The Impact of Active Rigs on Agricultural Green Total Factor Productivity in the Organization of the Petroleum Exporting Countries

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ABSTRACT

Background: This paper investigates the impact of active oil rigs (ARIGS) on agricultural green total factor productivity (AGTFP) in 12 organization of the petroleum exporting countries (OPEC) during the period from 1998 to 2019. Although ARIGS play a prominent role in OPEC economies, their ecological implications for agricultural productivity have received less attention.

Methods: We estimate a fixed-effects panel data model to explore the association between ARIGS, Oil Production (OPROD), GDP per capita, Population (POP) and AGTFP. The analysis includes control variables like methane (CH_4), nitrous oxide (N_2O) and the balance of payments in current accounts (CAB). OPROD is tested in a mediation analysis, with GDP and POP as moderators, including interaction terms.

Result: The findings show that AGTFP is negatively affected by ARIGS, a relationship mediated by OPROD. GDP alleviates the adverse effects of ARIGS and POP amplifies them. Such results highlight the need for policies to balance oil extraction and agricultural sustainability. Cited as an expected side effect of ARIGS, this underscores the need for OPEC nations to invest sufficiently in cleaner technologies and implement environmental regulations. Future studies should consider disaggregated data, as well as governance and institutional factors, to better understand the ARIGS-AGTFP association.

Key words: Active rigs, Agricultural green total factor productivity, Moderating mediation model, Oil production, Organization of the petroleum exporting countries.

INTRODUCTION

This research covers the organization of the petroleum exporting countries (OPEC), as oil production (OPROD) is a crucial element in productive national economic structures, measured by active rigs (ARIGS). These economies are highly dependent on petroleum extraction for revenue, export receipts and economic growth. Yet the environmental impacts of this reliance are growing more profound, especially as they relate to sustainability in agriculture, according to (Alsalman *et al*., 2023). The extraction of oil adds to GDP but also generates negative externalities that affect Agricultural green total factor productivity (AGTFP), such as soil degradation, water pollution and greenhouse gas emissions (Razek *et al.,* 2025). These environmental impacts are compounded by the broader effects of climate change, such as erratic rainfall, droughts and rising temperatures, which further threaten agricultural output. Dependence on oil can divert focus and energy away from developing agriculture-based practices (Chukwuneke *et al*., 2025). As such, the economic incentive of crude oil extraction needs to be weighed against its environmental impacts, especially in areas where agriculture is central to the rural economy and food security (Montant, 2025).

However, some studies articulate the general environmental effects of oil production in the literature; empirical research focusing on the impact of ARIGS on AGTFP through OPEC is scarce. There is little studies for the mediation and moderation roles of GDP per capita and population density (POP) in this relationship (Iqbal *et al.,* 2025). This study addresses these gaps by providing an empirical analysis of the direct and indirect impacts of ARIGS on AGTFP, with a focus on their role in improving agricultural sustainability towards OPEC.

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Literature review and hypotheses

The relationship between oil industry activity and agricultural sustainability in OPEC is limiting and represents a substantial research problem. In this study, ARIGS represents the extent of oil exploration and AGTFP considers not only output growth but also environment restrictions. AGTFP is an important statistical indicator for evaluating sustainable agricultural development (Shanmugan and Prakash, 2018). The association between activity in the oil industry as indicated by ARIGS and AGTFP for OPEC is not straightforward. Although these advanced reservoir intervention gas wells ARIGS enhance OPROD potential (Ansari, 2017). Industrial and price dynamics that block investment spillovers and therefore price stabilization, indirectly affect AGTFP (Zhou and Zhang, 2024). These dynamics are a function of the OPEC institutional role.

The Concepts of the resource curse and environmental sustainability among others are part of the theoretical framework (Omokpariola *et al*., 2025). However, from an environmental sustainability point of view oil recovery brings land degradation retrieving massive costs with ecosystem stress (Li *et al.,* 2023). High rig activity levels may negatively affect AGTFP, whereas oil revenues impact GDP positively. Recent studies examine the correlation between climate policy and the oil-agriculture nexus and find a 6.5% reduction in oil and gas investments while land tenure security has a positive effect AGTFP (Séogo and Zahonogo, 2023). The use of entropy in the green productivity assessment for China suggests a negative relationship between industrial efficiency and pollution through oil regions, which affected investor behavior to tilt their future investments towards AGTFP and sustainability (Wang *et al.,* 2024). There is an empirical gap between developed, developing and other countries. In advanced economies, regrowth of environmental standards, cleaner technologies and higher adaptive capacity attenuate degradation effects on any agriculture from rig expansion and climate induced shocks. Limited investment in sustainable agricultural practices, governance issues surrounding land and climate proclivity to increased damage results in extractive action having a net negative influence on agricultural productivity and environmental degradation (Yu and Deng, 2021) within developing nations where there are less fortified institutions than their developed counterparts. Globally, however, the relationships between ARIGS and AGTFP are determined by the exposure to climate factors, economic structure, GDP and institutional quality (Kumar and Upadhyay, 2019). Information in OPEC about the dual threats of oil dependence and climate risk about how ARIGS affect AGTFP are sorely lacking. This study addresses this gap.

