Green Growth in Algeria: Balancing Industry and Environment for Sustainable Economic Development

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Received: 13/01/2024

Accepted: 24/01/2024

Published: 26/01/2024

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Citation: Bouazza E Z , Green Growth in Algeria: Balancing Industry and Environment for Sustainable Economic Development. *Dirassat Journal Economic Issue* ,(1)15. p.119-136.

https://doi.org/10.34118/djei.v15i1.3713

Abstract

This study investigates the sustainable economic development of Algeria's industry from 1990 to 2021, focusing on the transition towards green growth. Employing a database for three industrial branches (hydrocarbon; iron, steel and mining; building materials) and a semi-logarithmic production function, the study evaluates the productivity changes in industrial workers and the implications for green growth using the KELM model. The findings reveal a decrease in CO2 emissions and a significant rise in energy efficiency and productivity. These changes reflect the industry's movement towards sustainable economic growth, emphasizing renewable energy and low-carbon industries. The study concludes that while Algeria has made progress towards balancing industrial growth and environmental sustainability, further development in new green sectors is crucial for achieving a more sustainable economic model.

Keywords: Algeria, energy efficiency, carbon dioxide emissions, KLEM model, sustainable economic development.

JEL classification codes: D24, O47, Q56

النمو الأخضر في الجزائر: تحقيق التوازن بين الصناعة والبيئة من أجل التنمية الاقتصادية المستدامة

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استلم في: **2024/01/13**

قبل في: **2024/01/24**

نشر في: 2024/01/26

***المؤلف المرسل**

https://doi.org/10.34118/djei.v15i1.3713

الملخص:

تبحث هذه الدراسة في التنمية الاقتصادية المستدامة للصناعة الجزائرية من 1990 إلى 2021، مع التركيز على التحول نحو النمو الأخضر. باستخدام قاعدة بيانات لثلاثة فروع صناعية (النفط والغاز، الحديد والصلب والتعدين، مواد البناء) ووظيفة إنتاج شبه لوغاريتمية، تقوم الدراسة بتقييم التغيرات الإنتاجية في العمال في قطاع الصناعة والآثار المترتبة على النمو الأخضر باستخدام نموذج KELM. تكشف النتائج عن انخفاض في انبعاثات ثاني أكسيد الكربون وزيادة في كفاءة الطاقة والإنتاجية. وتعكس هذه التغييرات تحرك الصناعة نحو النمو الاقتصادي المستدام، مع التركيز على الطاقة المتجددة والصناعات منخفضة الكربون. وتخلص الدراسة إلى أنه في حين حققت الجزائر تقدما نحو تحقيق التوازن بين النمو الصناعي والاستدامة البيئية، فإن مواصلة التطوير في القطاعات الخضراء الجديدة أمر بالغ الأهمية لتحقيق نموذج اقتصادي أكثر استدامة.

الكلمات المفتاحية: الجزائر، التنمية الاقتصادية المستدامة، انبعاثات ثاني أكسيد الكربون، كفاءة الطاقة، نموذج KLEM.

تصنيف JEL: D24, O47, Q56

1. Introduction

Algeria, the third largest emitter of CO_2 in Africa, is facing a critical juncture in its environmental journey. In 2022, the country witnessed a 2% increase in CO_2 emissions from energy use, reaching 155 Mt, following a significant 9% rise in 2021, continuing a trend of a 5% annual increase from 2010 to 2019 (Rahmane & Traich, 2022). This alarming trend echoes the global environmental and climate challenges. The report by BP Statistical Review , indicates that despite record growth in renewables, the share of world energy still coming from fossil fuels remains at 82% (Nakanwagi, 2021). Moreover, The U.S. Energy Information Administration (EIA) projects that world energy consumption will grow by nearly 50% by 2050 (Kahan, 2019). Recognizing the gravity of the situation, Algeria's Nationally Determined Contribution (NDC) has set an ambitious goal to reduce its greenhouse gas emissions by 7% by 2030 compared to a business-as-usual scenario (Rahmane & Traich, 2022). This target could increase to 22% with the provision of new financial resources from bilateral and multilateral partners, and the transfer of clean technology on concessional and preferential terms (Himri et al., 2022).

In a decisive move towards a brighter future, the concept of sustainable economic development stands as a critical solution. Amidst a backdrop of daunting statistics. It's a strategy that embraces economic advancement while meticulously reducing ecological footprints. This paradigm shift is more than a theoretical ideal; it's a measurable target, aiming to harmonize the dynamics of modern industries and lifestyles with the pressing need for environmental conservation. Therefore, the academic discourse on the path to sustainable economic development is rich and varied. On one side, scholars advocate for a transition to a green, low-carbon economy, underlining the importance of increased energy efficiency and productivity as key (Arning, Dütschke, Globisch, & Zaunbrecher, 2020; Bonsu, 2020; Möslinger, Ulpiani, & Vetters, 2023). This is particularly pertinent considering that the industrial sector alone accounts for approximately 24% of global CO_2 emissions (IEA, 2020). On the other side, some argue that sustainable development can be pursued through strategic investments in areas like education and infrastructure, without major industrial or economic overhauls (Biggeri, Ferrannini, Mehrotra, Di Tommaso, & Bianchi, 2023; He, Iqbal, & Su, 2023; Möslinger et al., 2023; Zhang, Xie, Sun, Wu, & Xue, 2024).

