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Investigating the Sustainable Value Chain of Petroleum Products in Iraq

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ABSTRACT

The present study aims to explain the mechanisms through which economic sustainability is achieved in the value chain of Iraqi petroleum products, by identifying and modelling the relationships among institutional, managerial, and environmental factors. In terms of purpose the research is applied, and in terms of nature it is descriptive-analytical with a mixed approach. In the first stage a set of variables affecting sustainability was extracted and the research instrument was designed. In the quantitative stage, data were collected through a researcher-made questionnaire based on a five-point Likert scale from 600 managers and experts active in the value chain of Iraq's oil industry. After data pre-processing and confirming the adequacy of the sample size, exploratory factor analysis was performed, which reduced 103 items to 26 latent variables and ultimately to 8 main constructs to validate the conceptual model and test the research hypotheses, partial-least-squares structural-equation modelling was applied using Smart-PLS software. The findings of the structural model showed that environmental performance has a positive and significant effect on economic sustainability, and that this variable is significantly influenced by resource efficiency and the regulatory and governance framework, whereas the direct effects of variables such as human capital, technological progress, social responsibility, and commitment to strategic planning on environmental performance were not statistically significant. The coefficient of determination for environmental performance and economic sustainability indicates an acceptable explanatory power of the proposed model. Overall, the results show that, in Iraq's oil industry, achieving economic sustainability depends more on governance effectiveness, genuine resource efficiency, and improved environmental performance than on symbolic managerial measures a finding that can serve as a basis for policymaking and strategic decision-making at both the firm and macro levels.

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INTRODUCTION

As the backbone of Iraq's economy, the oil industry plays a decisive role in the country's gross domestic product, foreign-currency revenues, employment, and fiscal stability; nevertheless, the national economy's heavy reliance on this industry has exposed it to deep structural, environmental, and institutional challenges. In recent decades, the rapid expansion of upstream and downstream oil activities, together with weak regulatory frameworks, deteriorating infrastructure, and inefficiency in resource management, has intensified negative environmental consequences including air, water, and soil pollution, increased gas flaring, energy waste, and the destruction of local ecosystems. These consequences have not only imposed considerable social and environmental costs on the country, but in the long run have also seriously threatened the economic sustainability of the oil industry, such that the continuation of profitability and competitive advantage in this industry appears practically unattainable without attention to sustainability requirements. In the sustainable-development literature, particularly in the field of energy-intensive industries, there is growing emphasis on the transition from traditional, purely economic exploitation patterns towards integrated approaches that combine economic, environmental, and social sustainability. However, a considerable part of the existing research has either focused on developed countries or analyzed sustainability in a one-dimensional manner, detached from the institutional and governance context. In the case of Iraq, despite the strategic importance of the oil industry, there is a tangible gap in empirical studies capable of explaining, in a data-driven and systematic way, the causal relationships among institutional, managerial, and technical factors with environmental performance and ultimately economic sustainability. In particular, it is not clear which components act as the main drivers under the real conditions of Iraq's oil industry, and which factors despite their

theoretical importance in practice have no significant effect on improving sustainability outcomes (Kai et al., 2026). On the other hand, the policymakers and managers of Iraq's oil industry face financial-resource constraints, political pressures, international environmental requirements, and social expectations, and are inevitably compelled to set their strategic priorities on the basis of credible evidence. The absence of a localized quantitative model capable of demonstrating the pathways of influence of variables such as the regulatory and governance framework, resource efficiency, technological progress, human capital, and social responsibility on environmental performance and economic sustainability has caused decisions to be made, more often than not, in a piecemeal, reactive, and strategically incoherent manner. This situation has increased the risk of resource waste, the persistence of inefficiency, and the intensification of environmental consequences, and has limited the possibility of a purposeful move towards a sustainable value chain of petroleum products (Alkaraan et al., 2025).

On this basis, the main problem of the present research is how, and through which pathways, economic sustainability is achieved in the real context of Iraq's oil industry, and what role can be envisaged for environmental performance as a mediating variable between institutional and operational factors. Specifically, this research seeks by identifying and reducing the key variables affecting sustainability, and by relying on advanced statistical analyses to present a quantitative and empirical model capable of explaining the causal relationships among regulatory and governance frameworks, resource efficiency, and other organizational factors with environmental performance and ultimately economic sustainability. Solving this problem not only addresses the existing knowledge gap in the literature on oil-industry sustainability in developing countries, but can also provide a scientific basis for designing practical policies and strategies aimed at ensuring the long-term

survival, efficiency, and economic and social legitimacy of Iraq's oil industry (Borj et al., 2025).

