of GDP. The sectoral EKC is limited. Moutinho et al. (2020) examined the EKC based on the sector GDP for seven sectors from 12 OPEC countries. The study established a U-shaped EKC for the agriculture, forestry and fisheries industries, construction sector, and other economic activities. On the other hand, an inverted U-shaped relationship was found for the manufacturing and transportation sectors. Sohag et al. (2019) also analyzed the sectoral EKC for OPEC countries and concluded a positive association between manufacturing sector value-added and CO_2 emissions while a negative relationship between agriculture value-added and CO_2 emissions. But for the service sector value-added, they found a mixed result for a short- and long-term relationship. In the short-term, the service sector decreases the CO_2 emissions, while for the long-term, it contributes the CO_2 emissions. Moreover, Murshed et al. (2020) examined the EKC hypothesis first for aggregated value-added then for sub-sectors in the service industry for 12 OPEC countries. For aggregated levels, their results supported the EKC hypothesis whereas results differed for sub-sectors of the service industry.

Moutinho et al. (2017) and Ramos et al. (2018) investigated sectoral EKC for Portugal, and they also concluded a mixed result. Moutinho et al. (2017) found an N-shaped association between sectoral value-added and CO_2 emissions, whereas Ramos et al. (2018) supported both the inverted U-shaped and N-shaped association for Portugal for 11 sectors. As can be seen from the previous studies, the sectoral EKC is heterogeneous in terms of its contribution to CO_2 emissions. This creates a need for further investigation for different countries and sectors.

Unlike sectoral EKC, some previous studies (including those in Table 1) tested the EKC hypothesis including a sectoral value-added variable to measure the sectoral effect and their results are also diverse. For instance, some studies (Asumadu-Sarkodie and Owusu 2017; Liu et al. 2017; Appiah et al. 2018; Waheed et al. 2018; Ben Jebli and Ben Youssef 2019; Ngarava et al. 2019; Olanipekun et al. 2019; Qiao et al. 2019) investigated the agricultural-induced environmental degradation. Gokmenoglu and Taspinar (2018) for Pakistan, Sarkodie (2018) for 17 African countries, Agboola and Bekun (2019) for Nigeria, Qiao et al. (2019) for G20 countries, Aydoğan and Vardar (2020) for E7 countries, and Gurbuz et al. (2021) for Azerbaijan supported the EKC hypothesis; however, the causal effect of the agriculture value-added on CO_2 emissions is contrasting. Sarkodie (2018), Qiao et al. (2019), and Aydoğan and Vardar (2020) found a positive impact, while Gokmenoglu and Taspinar (2018) and Agboola and Bekun (2019) could not find any association. Moreover, Gurbuz et al. (2021) observed an inverse association.

Besides the agriculture sector, some studies focused on different sectors to examine the relationship. Alam (2015) investigated the effect of value-added in the GDP for agriculture, manufacturing, and service sectors on CO_2 emissions in South Asian countries. He observed a negative association for agriculture while positive relation for manufacturing and service sectors. Hove and Tursoy (2019) for 24 emerging economies also supported the positive relationship for industry sector value-added. Pata (2018) examined the relation for manufacturing sector value-added and found a positive association for Turkey. Even though the sectoral value-added is included in the EKC model, the results are contradicting and