Despite the extensive global research on sustainable economic development, research in this field in Algeria is limited. This study contributes novel insights into the management of energy and environmental variables in the context of sustainable development, employing the KLEM model to evaluate the roles of energy consumption and carbon dioxide emissions in the manufacturing process. Our study aims to incorporate energy and environmental dimensions into the analysis of sustainable economic development, using an extended neoclassical growth model for productivity measurement and green growth accounting. Spanning from 1990 to 2021, we utilized a combination of economic, energy, and environmental data to assess the Algerian industry's current state and its potential for fostering sustainable development through green growth. Utilizing a panel dataset from three industries (hydrocarbon; iron, steel and mining; building materials) the study employed a parametric production function to examine the impact of inputs on growth.

The study seeks to answer two main questions: (1) What is the correlation between input parameters, particularly energy consumption and carbon dioxide emissions, and productivity in the Algerian industrial sector? (2) What are the expected outcomes of integrating green growth strategies into the Algerian industrial sector for promoting sustainable economic development? To address these questions, the study tests two central hypotheses using a parametric production function: Hypothesis 1 posits that green growth enhances productivity, reduce energy consumption, and mitigates environmental impacts, thereby fostering sustainable development. Hypothesis 2 suggests that the influence of green growth on sustainable development is moderated by factors like resource availability, technology adoption, and socio-economic and political stability.

With Algeria at a critical juncture, this timely study meaningfully advances academic discourse and policymaking on sustainable development. By addressing a key knowledge gap on an under-researched topic, the study's applied recommendations will support the country's sustainability journey. Also, this study makes an important contribution by incorporating environmental and energy variables into the analysis of Algeria's industrial sector. The innovative use of the KLEM model and green growth accounting provides novel insights beyond purely economic measures. Covering major industries over an extensive time period allows for a comprehensive evaluation of Algeria's sustainability challenges.

After the introduction, the study was structured as follows: The literature review examined sustainable development research in section 2; Then 3 section introduced Algeria's industrial sector and energy dynamics Section 4 outlined the methodology. Section 4 presented empirical findings that answer the research questions. The study concludes with a conclusion, which synthesizes the research findings and highlights their significance. Additionally, the paper proposes the policy implications based on the research results.

2. Literature review

The literature reviews section on such topics is usually divided into two main categories that examine issues of energy and the environment. The first category focuses on factors affecting energy or environmental changes, such as the cause of the stagnation or decline in energy consumption and pollution emissions (Obretenova, 2023; Rahman, 2020). Such kind of literature generally used different analysis methods to analyze changes in energy consumption or emissions into different effects, such as structural transformation from heavy industry to light efficiency improvement. Regression analysis or factor analysis is used to identify the main explanatory causes. The second category of literature studies the influence of energy or the environment on production, such as studies on the Kuznets curve relationship between income and environment, or research on the incorporation of energy or emissions into growth theory models (Le & Ozturk, 2020; Ridzuan, Marwan, Khalid, Ali, & Tseng, 2020). This study followed the growth theory framework of the second category of literature and includes energy consumption and carbon dioxide emissions as input factors, along with traditional factors such as capital and labour, in a semi-logarithmic function of production.

The concept of sustainable development arose in the eighties in response to the escalating environmental challenges caused by industrial activities, and today the limited nature of resources has been recognized, therefore the effect of economic and political change, productivity and power efficiency on long-term economic development and environmental changes has been the topic of numerous empirical interest in recent years (Mensah, 2019). The literature review illustrates the need of examining several variables when examining the relationship between energy consumption and economic growth. But, according to a huge number of research on energy-related topics, it is widely acknowledged that energy-related aspects are crucial for the success of economic growth. Energy variables are supported in a reasonably comprehensive way, and sustainable growth generally considers energy usage as a new input component. Energy, however, can also be thought of as a final product at market value or as a portion of the value of capital, and much like traditional capital and labour variables, it too contributes to the creation of value during the manufacturing process. The study by Chen and Golley (2014) has shed more light on green growth accounting was used to analyze the impact of energy consumption and carbon dioxide emissions on the transformation of the industrial growth pattern and sustainable development in China. Also, Early studies (Ouyang et al., 2019; Ahmad & Wu, 2022) emphasize the significance of industrial energy efficiency in fostering ecological sustainability as well as the part that various elements, including technological advancement, energy efficiency and innovation, play in promoting energy efficiency improvements.

On the other hand, identity determines the relationship between human economic and social activities and greenhouse gas emissions, and many domestic and foreign literature have carried out research on carbon emissions based on this equation. Kaya (1989) proposed the Kaya identity, through the method of factorization, the correlation between greenhouse gas emissions (related to energy use) and population, economic development level, energy use efficiency and carbon emission factors of unit energy consumption was established relation. Studies by Eskander and Nitschke (2021); Hwang, Um, Hwang, and Schlüter (2020) acknowledged that there is a strong positive relationship between carbon emissions and energy efficiency and provide valuable insights for policymakers and stakeholders seeking to promote sustainable economic development. These findings highlight the complex and dynamic relationship between energy, the environment, and sustainable economic growth.