MATERIALS AND METHODS

The research literature in the field of oil-industry sustainability shows that, over the past two decades, the concept of sustainability has evolved from a purely environmental approach into a multidimensional and integrated framework that simultaneously encompasses the economic, environmental, social, and institutional dimensions. According to the classical view of the Brundtland Commission, sustainable development requires meeting the needs of the present generation without jeopardizing the ability of future generations; nevertheless, recent research emphasizes that, in extraction-based industries such as oil and gas, achieving this goal is possible only through a redefinition of the value chain and of the manner of governing natural resources. Numerous studies have shown that an exclusive focus on maximizing short-term profit in the oil industry leads to long-term hidden costs including environmental destruction, social dissatisfaction, increased operational risks, and reduced institutional legitimacy factors that ultimately weaken the economic sustainability of firms and even of the national economy. From this perspective, economic sustainability is regarded not as the opposite of environmental requirements, but as the direct outcome of responsible resource management and the reduction of non-financial risks. In the environmental dimension, a considerable part of the literature emphasizes that environmental performance is a key and mediating variable in the relationship between managerial structures and economic outcomes. Studies show that firms with better performance in controlling pollutant emissions, reducing gas flaring, managing waste, optimizing water and energy consumption, and complying with environmental standards enjoy, in the long run, lower operational costs, lower legal risk, and easier access to international markets. This approach also explained within the

theoretical framework of the "Porter hypothesis" holds that efficient environmental regulations can stimulate innovation and lead to the simultaneous improvement of environmental and economic performance. However, empirical evidence in developing countries, especially in the oil industries, has reported heterogeneous results, indicating that the effect of this variable is strongly dependent on the institutional context, the level of governance, and the efficiency of regulatory mechanisms (Chofreh et al., 2025). In this regard, regulatory and governance frameworks are presented as one of the main pillars of the theoretical framework of sustainability. The literature on natural-resource governance shows that the existence of transparent laws, independent regulatory institutions, accountability, corruption control, and the effective enforcement of regulations is a necessary condition for translating sustainability goals into practical outcomes (Chung and Jin, 2025). In the absence of such frameworks, even heavy investments in clean technologies or social-responsibility programmers are often limited to symbolic and short-term results. Studies conducted in resource-dependent economies emphasize that weak governance leads to the "resource curse" a situation in which the abundance of natural resources, far from leading to sustainable development, weakens institutions, reduces productivity, and intensifies environmental degradation. From this perspective, the theoretical framework of the present research treats governance as a driving variable in improving environmental performance and, ultimately, economic sustainability (Fan & Bussracumpakorn, 2025). Resource efficiency likewise holds a central place in the industrial-sustainability literature and is often introduced as the link connecting the technical, environmental, and economic dimensions. Approaches such as cleaner production, the circular economy, and energy efficiency rest on the assumption that reducing the intensity of resource and energy consumption simultaneously reduces pressure on the environment

and improves economic efficiency. In the oil industry, resource efficiency not only helps reduce production costs and energy waste, but also plays a decisive role in reducing greenhouse-gas emissions and other pollutants. Nevertheless, studies show that achieving resource efficiency in heavy industries, rather than being the result of short-term managerial measures, requires structural reforms, long-term investments, and the alignment of macro-policies with sustainability goals. This view provides the theoretical basis for treating resource efficiency as one of the most important predictors of environmental performance in quantitative sustainability models (Shurpali et al., 2025, Ali et al., 2022, Chudik and Pesaran, 2015). Alongside institutional and technical factors, variables such as human capital, technological progress, commitment to strategic planning, and corporate social responsibility have also received broad attention in the sustainability literature. Human-capital theory emphasizes that the skills, knowledge, and competencies of the workforce are preconditions for innovation and the improvement of organizational performance; however, empirical evidence in the oil industries of developing countries shows that the effect of this variable is often indirect and dependent on the existence of supportive institutional structures. (Awan et al., 2022, Ameer et al., 2024). Similarly, modern environmental and digital technologies, in the absence of binding policies and economic incentives, do not necessarily lead to sustained performance improvement. Social responsibility is also presented in the literature as a tool for enhancing the social legitimacy of firms, but many studies warn that, in the absence of a genuine link to operational and environmental strategies, such measures are reduced to symbolic activities (Chettri et al., 2025, Ashraf et al., 2022). On this basis, the theoretical framework of the present research rests on a multi-level causal logic in which the regulatory and governance framework and resource efficiency, as exogenous and driving variables, shape environ-