Table 1 Highlight of related literature

Author	Method/Country	Period	Result
Ben Jebli and Ben Youssef (2019)	ARDL, VECM causality/Brazil	1980–2013	AGR ↔ CO2 There is cointegration. The causality between agriculture and CO_2 is bidirectional.
Asumadu-Sarkodie and Owusu (2017)	Johansen, Granger causality/Ghana	1961–2012	CO_2 → AGR. There is cointegration. The causality between agriculture and CO_2 is one-way.
Ngarava et al. (2019)	ARDL, Granger causality/South Africa	1990–2013	AGR → CO_2 There is cointegration. The causality between agriculture and CO_2 is one-way.
Waheed et al. (2018)	ARDL, FMOLS, DOLS, VECM/Pakistan	1990–2014	AGR → CO_2 There is cointegration. The causality between agriculture and CO_2 is one-way.
Liu et al. (2017)	Pedroni cointegration, FMOLS, DOLS, VECM causality/ASEAN countries	1970–2013	AGR → CO_2 There is cointegration. The causality between agriculture and CO_2 is one-way.
Olanipekun et al. (2019)	Panel PMG, MG, AMG/Central and West African countries	1996–2015	AGR ↔ CO_2 There is cointegration. The causality between agriculture and CO_2 is bidirectional.
Appiah et al. (2018)	Pedroni cointegration, DOLS, FMOLS, PMG/emerging countries	1971–2013	AGR ↔ CO_2 There is cointegration. The causality between agriculture and CO_2 is bidirectional.
Qiao et al. (2019)	Panel FMOLS, VECM causality/G20 countries	1990–2014	AGR → CO_2 There is cointegration. The causality between agriculture and CO_2 is one-way.
Khan et al. (2018)	Johansen, Toda-Yamamoto causality, FMOLS, CCR/Pakistan	1981–2015	No causal relation found between agriculture and CO_2
Çetin et al. (2020)	Structural fracture unit root tests, ARDL, Toda-Yamamoto causality test/Turkey	1968–2016	There is cointegration. In the long term, CO_2 emissions are diminished by agriculture value-added and agricultural land. The EKC holds for Turkey.
Latif et al. (2020)	Panel cointegration and Granger causality/13 developed and developing countries in Asia Pacific Region	2005–2017	AGR↔GDP In the short run, the causality between agriculture and CO_2 is bidirectional. The causality between renewable energy, population, and CO_2 emissions is one-way.
Ali et al. (2019)	Johansen cointegration, ARDL, Granger causality/Pakistan	1961–2014	In the long run, the relation between CO_2 emissions, land under cereal crops, and agriculture value-added is positive and insignificant, while in the short run, the relation between CO_2 and GDP is negative and insignificant.
Uddin (2020)	Granger causality, Panel cointegration/115 countries	1990–2016	There is no significant relation between agricultural GDP growth and CO_2 emissions for lower middle-, upper middle-, and high-income countries, whereas the relationship is significant and positive for low-income countries.
Bento and Moutinho (2016)	ARDL/Italy	1960–2011	In both the short run and long run, renewable energy consumption reduces CO_2 emissions, whereas, in the long run, international trade increases CO_2 emissions.
Antonakakis et al. (2017)	PVAR, panel effect-response function model/106 countries	1971–2001	The relation between economic growth and energy consumption is bidirectional and the effect of energy consumption on economic growth and CO_2 emission is heterogeneous.
Saidi and Hammami (2015)	GMM/58 countries	1990–2012	CO_2 emissions and energy consumption are positively related, while the effect of growth on energy consumption is positive and significant.
Safi et al. (2021).	Second- and third-generation panel cointegration/7 emerging countries	1995–2018	In both the short term and long term, imports and economic growth increase CO_2 emission, while financial instability, technological innovation, and exports significantly decrease consumption-based CO_2 emission.

Table 1 (continued)

Author	Method/Country	Period	Result
Khan et al. (2020)	Panel regression, quantile regression/22 developed and developing countries	1991–2016	The outcome of agriculture has a positive and significant effect on CO_2 emission from liquid with a 36.75% increase in environmental degradation and a negative impact on CO_2 emission in the total emissions by 19.12%.
Şimşek and Yiğit (2017)	PVAR/BRICT countries	1990–2015	The causality between GDP and urbanization, renewable energy, oil prices, and carbon emissions is one-way.
Başar and Akyol (2018)	Panel data analysis/81 countries	1995–2013	The effect of carbon emissions on economic growth is significant and positive. The rise in the use of primary energy resources in the industry due to economic development has raised the carbon emissions and hence the economic growth.
Pala (2018)	ARDL/22 developing countries	1990–2014	For the relation between economic growth and carbon emissions, the study provides mixed results for the countries in the sample.
Güllü and Yakışık (2017)	Johansen cointegration and Granger causality/MIST countries	1971–2010	The causality between economic growth and CO_2 emissions and energy consumption is one-way.
Wang and Zhang (2021)	OLS, FMOLS/182 countries	1990–2015	Trade openness reduces carbon emissions in high-income and upper middle-income countries, while rises in low-income countries. For low-middle-income countries, there is no significant relation.
Çetin and Yüksel (2018)	GMM, DOLS/Turkey	1960–2014	EKC hypothesis holds. Energy consumption and CO_2 emissions are positively related.
Apaydın and Taşdoğan (2019)	Structural VAR model/Turkey	1965–2017	The relation between economic growth and the primary energy consumption and the carbon emission is positive, and the primary energy consumption has more effect on carbon emissions than growth. Moreover, the impact of growth on primary energy consumption is positive and permanent.
Çoban and Kılınç (2015)	ADF, Johansen cointegration/Turkey	1990–2012	One-way causality exists between per capita consumption of renewable energy and per capita carbon emissions. Furthermore, the relation between per capita consumption of renewable energy and carbon emission is negative, while the relation between per capita GDP and per capita carbon emissions is positive.
Wang et al. (2020)	CS-ARDL/G7 countries	1996–2017	Economic globalization, financial development, and natural resources have a positive impact on carbon emissions, while agriculture value-added has an inverse impact.
Wang et al. (2019)	Agglomerative cluster analysis, the random forest algorithm/Eindhoven, the Netherlands	-	The effect of different categories of land use on carbon emissions is analyzed. The contribution of the retail trade and residential land use categories to carbon emissions is larger than other categories. Among the residential building category, terrace houses contribute the most.
Liu et al. (2020)	Carbon decomposition model, panel data/China	1995–2009	The effect of embedding in the global value chain (GVC) on the carbon emissions of China's exports is analyzed and concluded that GVC is one of the reasons for high carbonization in manufacturing exports.
Jiang et al. (2021)	FMOLS, DOLS, CCR/Australia	1972Q1–2014Q4	In the long run, the relation between expansionary commercial policy and CO_2 emissions is significant and positive. While contractionary commercial and monetary policies are able to diminish CO_2 emission, remittance, and fossil fuel increase.