Conceptual framework

The conceptual framework (Fig 1) illustrates the multifaceted impact of ARIGS on AGTFP, emphasizing both direct and indirect effects.

The direct impact of the ARIGS on AGTFP

The AGTFP in OPEC and ARIGS. An Increase in the significant level of rig activity, along with a price rise, gives a green light for more contribution to CH_4 emission and leads to ground process deterioration. This decreases the AGTFP, especially in regions where these trade-offs are not neutralized by digital innovation (Xiong *et al.,* 2023). Hypothesis 1: The direct effect of ARIGS on AGTFP is negative and significant in OPEC.

The mediating effect of OPROD

The effect of ARIGS on AGTFP significantly depends on OPEC OPROD, significantly evident imposes a great influence on regional agricultural production. OPROD decisions are determined by global demand and non-OPEC supply. OPEC's production policy varies with differences in technological advancement and market stability, which affect the economy's performance (Cui *et al*., 2025). This role connects the energy industry to AGTFP and ecosystem management, in line with Hypothesis 2, in which OPROD suggests mediating effects.

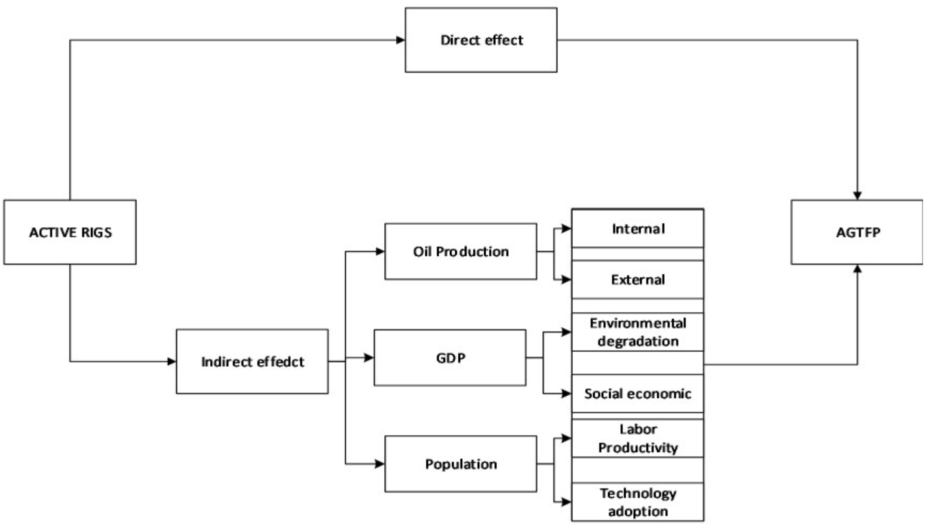

Fig 1: Conceptual framework.

The moderating role of GDP and POP

The roles of GDP growth and population are explored among OPEC that depend on fossil fuels. This potentially poses environmental and economic limitations (Montant, 2025). while GDP revenue also impacts the direction of development. As a result, it exacerbates ecological problems without making serious investments in greener capital. This is consistent with Hypothesis 3, as both POP and GDP moderate the effect of ARIGS on AGTFP.

MATERIAL AND METHODS

Data source and study area

This study utilizes data from two primary sources. The data were mainly collected in 2025 from the World Bank and OPEC databases (Table 1) at the Center of Research in the College of Management Science and Engineering, China Three Gorges University. All data were processed and analyzed using STATA version 17.0 and R version 4.5.2 to examine the impact of ARIGS on AGTFP in 12 existing OPEC countries: Algeria, Congo (Brazzaville), Equatorial Guinea, Gabon, Iran, Iraq, Kuwait, Libya, Nigeria, Saudi Arabia, UAE and Venezuela, based on panel studies over the period 1998-2019. The selection of these countries was based on their favorable policies regarding oil and food. This study focuses on oil-dependent economies, investigating how their resource-extraction infrastructure affects the sustainable use of agricultural land, especially amid digitalization and the shift away from reliance on a single industry.