Despite the difference in opinion, but since 2010 there has been a rapid rise in the idea of green growth, Ahmed, Kousar, Pervaiz, and Shabbir (2022); Cheng, Yi, Dai, and Xiong (2019) has attracted considerable attention that Green Growth offers a distinct approach. Proponents of green growth argue that by conserving the environment, we can enhance our prosperity and quality of life while avoiding significant costs. The theory of green growth asserts that economic growth can be achieved while also being ecologically sustainable, as technological advancements will enable the disconnection of GDP growth from resource utilization and carbon emissions. Hickel and Kallis (2020); Tawiah, Zakari, and Adedoyin (2021) in their systematic literature review, found that this concept offers the potential for "win-win" outcomes that can simultaneously achieve multiple desirable policy goals in developing countries, making it particularly appealing. International organizations, such as the Organisation for Economic Cooperation and Development (OECD), the United Nations Environment Programme (UNEP), support the theory of green growth.

The studies investigated different countries from different world regions, mainly from East Asia and the Pacific, South Asia, the Americas, Europe and Central Asia, Middle East and North Africa (MENA) and Sub-Saharan Africa. We focused on the studies that studied Algeria, from these studies we mention Bouznit and Pablo-Romero (2016) in their systematic literature review, they found the growth theory framework that includes energy consumption and CO2 emissions as input factors can be applied in Algeria. Such an analysis can provide valuable insights into the relationship between economic growth and energy consumption and emissions in Algeria. The model could be used to estimate the current and future levels of energy consumption and carbon dioxide emissions in Algeria based on the country's economic growth and other factors, such as changes in energy production and consumption patterns, the adoption of renewable energy technologies, and the implementation of energy-saving measures. However, the two studies use MCO method to estimate the impact of different policies on energy consumption and CO2 emissions in Algeria.

Given these points, the current studies on sustainable economic development in the industry in Algeria have the following limitations: Firstly, most of the literature overlooks the role of productivity and only focuses on the impact of the rapid growth of energy demand on carbon emissions in Algeria. Secondly, the current analysis primarily relies on forecasting carbon emissions and the factors that influence them. The current study addresses these limitations by estimating the post-logarithmic production function of the total industry factor productivity in Algeria based on energy consumption and emission constraints and dividing it through green growth accounting and analysis of the impact of energy consumption and carbon dioxide emissions on the transformation of the industrial growth pattern and sustainable development in Algeria.

3. Algeria's Industrial Sector and Energy Dynamics

In July 2016, Algeria embarked on a transformative journey with the unveiling of its 'new growth model', a strategic economic approach aimed at addressing the country's economic and environmental imbalances. This model seeks to shift Algeria towards a more sustainable production paradigm, with a focus on enhancing productivity across various industry sectors while reducing the impact on the hydrocarbon sector. The establishment of the Ministry of the Environment and Renewable Energies in 2017 marked a significant step in this direction, aligning with the Sustainable Development Goals for 2030 outlined in a government report (Ersoy & Terrapon-Pfaff, 2021). The model sets ambitious targets, including elevating the GDP growth rate for non-hydrocarbon sectors to 6.5% annually between 2020 and 2030 (Hafner, Raimondi, & Bonometti, 2023). Key sectors such as Agriculture, Industry, and Knowledge Services are projected to grow at annual rates of 6.3%, 7.4%, and 1.7%, respectively (Lee et al., 2023). In addition to the allocation of 120 billion dollars for the development of renewable energy (مداحي، 2022) . These efforts aim not only to boost the industrial sector's contribution to the GDP but also to enhance overall economic productivity and efficiency.