Table 1 (continued)

Author	Method/Country	Period	Result
Lv and Bai (2020)	China	2013–2016	The carbon emission trading policy has a positive effect on a firm's environmental innovation that supports carbon reduction innovation.
Ridzuan et al. (2020)	Cointegration test, autoregressive distributed lag test/Malaysia	1978–2016	In the long run, the relation between economic growth and urbanization and CO_2 emissions is positive and significant, while the relation is also positive but insignificant for livestock. Specifically, crops, fisheries, and renewable energy significantly and inversely affect CO_2 emissions. The EKC holds.
Strapasson et al. (2020)	The EU land use futures model (EULUF)/EU-28	-	The greenhouse gas emissions can be reduced by shifting to more vegetarian diets, decreasing food waste, and rising in crop and livestock yields and land multiuse.
Xu et al. (2020)	The gross export decomposition methodology and the world input-output database/EU		CO_2 emissions embedded in value-added trade can decrease CO_2 emissions because of the repetitive passing of intermediate products over numerous borders.
Khan et al. (2020)	Augmented mean group (AMG) and common correlated effect mean group (CCEMG) methods, second-generation panel cointegration methodologies/G7 countries	1990–2017	In the long term, the relation between CO_2 emissions and trade, income, environmental innovation, and the renewable energy consumption is stable. Imports and income increase consumption-based carbon emissions, whereas exports, environmental innovation, and renewable energy consumption decrease it.
Wang et al. (2017)	A semi-parametric panel regression, STIRPAT model/China	2000–2013	EKC holds for the electricity and heat production sector, but not for the manufacturing and mining sectors, while the EKC relation holds in the nexus of urbanization and carbon emission in the manufacturing sector but not in the other sectors.
Hove and Tursoy (2019)	Improved panel GMM/24 emerging economies	2000–2017	The EKC holds for nitrous oxide emissions but not for carbon dioxide emission and fossil fuel energy consumption. Industry value-added raises carbon dioxide and nitrous oxide emissions, while it decreases fossil fuel energy consumption.
Bölük and Mert (2015)	ARDL/Turkey	1961–2010	In the long run, the relation between electricity production from renewable sources, excluding hydropower and CO_2 emissions, is inverse and significant.
Alam (2015)	Regression analysis/South Asian countries	1972–2010	The effect of agriculture value-added on CO_2 emissions is negative and significant, while the impact is positive and significant for industrial and services value-added. The EKC does not hold.

need further investigation based on the sectoral EKC model to be able to measure the accurate effect.