Econometric models

We apply a fixed-effects panel-data model with moderating mediation to account for unobserved country-specific heterogeneity and identify country-level changes over time. This helps clarify the effect of AGTFP change on ARIGS. This paper examines the association between ARIGS, OPROD and GDP by using Baron and Kenny's (Apergis and Ozturk, 2015). Mediation analysis. The econometric models are as follows:

$$AGTFP_{it} = \beta_0 + \beta_1 ARIGS_{it} + \beta_i X_{it} + \lambda_i + \varepsilon_{it} \quad ...(1)$$

Where:

$AGTFP^{Pit}$ = Agricultural total factor productivity for country i at time t.

$ARIGS_{it}$ = ARIGS in country i at time t is a vector.

X_{it} = control variables.

ε_{it} = Random disturbance term.

β_0 = Model intercept term.

β_1= Coefficient of the ARIGS due to the basic. explanatory variables.

Finally, the moderate mediation of the long-term and the mediation by ARIGS, OPROD and GDP. The models become as:

$$AGTFP_{it} = \beta_0 + \beta_1 ARIGS_{it} + \beta_2 Control_{it} + \lambda_i + \varepsilon_{it} \quad ...(2)$$

$$OPROD_{it} = \propto_0 + \propto_1 ARIGS_{it} + \propto_2 GDP_{it} + \propto_3 ARIGS_{it} \times GDP_{it} + Control_{it} + \lambda_i + \varepsilon_{it} \quad ...(3)$$

$$AGTFP = \varphi_0 + \varphi_1 ARIGS_{it} + \varphi_2 GDP_{it} + \varphi_3 ARIGS_{it} \times GDP_{it} + \varphi_4 OPROD_{it} + \varphi_5 POP_{it} + \varphi_6 OPROD_{it} \times POP_{it} + \varphi 7\ Control_{it} + \lambda_i + \varepsilon_{it} \quad ...(4)$$

Where:

GDP_{it} = At time t for country i.

$ARIGS_{it} \times GDP_{it}$ = Indicates the interaction relationship between the ARIGS and GDP: Estimate at time t for country i.

$OPROD_{it}$ = At time t for country i;

POP_{it} = Population at time t for country i;

$\varphi_6 OPROD_{it} \times POP_{it}$ = Interaction relationship between the OPROD and POP at time t for country i.

$\propto_0$ and φ_0 = denotes the model intercept term.

$\propto_1$ to $\propto_3$ and φ_1 to φ_6 = Coefficient of variables.

In the second equation, we regressed AGTFP on ARIGS along with control variables and the direct effect of ARIGS on AGTFP. The third equation includes OPROD and its interaction (ARIGS. GDP) and taking OPROD as a mediator variable between ARIGS and AGTFP, over the score of independent-valued GDP variables for the moderate relationship between effect estimates from the two models on the eastern and western sides. The fourth equation builds on this by adding a term for POP and its constructive interaction with the production coefficient, OPROD * POP.

Construction of the AGTFP index

The entropy method provides a systematic process for weighing; it can be used as an index of the complexity and diversity among different countries in an inclusion-level comprehensive index for some years, directly measured from the AGTFP.

Step 1: Normalization of the decision matrix

$$P_{ij} = \frac{X_{ij}}{\sum_{i=1}^{m} X_{ij}} \quad ...(5)$$

Step 2: Computation of the entropy measure of project outcomes using this equation:

$$E_j = K \sum_{i=1}^{m} P_{ij} \ln P_{ij} \quad ...(6)$$

In which:

$$K = 1/\ln(m) \quad ...(7)$$

Step 3: Defining the objective weight based on the entropy concept.

$$D_j = 1 - E_j \quad ...(8)$$

$$W_j = \frac{1 - E_j}{\sum_{i=1}^{m} (1 - E_j)} \quad ...(9)$$

Where,
m = Number of alternatives for the years of evaluation.
P_{ij} = Standardization value.
x_{ij} = Actual value of evaluation index.
K = Entropy constant.
E_j = Entropy.
D_j = Diversity.
W_j = Signifies the objective weight.

Step 4: AGTFP Formula, Output/input efficiency ratio:

$$AGTFP_i = \frac{\sum_{i=1}^{m} \text{Output}}{\sum_{i=1}^{m} \text{Input}} \quad \text{...(10)}$$

Variance Inflation Factor (VIF) Formula:

To compute the VIF of a given independent variable is calculated using the following formula:

$$VIF_j = \frac{1}{1 - R_j^2} \quad \text{...(11)}$$

Where:
VIF_j = Variance inflation factor for the j^{th} variable.
R_j^2 = The coefficient of determination (R-squared) obtained when the j^{th} variable is regressed on all other variables.