Table N°1

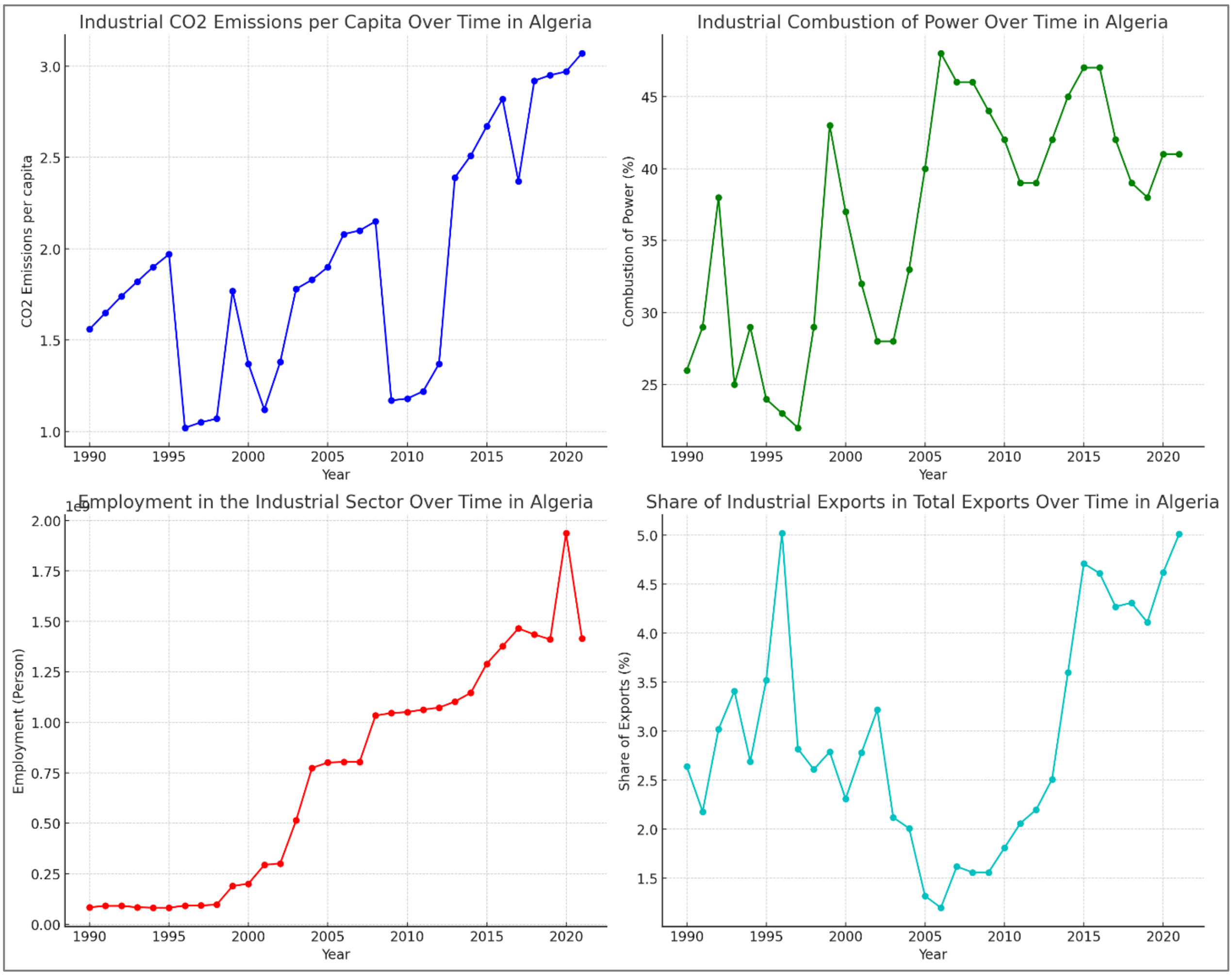
Rank Algeria in energy use according to CCPI 2022

Indicator	Weighting	Rating	Rating
Energy Use	20%	Very high	25
Energy Use (TPES) per Capita - current level	5%	Low	11
Energy Use (TPES) per Capita - current trend	5%	Low	46
Energy Use (TPES) per Capita - compared to a well-below-two-degrees benchmark	5%	Low	30
Energy Use 2030 Target - compared to a well below two-degrees-benchmark	5%	Low	26

Source: The Climate Change Performance Index.

Table N°1 presents mixed insights into Algeria's energy use. While Algeria's overall energy consumption is rated as "Very high" (25), indicating substantial usage, its per capita energy consumption is rated "Low" across various metrics. This suggests efficient or modest energy use per person. However, the trend in per capita energy use and the 2030 targets, though rated "Low", imply that there are challenges in aligning with global sustainability benchmarks. In summary, while Algeria shows efficiency in individual energy consumption, its total energy use remains a significant concern, highlighting areas for potential improvement in environmental sustainability.

Figure N° 1
Overview of Industrial and Environmental Trends in Algeria (1990-2021)



Source: Compiled by author.

Figure N° 1 presents a comprehensive view of the interplay between industrial growth, environmental impact, and economic factors in Algeria from 1990 to 2021. The increasing industrial CO2 emissions per capita and the growing share of industrial exports highlight the challenges and opportunities in balancing industrial development with environmental sustainability. The trend shows a general increase in industrial CO2 emissions per capita over the 31-year period, indicating a rise in emissions relative to the population. This suggests growing industrial activity or a higher carbon footprint of industries in Algeria. Additionally, the percentage of industrial combustion of power fluctuates over the years, with notable peaks and troughs. This variability might reflect changes in industrial energy sources, policies, or efficiencies in power usage in the industrial sector. Moreover, there is a significant increase in employment in the industrial sector, especially noticeable in the later years. This growth points to the expansion of the industrial workforce, possibly correlating with economic growth or industrial development in Algeria. Furthermore, this metric exhibits a gradual increase over the years, suggesting a rising contribution of industrial goods to the country's total exports. This could be indicative of a strengthening industrial sector and its increasing importance in Algeria's export economy.

Table N°2

Algeria's national final energy consumption by aggregates and sectors

	1990	1995	2000	2005	2010	2015	2020	2021
Final Energy Consumption	11,46	13,46	15,86	23,56	31,65	42,46	46,88	49,88
Industry & Construction	3,11	4,11	4,81	5,82	8,02	8,82	11,24	15,56
Transport	5,02	6,02	7,02	5,84	11,22	15,5	17,06	19,16
Households & Others	7,15	8,29	9,37	12,85	12,42	18,15	20,58	22,01
Non-Energy use	1,08	1,18	1,08	1,08	2,19	4,08	4,33	4,43
Energy industry own use	2,84	2,89	3,19	2,84	6,7	7,84	9,44	11,29
Losses	4,89	4,97	5,09	4,89	3,29	3,89	5,69	6,59
Total Energy Consumption	24,09	27,46	30,56	36,19	43,82	58,27	62,34	66,14

Source: Compiled by author.