mental performance, and environmental performance in turn, as a mediating variable, plays a decisive role in achieving economic sustainability. While consistent with modern theories of sustainability and resource governance, this framework attempts to fill the gap in the empirical literature concerning Iraq's oil industry and to present a localized, data-driven, and testable model capable of explaining the complexity of the relationships among the different dimensions of sustainability in a strategic and sensitive industry.

Methodology

From an ontological standpoint, the present research falls within the positivist paradigm, and in terms of purpose it is classified as applied research that, by adopting a sequential-exploratory mixed-methods approach, seeks to explain the causal relationships among the components of sustainability in Iraq's oil industry. Owing to its examination of the existing situation and its explanation of the relationships among variables, the nature of the research is descriptive-analytical, with the first phase resting on inductive logic and the second on deductive logic. In the qualitative stage, drawing on a content-analysis strategy and a systematic review of the literature, the initial dimensions of sustainability were extracted, and after convening an expert panel, the research measurement instrument was designed in accordance with the local context of Iraq's oil industry. This qualitative process led to the identification of the operational indicators and items that formed the basis of the researcher-made questionnaire. In the quantitative phase, the statistical population comprised all managers, policymakers, and senior experts active in the value chain of Iraqi petroleum products; using a stratified random sampling method, a sample of 600 individuals was selected. The data collected through a five-point Likert-scale questionnaire after passing through data-cleaning filters and confirmation

of the Kaiser–Meyer–Olkin (KMO) sampling-adequacy index and Bartlett’s test of sphericity entered the stage of advanced statistical analyses. At the inferential-analysis layer, exploratory factor analysis (EFA) with orthogonal (Varimax) rotation was first used to identify the factor structure and reduce the dimensions of the research. This statistical process led to the summarization and classification of the 103 initial items into 26 latent variables and ultimately 8 main constructs, which formed the foundation of the research’s conceptual model. After establishing the factor structure, partial-least-squares structural-equation modelling (PLS-SEM) was used with SmartPLS version 4 to test the hypotheses and validate the overall model. This method was chosen because of its high capability in handling complex models with a large number of constructs, as well as its non-parametric nature, which does not require the assumption of a normal data distribution. In this regard, the measurement models were first assessed in terms of indicator reliability, composite reliability (CR), Cronbach’s alpha, and convergent (AVE) and discriminant validity (based on the Fornell–Larcker criterion and the HTMT index). After confirming the quality of the measurement models, the structural model was analyzed to examine the path coefficients (β), the significance statistics (T-values), and the coefficient of determination (R^2), so that the predictive power of the model and the validity of the assumed relationships among the regulatory frameworks, resource efficiency, environmental performance, and economic sustainability could be empirically tested in the context of Iraq’s oil industry.

FINDINGS AND DISCUSSION

The descriptive statistics of this study were conducted with the aim of describing the characteristics of the sample and ensuring its representativeness of the statistical population; they showed that, although the data are organized systematically in tables and charts, their results are not inherently generalizable directly to the