Table 2 presents the AGTFP indicators, including inputs and outputs. It classifies AGTFP indicators by their description and measurement, characterizing both agricultural performance and environmental achievement. The inputs are: Agricultural area, freshwater withdrawal, labour and use of fertilizer; and the outputs are the food production index and CO_2 emission, according to (Lu *et al*., 2024). These indicators are not only often used in TFP measurement, but also measure efficiency with non-zero slack.

RESULTS AND DISCUSSIONS

Descriptive statistics in Table 3

The average value of AGTFP is 0.0835, with a range from 6.93e-06 to 0.229, indicating a moderate spread in efficiency. The mean ARIGS is 39.87, with extraction intensities ranging from 0 to 221. The average population is 32.67 million (range: 0.57-222.2 million), showing substantial demographic heterogeneity. GDP ranges from negative to positive values (-50.34 to 110.5). Financial volatility ranges from 13,983 to 173,664. OPROD (2,310-10,591) and Reserves (average = 87,616; maximum = 303,000) also vary, as CH_4

Table 1: Variables used in the study.

Type	Variables	Notation	Definition	Data sources
Independent variables	Active rigs	ARIGS	Active rig is a drilling rig engage in oil or Gas Wells drilling operations.	OPEC[1]
Dependent variables	Agricultural total factor productivity	AGTFP	Economic measures that assess efficiency by evaluating output increase without additional resource usage, of labor, capital, or land, indicates improved productivity and better utilization of production factors.	World bank[2]
Mediation variables	Oil Production	OPROD	Processing and transporting crude oil. API Gravity.	OPEC
Moderation variable	GDP	GDP	GDP curent US$	OPEC
	Population	POP	The total population is based on the de facto definition of population, which counts all residents regardless of legal status.	OPEC
Control variables	Current account balance	CAB	A combination of factors, including global oil markets, local production, transportation costs, taxes and government regulations, influences oil prices.	OPEC
	Methane	CH_4	CH_4 methane, a colourless, odourless and flammable gas.	World bank
	Oil Reserve	OR	The estimated quantity of oil that can be extracted with current technology.	
	Nitrous oxide	N_2O	Greenhouse gases are more effective at trapping heat than CO_2. Released in far lesser amounts than CO_2, N_2O's weaknesses are its long life in the atmosphere.	

[1]Organization of the petroleum exporting countries | (https://publications.opec.org/).
[2]World Development Indicators | DataBank (worldbank.org).

and N_2O signal environmental stress of sustainable agriculture.

Benchmark result

The positive effect of ARIGS on AGTFP is particularly notable when it interacts with GDP (2.816) in Model 3, as illustrated in Table 4. That means that all industrial activities that were encouraged by rigs in rich countries can improve agriculture productivity, which echoes the results of previous literature showing that technology transfer and better economic situations boost green agricultural outcomes, as stated by Ansari, (2017). But the negative impact of greenhouse gases also suggests that these benefits are not environmentally neutral. Policy-wise, this implies that high-income OPEC should encourage more drilling, manage methane emissions and reinvest oil revenues in climate-smart agriculture, land restoration and sustainable irrigation (Séogo and Zahonogo, 2023). The negative impacts of OPROD and AGTFP here indicate that energy production will provide environmental benefits, but its costs

Table 2: The indicators of AGTFP.

Indicator category	Indicator name	Indicator unit
Input indicators	Agricultural land	(% of land area)
	Annual freshwater withdrawals, agriculture	(% of total freshwater withdrawal)
	Labor force	(%) modelled ILO estimate)
	Fertilizer consumption	(kilograms per hectare of arable land)
Output indicators	Food production index	(2014-2016 = 100)
	Carbon dioxide (CO_2)	Mt CO_2e

Table 3: Descriptive statistics.

Variable	Obs	Mean	Std. dev	Min	Max
AGTFP	312	0.0835	0.0771	6.93e-06	0.229
ARIGS	312	39.87	43.85	0	221
POP	312	32.67	47.33	0.567	222.2
GDP	312	3.868	12.86	-50.34	110.5
CAB	312	13,983	28,017	-52,640	173,664
OPROD	312	2,310	2,377	54.88	10,591
OR	312	87,616	90,056	555	303,806
CH_4	312	0.0243	0.0293	0.000100	0.112
N_2O	312	1.205	1.550	0.00880	6.217

Note: Obs: Observation; Std. Dev: Standard deviation; Min: Minimum; Max: Maximum, Source: Authors.