Table N°2 provides a detailed view of the country's energy consumption across various sectors from 1990 to 2021. The data shows a consistent increase in total energy consumption, nearly tripling from 24.09 in 1990 to 66.14 in 2021. Notably, the industry and construction sector have seen a significant rise, particularly from 2020 to 2021, indicating rapid industrial growth. The transport sector also shows a marked increase, doubling its consumption from 2010 to 2021. Households and other sectors exhibit a steady increase, reflecting growing domestic and commercial energy demands. Non-energy use and energy industry's own use have escalated, particularly from 2005 onwards, suggesting increased industrial activity. Losses in energy have fluctuated but show an overall increase. This table highlights Algeria's expanding energy demands across all sectors, underscoring challenges and opportunities in energy management and sustainability.

4. Research Design

4.1. Methodology:

This study explores the interplay between energy and environmental variables in the realm of economic development, with a specific focus on the Algerian industrial sector. Our approach is rooted in the KLEM model, which integrates energy and other raw materials as intermediate inputs alongside traditional factors like capital and labour. This model is instrumental in analyzing energy consumption, increasingly recognized as a critical input in the production process.

However, a notable challenge in sustainable economic development research is the absence of market pricing for pollution emissions. Traditionally, these emissions have been sidelined in studies due to this pricing dilemma. In the literature, two primary methods emerge for addressing emission variables: one views pollution emissions as an input element, while the other perceives them as an undesirable outcome. Our study adopts the first approach, treating carbon dioxide emissions as an integral input. This perspective acknowledges that emissions, influenced by regulations and changes in environmental capital, can exert both positive and negative effects on growth. Therefore, the study tests two central hypotheses using a parametric production function to understand the impact of various inputs on growth:

Hypothesis 1: Green growth is anticipated to enhance productivity, reduce energy consumption, and mitigate environmental impacts, thereby fostering sustainable economic development within the Algerian industry.
Hypothesis 2: The influence of green growth on sustainable economic development in the Algerian industry is moderated by factors like resource availability, technology adoption, and socio-economic and political stability.

Our study constructs panel data spanning from 1990 to 2021, focusing on branches of industrial sector in Algeria, namely Hydrocarbons, Iron, Steel and Mining, and Building Materials. The choice of these sectors is dictated by the availability of data, as comprehensive information for other industrial branches is limited. The Algerian industrial landscape, as reported by the National Statistics Office (ONS) and the Algerian Ministry of Industry, is notably diverse, encompassing sectors like Oil Extraction, Gas Production and Supply, Mechanical, Electrical and Electronic Constructions, Textiles, Food Industry, Chemical and Petrochemical Industries, Wood and Paper Industries, Leather and Shoes Industries, and Mines. However, our study zeroes in on the selected three branches to provide a focused and detailed analysis within the available data constraints.

4.2. Conceptual framework:

The KLEM model refers to a production function or model that includes four main factors of production: Capital (K), Labor (L), Energy (E), and Materials (M) (Malliet & Reynès, 2022). This model is an extension of the simpler production functions like the Cobb-Douglas model, which traditionally considered only capital and labor as inputs (Hartwig & Pfaff, 2021). In the KLEM model, the inclusion of energy and materials allows for a more comprehensive analysis of production processes, especially in contexts where energy and raw materials play a critical role. This model is particularly relevant in industrial and environmental economics, where the impacts of energy consumption and material use on production efficiency and environmental outcomes are significant. The KLEM model is useful for analyzing how changes in any of these inputs affect output, productivity, and economic growth. It also helps in understanding the trade-offs and synergies between economic output and environmental impacts, making it a valuable tool in the field of sustainable development and environmental policy.

The general form of the KLEM production function can be expressed as follows:

$$Y = A \times f(K, L, E, M) \tag{1}$$

Y: represents the total output or production.
A: stands for Total Factor Productivity (TFP), which reflects the efficiency with which the inputs are transformed into output. It captures factors like technology, organizational efficiency, and other non-quantifiable aspects of production.
$f(K, L, E, M)$: is a function that describes the relationship between output and the inputs: Capital, Labor, Energy, and Materials. The specific form of this function can vary based on the assumptions of the model (e.g., whether it assumes constant returns to scale, the substitutability between inputs).

Key aspects of the KLEM model include:
Capital (K): This refers to physical assets like machinery, buildings, and equipment used in the production process.
Labor (L): This represents the human workforce involved in production.
Energy (E): This factor accounts for the energy (electricity, fossil fuels, renewable energy, etc.) used in production processes.

Materials (M): This includes raw materials, intermediates, and other physical inputs other than capital assets.

In a more detailed or specific application, this function can be further defined. For example, a commonly used specification is the Cobb-Douglas production function, extended to include Energy and Materials:

$$Y = A \times K^{\alpha} \times L^{\beta} \times E^{\gamma} \times M^{\delta} \quad (2)$$

$\alpha, \beta, \gamma, \delta$:are the output elasticities of Capital, Labor, Energy, and Materials, respectively. These coefficients indicate the percentage change in output resulting from a one percent change in each input, ceteris paribus (all other factors being held constant).