The previous literature extensively discussed the economic growth, energy, and environmental degradation nexus. Although energy is vital to support economic growth through production and transportation, its contribution to CO_2 emissions cannot be disregarded due to fossil fuel usage. This is especially true for Turkey since 88% of the energy supply is based on fossil fuels (OECD, 2019). This contributes extensively to the CO_2 emissions, and as a result of that, climate change has been observed in Turkey. The effect of climate change has been seen as earthquakes, false springs, floods, land degradation, hailstorms, and sea snot (Malik 2021). Previous studies for Turkey (see Acaravci and Ozturk 2010; Pata 2018) found that energy consumption increases CO_2 emissions; therefore, the energy sector in Turkey contributes to climate change.

Due to the adverse impact of the energy-intensive sectors (Adedoyin and Bekun 2020), some studies focused on the relationship between renewable energy and CO_2 emissions or the environmental aspects of alternative energy usage (Adedoyin et al. 2021a, b, c; Alola and Alola 2018; Saint Akadiri et al. 2019). For instance, Latif et al. (2020) found a causal relationship between renewable energy (RE) and population and CO_2 emissions. Bento and Moutinho (2016) emphasized that renewable energy consumption decreases carbon emissions in the short and long terms. Çoban and Kılınç (2015) suggested that the relation between per capita consumption of renewable energy and per capita carbon emissions is inversely related while the per capita GDP is positively related. Khan et al. (2020) stated that in the long run renewable energy consumption is useful in reducing consumption-based CO_2 emissions. Ridzuan et al. (2020) showed that renewable energy significantly diminished CO_2 emissions in the long term. Bölük and Mert (2015) focused on Turkey, and they highlighted the potential and the importance of renewable energy sources for CO_2 emission reduction. Çetin et al. (2020) also examined the case of Turkey as it relates to agriculture value-added and CO_2 emissions nexus arising from agricultural land utilization and other agricultural activities. Moreover, due to the sectoral differences, this study aims to examine the sectoral EKC for Turkey while controlling for energy utilization in one model and the renewable and non-renewable energy utilizations in the other models.

Data

The current study employs the dataset for the case of Turkey over the period of 1991 to 2019. Accordingly, data description with the declaration of measurement and sources are presented in Table 2. The British Petroleum, BP (British Petroleum 2020), and the World Development Indicator (WDI) of the World Bank (World Bank 2020) are the sources of the dataset.

Concerning the statistical properties (see Table 3, part A), with the exemption of merchandize value-added, export value-added, and share value-added, the series are all positively skewed. While the deviation from the mean is highest for carbon emission (CEM), the remaining series with the exemption of share value-added deviates by about 3 and 7. In addition, the correlation matrix is presented in Table 3 (part B). With the correlation matrix, there is significant evidence of a correlation between the dependent and explanatory variables. In specific, carbon emission negatively correlates with agriculture value-added and with renewable energy; this is in line with the literature. On the other hand, carbon emission exhibits a positive correlation with the remaining explanatory variables at a 1% statistically significant level.

Empirical approach

This part of the study illustrates the model description and empirical approaches from the preliminary tests and the main and diagnostic estimations.

Theory and model

The adopted theoretical framework in this study is the environmental Kuznets curve (EKC) model. The model developed by Grossman and Krueger (1995) examined the nexus between income and environmental degradation, suggesting an inverse U-shaped pattern. In the current context, it means that environmental degradation and CO_2 emissions increase as income increases until a certain turning point. And, after that point, CO_2 emissions start to fall with further rises in income due to the increased environmental consideration. Unlike the previous studies, we focus on the sectoral EKC model. Thus, rather than taking the aggregate level of GDP, we use sectoral value-added in lieu of GDP and GDP-square to examine the sectoral EKC.

In the literature, there are sparse studies that have established the environmental effect of value-added from varying sectors. In specific, a carbon emission effect has been examined for only the services and agriculture value-added (Xu et al. 2017; Agboola and Bekun 2019; Balsalobre-Lorente et al. 2019; Murshed et al. 2020; Wang et al. 2020). Consequently, this study deepened the literature by using a more precise approach. In the first part, this study examines the carbon emission effect arising from the agriculture value-added, merchandize value-added, export of goods and services value-added, and stock traded value-added for Turkey. In addition, the literature is further advanced by examining the EKC from the perspective of each of the components of the GDP as measured by the agriculture value-added, merchandize value-added, export of goods and services value-added, and stock traded value-added. Consequently, the models for