Table 4: Benchmark result.

Variables	(1) Model1	(2) Model2	(3) Model3
ARIGS	0.092** (0.036)	-0.282*** (0.088)	-0.163* (0.090)
GDP		-0.108** (0.048)	-0.123** (0.048)
c.ARIGS#c.GDP		2.816*** (0.684)	2.289*** (0.712)
OPROD			-0.498*** (0.102)
POP			-0.295** (0.114)
c.OPROD#c.POP			2.288* (1.210)
OR	-0.170*** (0.037)	-0.061 (0.038)	-0.174*** (0.038)
N_2O	-0.013*** (0.004)	0.013*** (0.004)	-0.010** (0.004)
CAB	-0.102*** (0.035)	0.095*** (0.033)	-0.066** (0.034)
CH_4	0.038 (0.028)	0.023 (0.027)	0.034 (0.028)
Constant	0.112*** (0.007)	0.070*** (0.008)	0.162*** (0.011)
Observations	264	264	264
R-squared	0.134	0.360	0.260
Number of CountryID	12	12	12
Country FE	YES	YES	YES
Year FE	YES	YES	YES

Note: Benchmark is in parentheses. Significance levels indicate the difference between Model1, Model2 and Model3.
***p<0.01, **p<0.05, *p<0.1. Source: Authors.

must also be identified in line with the claims made by (Qu *et al*., 2022). The moderating effects of GDP and population density also indicate that development and governance are important in dynamic oil-agriculture.

Table 5: Heterogeneity result.

Variables	(1) High Income	(2) Low and Middle Income
ARIGS	-0.023 (0.411)	-0.346*** (0.064)
GDP	0.743** (0.297)	-0.141*** (0.038)
c.ARIGS#c.GDP	1.687 (3.335)	2.297*** (0.553)
OPROD	-0.740 (0.451)	-0.436*** (0.092)
POP	-5.650*** (1.895)	-0.100 (0.070)
c.OPROD#c.POP	20.205*** (5.537)	-0.502 (1.096)
OR	1.097** (0.528)	-0.050* (0.027)
N_2O	-0.030 (0.021)	-0.000 (0.003)
CAB	-0.077* (0.046)	-0.035 (0.054)
CH_4	-0.186* (0.101)	0.061*** (0.023)
Constant	-0.094 (0.089)	0.158*** (0.009)
Observations	78	234
R-squared	0.836	0.514
Number of CountryID	3	9
Country FE	yes	yes
Year FE	yes	yes

Note: Heterogeneity is in parentheses. Significance levels indicate the difference between high-level and low and middle-level groups. *** p<0.01, ** p<0.05, * p<0.1. Source: Authors.

Heterogeneity analysis

As illustrated in Table 5, the impact of ARIGS on AGTFP is greater in high-income countries than in low-middle-income countries. ARIGS generate positive effects in rich nations and negative effects in poor nations. The divergence indicates that the same extractive activity yields different outcomes, depending on the structure of the economy and the strength of institutions. Advanced economies have stronger regulations, superior technology and higher adaptive capacity to avoid the negative spillovers of drilling, while low-income countries face governance issues, low green investment and climate vulnerability that magnify the adverse effects of extraction on agriculture aligned with (Shanmugan and Prakash, 2018). The oil industries in low- and middle-income OPEC should include mandatory environmental impact assessments, stronger protection for agricultural land and rehabilitation funds paid by oil companies.

Robustness results

The robustness of these associations across different model specifications is presented in (Table 6). Both AGTFP are consistently explained by the main and multiple term effects of ARIGS, GDP and their interaction, noting that GDP does not merely serve as a control variable but is critical to determining whether rig exposure translates into agricultural opportunity or risk. Findings are consistent with prior research that indicates productive spillovers from oil revenue emerge in instances where fiscal, production and institutional properties are aligned with (Wang *et al.*, 2022). This fact implies that the policies of OPEC' energy

Table 6: Robustness result.