4.3. Data and variables:

We used the production function to analyze the total factor productivity (TFP) of 03 industries in Algeria from 1990-2021. The KLEM model, extended to include CO2 emissions and green growth strategies, can be represented as:

$$P = A \times f(K, L, E, M, CO2) \quad (3)$$

Where:

P is the productivity, A represents total factor productivity or efficiency of the system. the function f models how these inputs (capital, labor, energy, materials, CO2 emissions, and green growth strategies) collectively affect productivity.

Table N°3
Variable description

Variable		Unit	Source
	Dependent Variable		
P	Productivity	USD per Man-hour	World Bank, International Labour Organization (ILO)
	Independent Variable		
K	Capital	Million US$	World Bank, International Monetary Fund (IMF)
L	Labour	Number of Workers	National Office of Statistics (Algeria)
E	Energy Consumption	Kilowatt-hours (kWh)	International Energy Agency (IEA), Algeria's Ministry of Energy
M	Materials	Million US$	National Office of Statistics (Algeria), UN Comtrade Database
$CO2$	carbon dioxide emissions	units of metric tons of CO2 equivalent	World Bank, United Nations Framework Convention on Climate Change (UNFCCC)

Source: compiled by author.

Where:

Productivity (P): Measures the output efficiency of the industrial sector in Algeria. It is an outcome

variable that reflects how effectively the other inputs are transformed into industrial output.
Capital (K): Refers to investments in industrial infrastructure, technology, and equipment within Algeria's key sectors: hydrocarbon; iron, steel and mining; building materials. This includes machinery, buildings, and technological advancements critical for industrial processes.
Labour (L): Encompasses the workforce in Algeria's industrial sector, including numbers, skills, and qualifications. It reflects human capital involved in production, considering education, experience, and labor policies.
Energy Consumption (E): The total energy utilized by the industries, with a focus on the type of energy (e.g., fossil fuels, renewables) and its efficiency. This variable is crucial for understanding the energy dependency and efficiency of the industrial processes.
Materials (M): Includes raw materials and intermediate goods consumed in the industrial processes. This variable captures the input side of the manufacturing processes, essential for the production of goods.
CO2 Emissions: The volume of carbon dioxide emissions generated by the industrial sector. This is a critical environmental variable, indicating the ecological impact of industrial activities.

5. Results and Discussion

5.1. Results:

Based on the model above, in order to test the impact of different energy consumption and carbon emission levels on sustainable economic development in the Algerian industry based on the different influences of development. This study divides 03 industrial sub-sectors into low energy consuming and high energy consuming group (efficiency power usage). Low emission of CO2 and high emission group.

Table N°4
Descriptive Statistics

Variables	Mean	Std. Error	Min	Max	Mean	Std. Error	Min	Max
	Low Energy				High Energy			
Gross industrial output value (Million US$)	23	0,93	6	41	114	1,87	28	226
Labour (10,000 people)	11	0,9	4	14	18	1,3	8	59
Energy consumption (fossil fuel consumption)	118	0,93	11	15	47	2,02	93	192
CO2 emissions (10,000 tons)	159	0,96	7	19	37	2,03	106	237
	Low emission				High emission			
Gross industrial output value (Million US$)	39	0,89	6	93	72	1,81	21	226
Labour (10,000 people)	90	0,89	4	41	11	1,49	4	59
Energy consumption (fossil fuel consumption)	32	0,19	11	43	39	2,09	90	192
CO2 emissions (10,000 tons)	81	0,96	7	72	41	2,02	195	237

Source: Prepared by the author, based on Python 3.11.5 output.

Table 4 presents the descriptive statistics of the low and high energy consumption and CO2 emission groups in the Algerian industry. The statistical analysis presented in the tables provides some useful information about the relationship between energy consumption, CO_2 emissions, and economic development in the Algerian industrial sector. However, it is important to note that statistical correlation does not necessarily imply causation, and there may be other factors that influence sustainable economic development beyond the variables measured here. That being said, the fact that the low energy consumption and low CO_2 emission group had a lower mean energy consumption and CO_2 emission levels, while still achieving a comparable mean gross industrial output value, suggests that efficiency in energy usage and reducing emissions may contribute to sustainable economic development.

Table N°5

Estimated results of fixed-effects model beyond the logarithmic production function

Variables	Coefficient	Std. Dev	P-value	Variables	Coefficient	Std. Dev	P-value
Constant	1.0143	0.3434	0. 000	(1P2) lnB2	0. 0876	0.0001	0. 131
lnB_{it}	- 0.2041	0.1521	0. 384	(1P2) lnG2	0. 5310	0.0001	0. 000
lnG_{it}	0.5718	0.1637	0. 000	$tlnK_{it}$	- 0. 0207	0.1793	0. 000
$lnKlnL_{it}$	- 0.7302	0.0411	0. 031	$tlnL_{it}$	0.2816	0. 0011	0. 000
$lnKlnE_{it}$	0.4973	0.0188	0. 000	$tlnB_{it}$	0.2196	0. 0012	0. 000
$lnKlnC_{it}$	- 0. 3952	0.0113	0. 000	$tlnG_{it}$	0. 0421	0. 0042	0. 000
$lnLlnE_{it}$	- 0.1380	0.0563	0. 042	Std. Dev		**1. 4534**	
$lnLlnC_{it}$	- 0. 0175	0.0863	0. 043	Error standard		**0. 2762**	
$lnElnC_{it}$	- 0.1472	0.0617	0. 000	number of observations per group		**17**	
R2				**0.9248**			
Adj - R2				**0.9167**			
Durbin Watson				**2.1095**			

Source: Prepared by the author, based on Python 3.11.5 output.