Table 2 The description of the variables

Variables	Unit of measurement	Source
Carbon emission (CEM)	Million tonnes of carbon dioxide (CO_2)	BP
Agriculture value-added (Agriculture)	Agriculture, forestry, and fishing, value-added (% of GDP)	WDI
Merchandize value-added (Merchandize)	Merchandise trade (% of GDP)	WDI
Export value-added (Export)	Exports of goods and services (% of GDP)	WDI
Share value-added (Share)	Stocks traded, total value (% of GDP)	WDI
Energy utilization (Energy)	Total oil consumption (million tonnes)	BP
Non-renewable energy (Nrenewable)	Agricultural land area of other crop products (measured in thousand hectares)	BP and WDI
Renewable energy (Renewable)	Agricultural land area of crop products (measured in thousand hectares)	BP and WDI

Table 3 Statistical properties of the variables

(A) Summary statistics

Statistics	CEM	Agriculture	Merchandize	Export	Share	Energy	Nrenewable	Renewable
Mean	247.779	9.995	37.934	21.96	33.789	33.206	33.206	13.622
Median	224.823	9.026	38.791	22.243	36.207	31.085	31.085	13.24
Maximum	397.108	16.855	52.936	31.614	60.799	49.258	49.258	19.05
Minimum	139.626	5.818	23.09	13.674	5.267	22.35	22.35	9.46
Std. Dev.	80.412	3.485	7.934	3.887	13.932	7.109	7.109	3.098
Skewness	0.397	0.67	− 0.282	− 0.065	− 0.439	1.098	1.098	0.445
Kurtosis	1.947	2.065	2.496	4.071	2.639	3.343	3.343	1.949
Jarque-Bera	2.101	3.355	0.69	1.407	1.09	5.971	5.971	2.292
Probability	0.35	0.187	0.708	0.495	0.58	0.051	0.051	0.318
(B) Correlation evidence								
Variables	CEM	Agriculture	Merchandize	Export	Share	Energy	Nrenewable	Renewable
CEM	1							
Agriculture	− 0.873[a]	1						
Merchandize	0.863[a]	− 0.756[a]	1					
Export	0.662[a]	− 0.615[a]	0.842[a]	1				
Share	0.678[a]	− 0.763[a]	0.666[a]	0.565[a]	1			
Energy	0.912[a]	− 0.729[a]	0.765[a]	0.685[a]	0.553[a]	1		
Nrenewable	0.912[a]	− 0.729[a]	0.765[a]	0.685[a]	0.553[a]	1	1	
Renewable	− 0.646[a]	0.832[a]	− 0.650[a]	− 0.418[b]	− 0.7623	− 0.386[b]	− 0.386[b]	1

Note: The statistical significance levels at 1% and 5% are, respectively, represented as [a] and [b]

the first aforementioned approach are presented as:

$$\text{CEM} = f\ (\text{Agriculture}, \text{Merchandize}, \text{Export}, \text{Share}, \text{Energy}) \quad (1)$$

As disclosed above, the models describing the carbon effect from each of the agriculture value-added, merchandize value-added, export of goods and services value-added, and stock traded value-added are respectively presented as:

$$\text{CEM} = f\ (\text{Agriculture}, \text{AgricultureSq}, \text{Nrenewable}, \text{Renewable}) \quad (2a)$$

$$\text{CEM} = f\ (\text{Merchandize}, \text{MerchandizeSq}, \text{Nrenewable}, \text{Renewable}) \quad (2b)$$

$$\text{CEM} = f\ (\text{Export}, \text{ExportSq}, \text{Nrenewable}, \text{Renewable}) \quad (2c)$$

$$\text{CEM} = f\ (\text{Share}, \text{ShareSq}, \text{Nrenewable}, \text{Renewable}) \quad (2d)$$

Cointegration estimations

Investigating the cointegration evidence in the above models involves a handful of technical steps. In the first stage, the stationarity of the variables is investigated. In this case, the variables are all stationary after the first difference[1], thus paving way for the implementation of the second step. Then, we proceed to offer evidence of cointegration in the model by employing the information maximum likelihood approach of Johansen (1988, 1995). As indicated in Table 4, the result illustrates that there are at most three significant existence of cointegration in the employed model. Specifically, for Eq. 1, there is evidence of a long-run relationship among the variables.