Variables	(1) Model 1	(2) Model 2	(3) Model 3
ARIGS	0.085** (0.035)	-0.294***(0.092)	-0.170* (0.086)
GDP		-0.108**(0.050)	-0.124*** (0.046)
c.ARIGS#c.GDP		2.874***(0.714)	2.296*** (0.680)
OPROD			-0.493*** (0.102)
POP			-0.312*** (0.114)
c.OPROD#c.POP			2.018 (1.235)
OR	-0.166*** (0.037)	-0.038 (0.041)	-0.160*** (0.038)
N_2O	-0.014*** (0.004)	0.016*** (0.004)	-0.010** (0.004)
CAB	-0.089*** (0.034)	0.091*** (0.035)	-0.055* (0.033)
CH^4	0.028 (0.030)	0.036 (0.032)	0.028 (0.029)
Constant	0.121*** (0.008)	0.065*** (0.010)	0.171*** (0.011)
Observations	240	240	240
R-squared	0.133	0.346	0.286
Number of CountryID	12	12	12
Country FE	yes	yes	yes
Year FE	yes	yes	yes

Note: Robustness tests are in parentheses. Significance levels indicate the difference between Model1 and Model2 and Model3. ***p<0.01, **p<0.05, *p<0.1. Source: Authors.

development should be linked to agricultural upgrading, rather than treated separately. These significant effects emerge in low-income countries, where countervailing policies can mitigate the adverse impacts of ARIGS.

Margins plot

The fluctuations of AGTFP in accordance with GDP and population are shown in Fig 2. The positive effect of ARIGS on AGTFP becomes more pronounced as GDP increases, especially in high-income countries. Moreover, population density also significantly moderates the effect of OPROD on AGTFP. This verifies that macroscale capacity and demographic stress determine the scale and intensity of the AGTFP*ARIGS link. Far better GDP countries can convert oil revenue into productive agricultural inputs the similar finding was reported (Amand, 2020). The policy response must consider economic and demographic dynamics, in which oil revenues support sustainable agricultural practices to alleviate stress on the environment.

Correlation matrix

Strong multicollinearity between OPROD variables is observed in the pairwise correlation matrix illustrated in (Fig 3). The positive correlations (r = 0.88) between CO_2 and OPROD, (OR r = 0.84), or (ARIGS, r = 0.77) corroborate previous studies that associate higher emissions with increased extraction activities 24-27. Relatedness among these variables is illustrated by the moderate correlations between CH_4 and CO_2 (r = 0.60) and between CH_4 and OPROD emissions (r = 0.52), implying similar control challenges for these variables. Similar results were reported by (Otse *et al.*, 2025). Hydrocarbon-related variables exhibit negative or weak correlations with both GDP and POP, with the notable exception of a weak negative correlation between GDP and CO_2, OPROD and OR. POP is modestly positively correlated with ARIGS (r = 0.21), indicating weak collinearity with OPROD activities that align with Kumar *et al.* (2024).

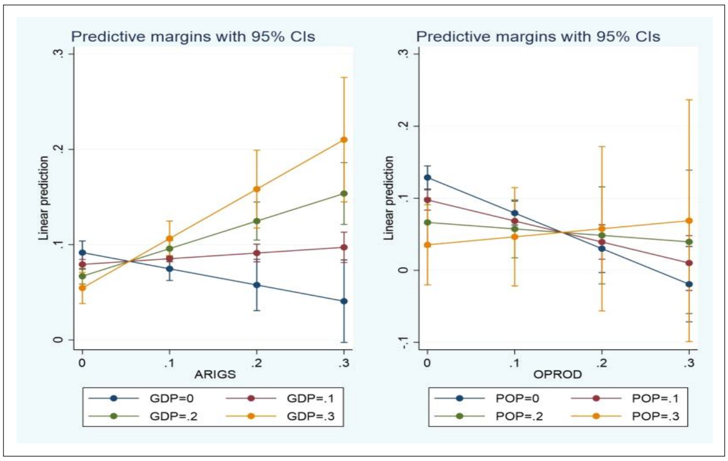

Fig 2: Margins plot of GDP and POP in AGTFP.