The rationality of the model setting is verified by hypothesis testing. Firstly, compare the production function of transcendental logarithm and Cobb-Douglas (CD) form, and the null hypothesis is that CD production function is better than transcendental logarithm; secondly, test whether there is technological progress, and the null hypothesis is that there is no technological progress. If the panel data model is estimated by the fixed effect method, both null hypotheses can be completed by the general F test, because the fixed effect method is essentially a mixed least squares estimation of the variance model of the group transformation. These tests aim to ensure that the estimated coefficients are statistically significant and unbiased. Assuming the null hypothesis that the true coefficient is zero. A small p-value (typically less than 0.05) suggests that the corresponding independent variable is statistically significant and has a non-zero effect on the dependent variable. The overall significance test results show that the null hypothesis that the overall fit of the model is not significant can be rejected.

- (R^2= 0.9248): This is the coefficient of determination, which represents the proportion of the variance in the dependent variable that is explained by the independent variables. In this case, it is 0.9248, which suggests that the independent variables explain 92,48% proportion of the variation in the dependent variable. Which means that the model has a good fit and explains a significant portion of the variability in the response variable.

- Durbin Watson: A value close to 2 suggests no autocorrelation, while values above or below 2 suggest positive or negative autocorrelation, respectively. In this case, the value is 2.1095, which suggests no significant autocorrelation.
- Hausman test of fixed effect and random effect model setting: chi square (20) = 31 17, Prob> chi2= 0.0000. The Hausman test is used to compare the fixed effect and random effect model settings. The test results show that the null hypothesis that the random effect model is preferred over the fixed effect model can be rejected. The chi-square statistic value of 2831.26 is significant (p-value is less than 0.0000), which indicates that the fixed effect model is preferred over the random effect model. This means that the assumption of individual specification effects being uncorrelated with the independent variables is not met and the fixed effect model provides a better fit for the data.

Table N°6
Green Growth of Algeria by Industry

Industry	Industrial output value growth rate	Growth rate	Contribution of Factor Inputs			
			Productivity		Energy Efficiency	Emission
			Labour	Capital		
Hydrocarbon	0.1508	0.1011	0.1022	0.1803	0.1428	0.2983
Iron, steel and mining	0.0385	0.1043	0.0069	- 0.1007	- 0.0058	- 0.0123
Building materials	0.4623	0.1009	0.1474	0.1022	0.1022	0.1332

Source: Prepared by the author, based on Python 3.11.5 output.

Table 6 offers useful insight on Algeria's green growth by industry, which enables to identify individual growth trends, sustainable development challenges in each sub-sector, and potential areas for efficiency and sustainability improvement. Besides, table provides information on the green growth accounting results and factor contributions in various industries in Algeria. The table highlights the growth rate of the output value, total factor productivity (TFP) growth rate, and the growth rate and contributions of four input factors, namely labour, capital, energy, and materials.

According to an examination of the table, the highest industries in terms of the rate of growth of industrial output value are the chemical and petrochemical, building products, and hydrocarbon industries. The factors influencing each group's growth vary, though. For instance, TFP growth is mainly what drives the chemical and petrochemical sectors, while capital and energy are what mostly drive the building materials and hydrocarbons employers, respectively. The iron, steel, and mining industry, on the other hand, has a low rate of industrial output value growth and negative growth rate contributions from labour and capital elements, indicating potential areas for development in terms of sustainability and efficiency. The textile industry's negative labour and energy contributions point to possible areas for increased labour and energy productivity. The table also highlights how important productivity, emissions, and energy efficiency are to the growth. For instance, energy efficiency is crucial to the growth of the gas production and supply business, whereas emission considerations have a big impact on the development of the oil extraction sector.

5.2. Discussion:

This study appears to be the first to find that the model indicates that the logarithmic production function has a significant impact on sustainable economic development in the Algerian industrial sector. The balance of capital, labour, and gross industrial output has a positive impact on sustainable economic development, while energy consumption and carbon dioxide emissions have a negative impact. Furthermore, one interesting aspect that emerged from the analysis is that the model suggests a significant interaction effect between energy consumption on sustainable economic development.