entire target population. The gender composition of the sample indicates a predominance of female respondents (83.35 percent) compared with male respondents (16.64 percent), and in terms of age the greatest concentration of the sample lies in the 26-to-36 range, followed by the 37-to-47 age group with the highest frequency. Before the final analysis, the data were refined through a systematic pre-processing procedure including the identification and removal of indifferent respondents, the examination of duplicate cases, the control of outliers, and the assessment of missing data, leaving 600 valid observations for analysis. The sampling-adequacy and sphericity tests (KMO = 0.788 and the significance of Bartlett’s test at the 99 percent confidence level) confirmed the suitability of the data for exploratory factor analysis. Moreover, the validity and reliability of the instrument at the exploratory stage were assessed at an acceptable level using the Guttman test, and 26 latent factors with factor loadings above 0.5 were extracted. The examination of the descriptive indices of the questionnaire items also showed that all values lay within the permissible range of the five-point Likert scale, and, based on Kline’s suggested skewness and kurtosis criteria, the data distribution is in an acceptable condition in terms of normality a fact that makes it possible to continue the statistical analyses in the subsequent stages of the research. As the means of the variables in the sample show, all are above the value of 3 (the mid-point), indicating that the variables enjoy relative agreement within the sample; on the other hand, Stevens (2002) stated that, for each variable to be free of respondents’ indifferent answers, the dispersion of responses must be greater than 0.5; otherwise, none of the inferential-statistics tests will be valid. It can be seen that this condition is also met, and finally the two indices of skewness and kurtosis for the variables fall within their permissible range that is, the necessary and sufficient condition for the normality of the data distribution is satisfied,

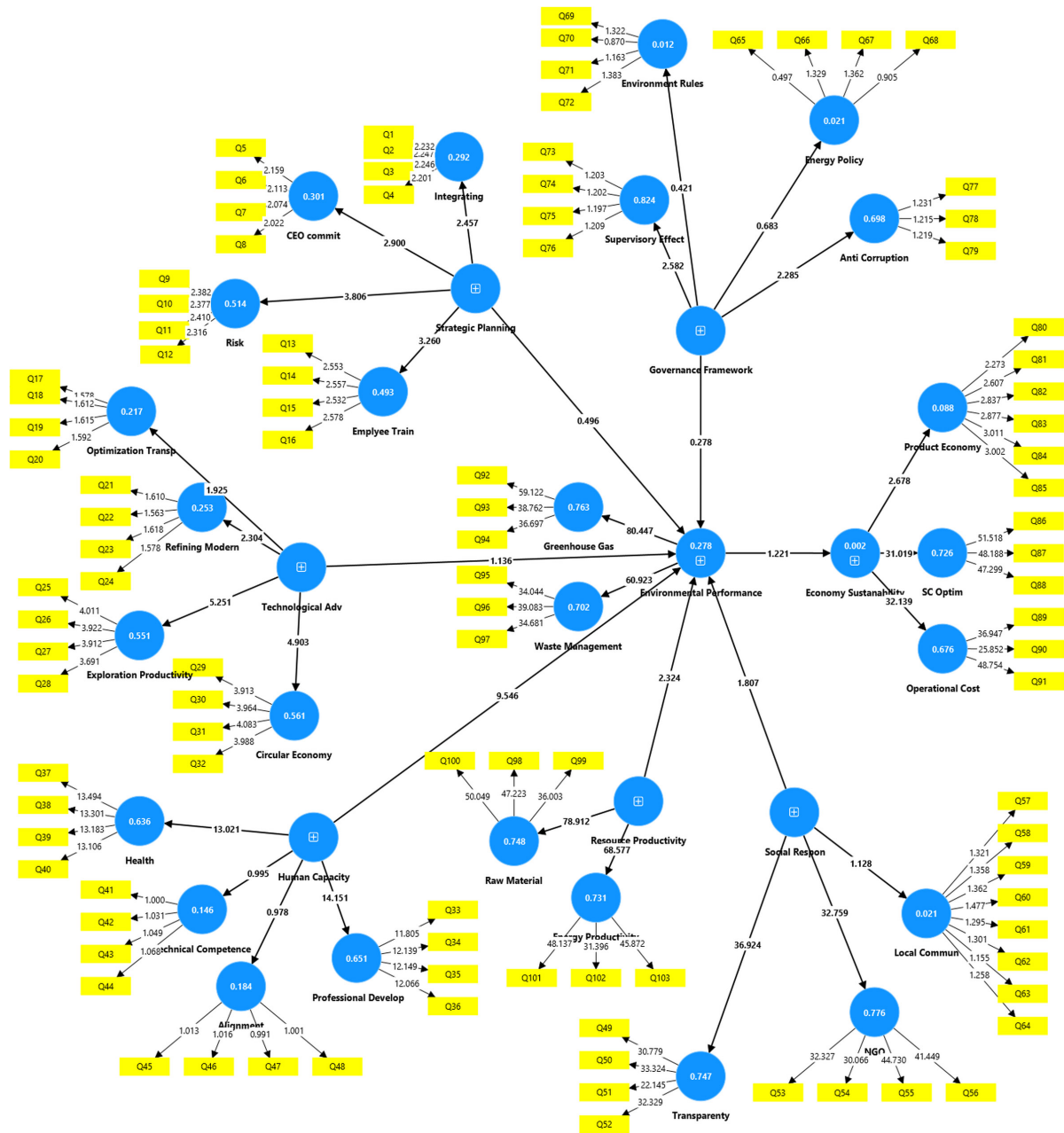


Figure 2: The initial reflective outer model in the coefficient-significance (T-value) mode (source: author, from the SmartPLS output).