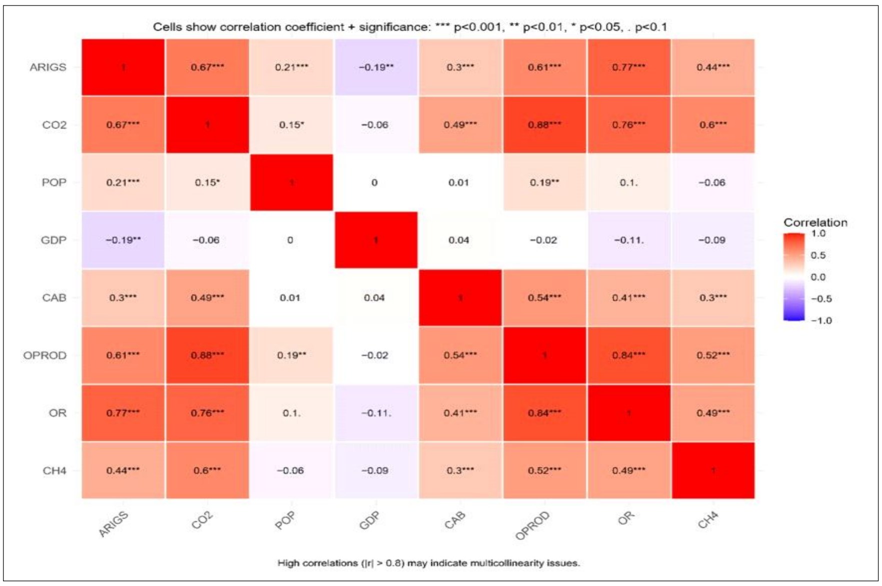

Fig 3: Multicollinearity correlation matrix of predictor variables.

The study suggests differentiated policy interventions appropriate to the economic and environmental circumstances across OPEC. High-income nations should focus on reforms to ARIGS efficiency and on the adoption of sustainable energy technologies, such as a renewable-based energy acquisition policy, which would have positive effects on AGTFP and reduce environmental degradation. By contrast, low and middle-income OPEC must implement policies that facilitate sustainable energy generation and integrate environmental sustainability in their industrial strategies. These capacity-building endeavors will safeguard agricultural prosperity in these regions (Semrau, 2026). The findings reveal that diversified enterprises could foster GDP growth and increase agricultural resilience, underscoring the need for policies to harmonize economic growth, the electricity sector and ecological sustainability in OPEC by embracing sustainable agriculture.

CONCLUSION

This study advances understanding of the complex relationship between ARIGS and AGTFP in OPEC. The findings reveal a context-dependent effect; while the Poorest countries experience more substantial adverse effects from environmental degradation, land competition and institutional weakness. Combining economic, demographic and ecological considerations, the present paper offers a more inclusive view of sustainable development in an oil-based economy. The results support the view that a country's wealth in oil revenue provides no guarantee of sustainable agriculture and that the sustainability outcome is influenced by governance systems and dynamics of technological change. To prevent the resource curse, OPEC needs to pursue sustainable oil investments that include greener technologies and policies. Caveats included pooled data and excluded recent issues. Future research should use disaggregated data and mixed methods to incorporate governance and institutional elements into the analysis. Policy implications include the need for stronger environmental regulation and investment in sustainable agriculture.

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Disclaimers

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Conflict of interest

The authors declare that there are no conflicts of interest in relation to the publication of this article. The study design, data collection, analysis, decision to publish and manuscript preparation were not influenced by any funding or sponsorship.

REFERENCES

Alsalman, Z., Herrera, A.M. and Rangaraju, S.K. (2023). Oil news shocks and the U.S. stock market. *Energy Economics.* **126(2):** 106891. doi: 10.1016/j.eneco.2023.106891.

Amand, R. (2020). Analysis of total factor productivity of chickpea in major producing States in India. *Indian Journal of Agricultural Research.* **54(3):** 293-300. doi: 10.18805/IJARe.A-5306.

Ansari, D. (2017). OPEC, Saudi Arabia and the shale revolution: Insights from equilibrium modelling and oil politics. *Energy Policy.* **111:** 166-178.

Apergis, N. and Ozturk, I. (2015). Testing environmental kuznets curve hypothesis in Asian countries. *Ecological Indicators.* **52:** 16-22.

Chukwuneke, J.L., Uyeri, O.C., Orugba, H.O., Olisakwe, H.C., Okoro, V.I., Okeke, J.C. and Egbuna, I.C. (2025). Production of bio-oil, physico-chemical and thermal analysis of degradation of pig fur biowaste. *Chemical Thermodynamics and Thermal Analysis*. **19(2):** 100193. doi: 10.1016/j.ctta.2025.100193.

Cui, H., Hou, S.N., Wang, X.Y. and Zhu, H. (2025). Organic fertil izer-mediated cultivated land conservation and pollution source control in agricultural ecosystem, Northeast China. *Environmental Technology and Innovation.* **37:** 103945. doi:10.1016/j.eti.2024.103945.