Thus, the significant evidence of cointegration (see Table 4), we proceed to employ the fully modified ordinary least square (FMOLS) and canonical cointegration regression (CCR) (see Phillips and Hansen 1990; Park 1992; Saikkonen 1992; Stock and Watson 1993). By using a logarithmic transformation of the variables (except for the agriculture value-added, merchandize value-added, export value-added, and share value-added since they are expressed in percentages), the ordinary least square (OLS) expression for Eq. 1 is provided as:

$$\text{CEM}_t = \beta_0 + \beta_1 \text{Agriculture}_t + \beta_2 \text{Merchandize}_t + \beta_3 \text{Export}_t + \beta_4 \text{Share}_t + \beta_5 \text{Energy}_t + \varepsilon_t \quad (3)$$

where ε_t is the error term at t = 1991, 1992, …, 2019, β_0 is the intercept, and β_1 to β_5 are the respective coefficient quantifying the magnitude of nexus between CEM and the explanatory variables. In specific, Phillips and Hansen

[1] The stationarity result is available upon request.

Table 4 Cointegration evidence for Eq. (1)

Unrestricted cointegration rank test (trace)				
Hypothesized no. of CE(s)	Eigenvalue	Trace statistic	0.05 critical value	Prob.**
None [a]	0.950	204.933	95.754	0.000
At most 1[a]	0.907	126.900	69.819	0.000
At most 2 [a]	0.702	65.138	47.856	0.001
At most 3 [b]	0.563	33.689	29.797	0.017
At most 4	0.357	12.151	15.495	0.150
At most 5	0.025	0.661	3.841	0.416
Unrestricted cointegration rank test (maximum eigenvalue)				
Hypothesized no. of CE(s)	Eigenvalue	Max-Eigen statistic	0.05 critical value	Prob.**
None [a]	0.950	78.033	40.078	0.000
At most 1 [a]	0.907	61.762	33.877	0.000
At most 2 [b]	0.702	31.449	27.584	0.015
At most 3 [b]	0.563	21.537	21.132	0.044
At most 4	0.357	11.490	14.265	0.131
At most 5	0.025	0.661	3.841	0.416

Note: CE is the cointegrating equation and [a] and [b] indicate the level of significance at 1% and 5%. MacKinnon-Haug-Michelis (1999) p values

(1990) estimate the FMOLS coefficient for Eq. (3) such that:

$$\widehat{\beta}_{FMOLS} = \left\{ \sum \sum_{t=1}^{T} \left(xt - \overline{x} \right) \left(xt - \overline{x} \right) \right\}^{-1} * \left\{ \sum \sum_{t=1}^{T} \left(xt - \overline{x} \right) \left(\overline{GDP} - T \Delta \varepsilon \mu \right) \right\} \quad (4)$$

On the contrary, Park's (1992) approach[2] employs the least squares of the stationary transformed series to overcome common challenges potentially associated with cointegrating equations.

In the second part of the study, the long-run (cointegration) evidence is also investigated. Concerning the models (2a), (2b), (2c), and (2d), the aforementioned FMOLS and CCR are similarly employed. The essence of this investigation is to reveal the validity of the EKC hypothesis from the perspectives of each of the components of value-added of the GDP. Indicatively, the results are illustrated in Table 4.

Robustness and diagnostic

In order to offer a convincing estimation, the autoregressive distributed lag (ARDL) of Pesaran et al. (2001) provides long-run and short-run inferences. In addition, the speed of adjustment of disequilibrium along with relevant diagnostic tests is presented.

[2] Detail is not provided for space constraint. For further information, please see Park (1992).

Findings and discussion

Long-run results

As revealed in the long-run estimates (see Table 5), there is significant evidence that agriculture value-added mitigates carbon emission for both FMOLS and CCR estimators. The meaning is that contributions from agriculture toward the economic measure (e.g., the GDP) are not detrimental to Turkey's environmental quality. In a similar observation, Wang et al. (2020) revealed the existence of an inverse relationship between agriculture value-added and carbon dioxide emission for the panel of G7 countries. Moreover, our study revealed the validity of the EKC hypothesis from the perspective of agriculture value-added (see Table 5). This implies that the desirable negative impact between agriculture value-added and carbon emission is only possible when the contribution from agriculture to the economy attains a specific threshold. Thus, agriculture value-added compounds the environmental woe such that the undesirable effect is soon overturned after the share of agriculture value-added in the GDP is increased to a certain threshold. Moreover, the effects of renewable energy utilization and non-renewable energy utilization on environmental quality are expectedly negative and positive, respectively. Our results of renewable energy utilization-environmental quality nexus and conventional energy utilization and environmental quality nexus are supported by existing studies. While Adedoyin et al. (2021b) and Adedoyin et al. (2021c) both support the evidence of the role of alternative and conventional energy utilization in