Test of indicator homogeneity (confirmatory factor analysis)

Confirmatory factor analysis (CFA), or the covariance-based measurement model, is performed to examine the homogeneity of the indicators of

a latent variable. According to Ringle (2016), the researcher's goal is to ensure a high correlation among the questionnaire indicators with one another. This test is run as a prerequisite for the other tests. In this process, confirmatory factor

analysis removes the indicators that play little role in measuring the variables and refines the model. Following the recommendation of Hair (2010) and Henseler (2009), the researcher must examine the factor loadings (the standardized correlation coefficients between the latent and manifest variables). These factor loadings should be greater than 0.7 so that the indicators

can be claimed to be homogeneous and unidimensional and be retained in the model. However, Hair (2010) introduced an exception: if the factor loading is above 0.65 and the reliability tests show no problems, that indicator may be retained in the model (Moradi & Miralmsi, 2019: 211). The factor loadings obtained are reported in Table 1. (Tab. 1)

Table 1: Factor loadings of the initial reflective outer model - confirmatory factor analysis (source: author, from the SmartPLS output).

Construct	Indicators (factor loadings)
Sustainability Integration	Q1 (0.759), Q2 (0.779), Q3 (0.762), Q4 (0.780)
Top Management Commitment	Q5 (0.771), Q6 (0.771), Q7 (0.775), Q8 (0.777)
Risk Management & Resilience	Q9 (0.787), Q10 (0.808), Q11 (0.766), Q12 (0.788)
Employee Engagement & Training	Q13 (0.792), Q14 (0.745), Q15 (0.770), Q16 (0.785)
Transport & Storage Optimization	Q17 (0.748), Q18 (0.785), Q19 (0.737), Q20 (0.765)
Refining Process Modernization	Q21 (0.764), Q22 (0.720), Q23 (0.758), Q24 (0.744)
Exploration & Production Efficiency	Q25 (0.761), Q26 (0.765), Q27 (0.712), Q28 (0.731)
Circular Economy Initiatives	Q29 (0.780), Q30 (0.797), Q31 (0.784), Q32 (0.701)
Professional Development	Q33 (0.743), Q34 (0.771), Q35 (0.797), Q36 (0.798)
Health & Safety	Q37 (0.749), Q38 (0.743), Q39 (0.737), Q40 (0.754)
Technical Competence	Q41 (0.625), Q42 (0.723), Q43 (0.728), Q44 (0.757)
Educational System Alignment	Q45 (0.720), Q46 (0.810), Q47 (0.712), Q48 (0.789)
Transparency & Accountability	Q49 (0.728), Q50 (0.739), Q51 (0.675), Q52 (0.745)
Government-NGO Collaboration	Q53 (0.734), Q54 (0.729), Q55 (0.778), Q56 (0.780)
Local Community Development	Q57 (0.673), Q58 (0.619), Q59 (0.693), Q60 (0.709), Q61 (0.664), Q62 (0.588), Q63 (0.610), Q64 (0.604)
Energy Sector Policies	Q65 (0.309), Q66 (0.842), Q67 (0.776), Q68 (0.568)
Environmental Regulations	Q69 (0.761), Q70 (0.525), Q71 (0.688), Q72 (0.845)
Regulatory Body Effectiveness	Q73 (0.786), Q74 (0.706), Q75 (0.779), Q76 (0.811)
Anti-corruption Measures	Q77 (0.815), Q78 (0.770), Q79 (0.778)
Sustainable Product Economy	Q80 (0.544), Q81 (0.662), Q82 (0.660), Q83 (0.702), Q84 (0.699), Q85 (0.688)
Supply Chain Optimization	Q86 (0.818), Q87 (0.812), Q88 (0.810)
Operational Cost Reduction	Q89 (0.776), Q90 (0.720), Q91 (0.802)
GHG Emission Reduction	Q92 (0.827), Q93 (0.784), Q94 (0.774)
Waste Management	Q95 (0.763), Q96 (0.773), Q97 (0.757)
Raw Material Conservation	Q98 (0.804), Q99 (0.770), Q100 (0.815)
Energy Efficiency	Q101 (0.810), Q102 (0.753), Q103 (0.795)