Iqbal, S., Zhang, Q. and Chang, M. (2025). Turning waste to watts: Studying tyre pyrolysis oil production supply for electricity generation and net-zero carbon emission with life cycle assessment approach. *Energy*. **324(6):** 135597. doi: 10.1016/j.energy.2025.135597

Kumar, A., Sharma, N.K., Kumar, R., Sanadya, S.K. and Sahoo, S. (2024). Correlation and path analysis studies in mungbean [*Vigna radiata* (L.) Wilczek] under arid environment of Western Rajasthan. *Indian Journal of Agricultural Research.* **58(Special Issue):** 1003-1010. doi: 10.18805/IJARe.A-6195.

Li, H., Lin, Q., Wang, Y. and Mao, S. (2023). Can digital finance improve china's agricultural green total factor productivity? *Agriculture.* **3(7):** 1429. doi: 10.3390/agriculture13071429.

Lu, S., Zhuang, J., Sun, Z. and Huang, M. (2024). How can rural digitalization improve agricultural green total factor productivity: Empirical evidence from counties in China. *Heliyon*. **10(15):** e35296. https://www.ncbi.nlm.nih.gov/pubmed/39165988.

Montant, G. (2025). The effectiveness of OPEC and OPEC+ from 2009 to 2024: An empirical appraisal. *Resources Policy.* **103.** doi: 10.1016/j.resourpol.2025.105529.

Omokpariola, D.O., Agbanu-Kumordzi, C., Samuel, T., Kiswii, L., Moses, G.S. and Adelegan, A.M. (2025). Climate change, crop yield and food security in Sub-Saharan Africa. *Discover Sustainability.* **6(1):** 1-21. doi: 10.1007/s43621-025-01580-4.

Otse, E.J., Obunadike, G.N. and Abubakar, A. (2025). Linear regression approach to solving multicollinearity and overfitting in predictive analysis. *Journal of Science Research and Reviews.* **2(1):** 108-117. doi: 10.70882/josrar.2025.v2i1.35.

Qu, Y., Li, J. and Wang, S. (2022). Green total factor productivity measurement of industrial enterprises in Zhejiang Province, China: A DEA model with undesirable output approach. *Energy Reports*. **8:** 307-317.

Razek, N., Galvani, V., McQuinn, B. and Rajan, S. (2025). Does Saudi Arabia's International competitiveness improve due to sanctions imposed on competitors? the case of two wars. *Structural Change and Economic Dynamics.* **74:** 457-482.

Kumar, S. and Upadhyay, S.K. (2019). Impact of climate change on agricultural productivity and food security in India: A state level analysis. *Indian Journal of Agricultural Research*. **53(2):** 133-142. doi: 10.18805/IJARe.A-5134.

Semrau, F.O. (2026). Upstreamness, foreign environmental regulation and CO_2 emissions in Indian manufacturing firms. *Journal of Environmental Economics and Management.* **138:** 103324. doi: 10.1016/j.jeem.2026.103324.

Séogo, W. and Zahonogo, P. (2023). Do land property rights matter for stimulating agricultural productivity? Empirical evidence from Burkina Faso. *Land Use Policy.* **125.** doi: 10.1016/j.landusepol.2022.106475.

Shanmugan, K. and Prakash, B.B. (2018). Total factor productivity in Indian agriculture: An exploratory analysis based on literature review. *Agricultural Reviews.* **39(2):** 113-121. doi: 10.18805/ag.R-1754.

Wang, K.H., Wen, C.P., Long, H. and Moldovan, N.C. (2024). Towards sustainable development: Exploring the spillover effects of green technology innovation on energy markets and economic cycles. *Technological Forecasting and Social Change.* **203.** doi: 10.1016/j.techfore.

Wang, X., Yeung, G., Li, X. and Wang, L. (2022). Does inter-regional investment by publicly listed companies promote local green total factor productivity? A study of the mediation effects of green patents in China. *Journal of Cleaner Production*. **339(6):** 130582. doi: 10.1016/j.jclepro.2022.130582.

Xiong, M., Li, W., Xian, B.T.S. and Yang, A. (2023). Digital inclusive finance and enterprise innovation-empirical evidence from Chinese listed companies. *Journal of Innovation and Knowledge.* **8(1):** 100321. doi: 10.1016/j.jik.2023.100321.

Yu, M. and Deng, X. (2021). The inheritance of marketization level and regional human capital accumulation: Evidence from China. *Finance Research Letters.* **43(2):** 102268. doi: 10.1016/j.frl.2021.102268.

Zhou, X. and Zhang, Y. (2024). Administration or marketization: Environmental regulation, marketization and agricultural green total factor productivity. *J. Environ Manage*. **370:** 122433. https://www.ncbi.nlm.nih.gov/pubmed/39276656.