Table 5 The long- run estimates

A: CEM = *f* (Agriculture, Merchandize, Export, Share, Oil)

	Agriculture	Merchandize	Export	Share	Energy	Intercept		
FMOLS	− 0.037[a]	0.022[a]	− 0.027[a]	0.001	0.617[a]	3.418[a]		
CCR	− 0.035[a]	0.021[a]	− 0.028[a]	0.002	0.648[a]	3.296[a]		
B: Sector analysis[a] (illustrates the effect of the growth in sectoral value-added alongside the effect of renewable and non-renewable energy use)								
	Model 1		Model 2		Model 3		Model 4	
	FMOLS	CCR	FMOLS	CCR	FMOLS	CCR	FMOLS	CCR
Nrenewable	0.552[a]	0.486[a]	0.903[a]	0.898[a]	1.137[a]	1.137[a]	1.292[a]	1.286[a]
Renewable	− 0.613[a]	− 0.563[a]	− 0.713[a]	− 0.719[a]	− 0.779[a]	− 0.772[a]	− 0.776[a]	− 0.780[a]
Agriculture	0.061[a]	0.047						
AgricultureSq	− 0.002	− 0.001						
Merchandize			− 0.054[a]	− 0.053[a]				
MerchandizeSq			0.001[a]	0.001[a]				
Export					− 0.088[b]	− 0.080[c]		
ExportSq					0.002[b]	0.002[c]		
Share							− 0.014[b]	− 0.013[b]
ShareSq							0.002[b]	0.001[c]

Note: The [a] , [b] , and [c] are the 1%, 5%, and 10% statistical significance level. The FMOLS and CCR are, respectively, the fully modified ordinary least square and canonical cointegration regression

aSector analysis illustrates the effect of the growth in sectoral value-added alongside the effect of renewable and non-renewable energy use

environmental quality, Adedoyin et al. (2020) affirms the desirable environmental effect of agriculture value-added.

Similarly, while the investigation revealed that export value-added contributes to the reduction of carbon emission, the impacts of merchandize value-added and share value-added are both leading to the increase of carbon emission in the country. From the result of the FMOLS and CCR approaches, further investigation revealed that the EKC hypothesis is not valid from the perspectives of merchandize value-added, export value-added, and share value-added. The implication is that the contributions from merchandize, export of goods and services, and stock of shares in the country's economy (GDP) initially reduce the effect of carbon emission, thus improving environmental quality. However, the effect from these components (merchandize, export, and share) will soon begin to cause more harm to the environment by inducing the emission of carbon dioxide when the respective components of the GDP attain a certain threshold. In essence, the study implies that there is significant evidence of a U-shaped relation between carbon emission and the merchandize, export, and share value-added in Turkey. In the literature, Murshed et al. (2020) affirm that EKC is only valid for the construction services but EKC does not hold for the restaurant, tourism, and transportation services in the panel of 12 OPEC. Meanwhile, Xu et al. (2017) revealed that more carbon emission is embedded in Chinese export than in the country's imports.

Table 6: Robustness and diagnostics tests

Robustness	Long-run	Short-run
Agriculture	− 0.17	− 0.056
Merchandize	1.086[a]	0.259[a]
Export	− 1.040[b]	− 0.341[a]
Share	0.122	0.040[c]
Energy	0.771[a]	0.252[a]
Adjustment parameters		− 0.327[a]
Diagnostic		
Normality: Jarque-Bera (*p value*) = 0.244 (*0.885*)		
Heteroskedasticity: F statistic (*p value*) = 0.792 (0.603)		
Ramsey's regression specification error test (RESET): F statistic (p value) = 0.017 (0.898)		

Note: The a, b, and c are the 1%, 5%, and 10% statistical significance level

Additional results

In the first part of Table 6, the long-run and short-run estimates offer robustness evidence to the examined model (1). Similar to the results of the FMOLS and CCR illustrated above, the ARDL approach further supports that agriculture value-added mitigates carbon emission, although the impact is not statistically significant. Except for the export value-added, there is statistical evidence that total energy consumption and