The distinction between high and low energy consumption and emission groups aims to extract time-varying patterns of industry heterogeneity. Table 6 showed that the level of productivity of the Algerian industry has already witnessed an improvement in some sectors, such as oil extraction and gas production, as a result of Algeria's focus on developing them due to their revenues. Similar to (Ghedamsi et al., 2016) work, the present study shows the oil and gas industry is the primary driver of economic growth in the country, and efforts to diversify the economy have been limited. This lack of diversification leaves the economy vulnerable to fluctuations in the global oil market and prevents the development of other industries that could contribute to sustainable economic growth. While the expected finding was that increased labour and productivity lead to improved efficiency, this study showed that the changes in productivity levels do not necessarily correspond to higher energy consumption and higher pollution in the industry, although the effect may still vary.

The results indicate that different industries have distinct sources of industrial production growth, which are the outcome of the interaction of multiple growth drivers, including total factor productivity, labour contribution, energy consumption, and carbon emissions. Although labour does not contribute as much as expected, total factor productivity primarily drives industries with low energy usage and emissions. This could address the first question raised in this paper. A quick glance at Table 3 shows that most of the three industrial sub-sectors consider the effects of factor growth to be positive for total factor productivity and energy and capital requirements, while the impacts of labour output and CO2 emissions are primarily negative, suggesting a growth-hindering role. Thus, the second question raised in this paper can be answered: the productivity of the Algerian industry has indeed improved, but at a very slow pace. In the same way, through Table 5, the lack of diversification in the Algerian economy is a factor that makes it difficult to achieve sustainable economic development in industry.

These data are not consistent with those reported by (Chaouachi & Balsalobre-Lorente, 2022; Harouache, Chen, Sarpin, & Majeed, 2021; Lagha & Bachi, 2018; Nwani, Effiong, Okpoto, & Okere, 2021), who suggest that improving labour in many industries contributes to high levels of productivity. Interestingly, it was observed that the contribution of labour to the increase in productivity is not as high as expected as a result of low levels of education and skill in the workforce, and the labour force is underprepared in terms of education and skills. Also, outdated or ineffective work procedures reduce productivity. Workers have to spend extra time on jobs or may be compelled to do superfluous processes.

What particularly stands out is it is evident that the findings of this study differ from those anticipated. The reforms that were implemented resulted in minimal changes, and their impact on factors such as productivity, energy efficiency did not significantly reduce carbon dioxide emissions. This is due to the nature of the Algerian economy, where hydrocarbons are the primary source of industrial growth, posing the greatest obstacle to green growth. Industries driven by capital and energy, particularly the oil and natural gas mining industry, are the primary source of carbon dioxide emissions. On the other hand, other industries do not have a substantial impact on industrial growth in Algeria.

6. Conclusion

While debates among economists about the best way to reach sustainable economic development continue. In this study, we examined the patterns of energy consumption and productivity in Algeria's industrial sector and their impact on carbon dioxide emissions. The study employed KELM model from 03 branches of industry sector in the period 1990 to 2021. The analysis considers the constraints posed by energy consumption and emissions through the utilization of logarithmic production function based on energy consumption and emissions constraints, and segments it through green growth accounting.

Our findings reveal a complex scenario. Contrary to widespread assumptions, increased labour input does not necessarily lead to higher productivity levels. This insight challenges traditional beliefs about industrial efficiency and labour dynamics in Algeria. A crucial revelation of our study is the Algerian industry's heavy reliance on hydrocarbon sources. This dependence significantly impedes the nation's journey towards sustainable economic development. Such a model is not only unsustainable in the long run but also counterproductive to global environmental efforts. Besides, although the extractive industry with high energy consumption and emissions has generally improved, it still lags behind the national average. Some heavy and chemical industries continue to grow and rely on factor inputs and which become a hindrance to overall industrial productivity. Additionally, our study underscores the urgent need to overhaul the structural underpinnings of the Algerian economy. Moving away from a hydrocarbon-centric economic model to a diversified, technology-driven industrial economy is crucial. This shift is vital not just for Algeria's sustainable future but also as a commitment to global environmental stewardship.

To ensure sustainable economic development in the future, we recommend that: Firstly, the introduction of carbon pricing schemes can serve as a financial incentive to reduce emissions. Secondly, the role of renewable energy sources, especially solar power, in Algeria is promising. Investing in these resources is crucial for enhancing energy efficiency and reducing environmental impacts. Thirdly, offering tax incentives for green technology can catalyse a much-needed transition to low-emission industrial processes. Also, to achieve sustainable growth in the industry in the future, we must always adhere to the principle that science and technology are the basic productive forces. Efforts should be made to develop high-tech industries with low energy consumption and low emissions per unit of added value and accelerate the transformation of traditional heavy industries. In addition, the Algerian economy is currently not classified as an agricultural or industrial economy, and therefore, this requires addressing structural constraints and contradictions that hinder growth and the sustainable development of the real economy in Algeria. These strategies are not mere suggestions; they are imperative for the transformation of Algeria's industrial framework into a sustainable, environmentally responsible model.

This study on Algeria's industrial sector's energy consumption, productivity, and CO2 emissions acknowledges key limitations. Primarily, the absence of comprehensive data across all industrial branches limited our analysis, affecting the generalizability of our findings. This data gap suggests that more inclusive datasets might yield different results. Future research should aim to encompass a wider range of industrial sectors, especially from countries with richer data sources. Additionally, our study's exclusion of renewable energy as a variable is a notable limitation. Incorporating this factor in future research could significantly enhance our understanding of sustainable industrial development.

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