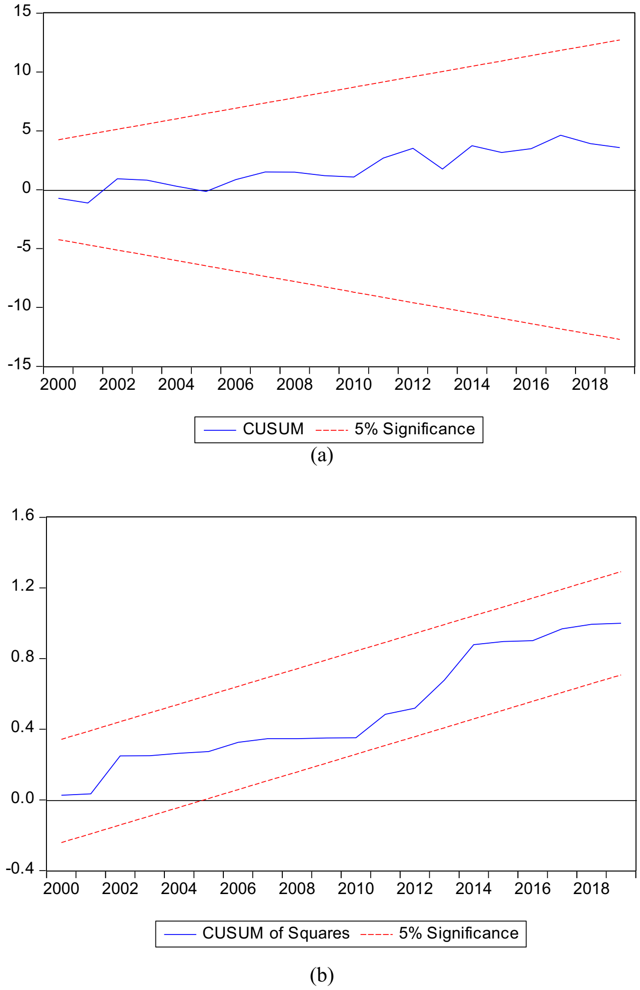

Figure 1 The model stability by CUSUM (**a**) and CUSUM of squares (**b**)

merchandize and share value-added are not environmentally friendly, thus affirming the aforementioned observation.

In the diagnostic approach, the investigation employed the Ramsey (1969) test to examine any evidence of specification error. Generally, Ramsey (1969) test for specification errors that possibly arises from (i) omitted variables, (ii) incorrect functional form, and (iii) correlation between the explanatory and error term. In addition, Figure 1 demonstrates the stability of the model in question (Eq. 1) through the desirable observation from the cumulative sum (CUSUM) and cumulative sum of squares.

Concluding remark and policy

By contributing to the EKC literature, the current study examined the nexus between carbon emission and the value-added contributions to the economy via the value-added from agriculture, merchandize, export, and share. In specific, the current study explored the case of Turkey for 1991–2019 by using the FMOLS, CCR, and ARDL estimators. Therefore, the investigation found that agriculture value-added mitigates carbon dioxide emission. In addition, the study found that the EKC hypothesis is valid from the perspective of agriculture value-added through the FMOLS and CCR estimators. Furthermore, the contributions of merchandize and share to the economy induce CO_2 emission, while the export of goods and services contribution to the economy is environmentally desirable. Moreover, the EKC hypothesis is not valid from the perspectives of merchandize, export, and share components of the economy (GDP). Thus, the relationship between carbon emission and each of merchandize, export, and share value-added is of a U-shaped pattern.

The significance of this study is that it offers policy directives to the government and the stakeholders in the agricultural sector, trade, and service industries. In the aspect of the agricultural sector, the sustainable approach should be expanded in order to avoid the reversal of the current trend of environmental sustainability in the sector. Moreover, a review of the activities leading to the contributions by the merchandize and share value-added is essential. For instance, the policy instrument might be to jettison the traditional or business-as-usual approaches, especially those that are not environmentally friendly. In achieving this, a tax policy that encourages low-carbon energy utilization in the service sectors could be a proven and effective instrument. With respect to study opportunities in the future, the value-added from other aspects of the economy (other than agriculture, share, export, and manufacturing) could be explored along the path of environmental sustainability drive. We consider this aspect as a likely weakness or gap in the current study that should be of interest to policymakers.

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Authors' contributions Andrew Alola: Writing, original draft; formal analysis.
Tugba BAS: Conceptualization, formal analysis.
Funda KARA: Investigation, methodology.

Declarations

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