Based on the results of the table, the indicators measuring the variables whose loadings are not above 0.7 can be removed. Accordingly,

indicators Q56-Q58, Q61-Q63, Q65, Q68, Q70, and Q80-Q82 were removed from the set of research items and their corresponding variables.

In addition, components with factor loadings below 0.5 were removed from their related latent variable in the model.

Cronbach's alpha

Cronbach's alpha is considered the oldest test

of indicator consistency among the reliability tests. This test addresses the internal correlation of the items of a variable outside the model. According to Tenenhaus (2005), the correlation of the items of a variable should be at least above 0.7. (Tab. 2)

Table 2: Cronbach's alpha test

Construct	Cronbach's alpha
Educational System Alignment	0.755
Anti-corruption Measures	0.794
Top Management Commitment	0.778
Circular Economy Initiatives	0.765
Employee Engagement & Training	0.776
Energy Sector Policies	0.731
Energy Efficiency	0.791
Environmental Regulations	0.726
Exploration & Production Efficiency	0.729
GHG Emission Reduction	0.709
Health & Safety	0.734
Sustainability Integration	0.772
Local Community Development	0.806
Government-NGO Collaboration	0.749
Operational Cost Reduction	0.750
Transport & Storage Optimization	0.754
Professional Development	0.782
Raw Material Conservation	0.712
Refining Process Modernization	0.736
Risk Management & Resilience	0.796
Supply Chain Optimization	0.744
Regulatory Body Effectiveness	0.773
Technical Competence	0.775
Transparency & Accountability	0.794
Waste Management	0.745

Fortunately, all the research components have a Cronbach's alpha coefficient of 0.70 and above, indicating an acceptable reliability of the items in each group of variables.

Composite reliability (Dillon-Goldstein's rho)

This is the most important reliability test of the model in all structural-equation-modelling soft-

ware, because its definition is similar to that of Cronbach's alpha, with the difference that it estimates the correlation of the items of a variable inside the model; and because many parameters such as factor loading, path coefficient, and measurement error affect the model, this coefficient expresses the true reality of the generalizability of the results. According to Henseler (2009), the

value of this coefficient, like Cronbach's alpha, must be above 0.7 for each variable. (Tab. 3)

Table 3: Composite reliability test - Dillon-Goldstein's rho

Construct	CR
Educational System Alignment	0.831
Anti-corruption Measures	0.856
Top Management Commitment	0.850
Circular Economy Initiatives	0.688
Employee Engagement & Training	0.856
Energy Sector Policies	0.829
Energy Efficiency	0.828
Environmental Regulations	0.831
Exploration & Production Efficiency	0.843
GHG Emission Reduction	0.838
Health & Safety	0.834
Sustainability Integration	0.832
Local Community Development	0.854
Government-NGO Collaboration	0.842
Operational Cost Reduction	0.810
Transport & Storage Optimization	0.844
Professional Development	0.859
Raw Material Conservation	0.839
Refining Process Modernization	0.834
Risk Management & Resilience	0.838
Supply Chain Optimization	0.867
Regulatory Body Effectiveness	0.854
Transparency & Accountability	0.833
Waste Management	0.855

Spearman correlation of indicators (rho_A)
 Many researchers in the field of statistics believe that the Likert scale is inherently an ordinal scale, and that researchers in the humanities cannot rely on Cronbach's alpha and composite reliability, which use Pearson's correlation formula a parametric test for the correlation of

their items. To answer this criticism, Ringle added a test to the PLS software in 2017 called rho_A, which is in fact the non-parametric Spearman correlation among the items, so as to show that the results do not change. Therefore, following Ringle's view, the cut-off point for each variable is 0.7. (Tab. 4)

Table 4: Spearman correlation test of the indicators – rho_A

Construct	rho_A
Educational System Alignment	0.755
Anti-corruption Measures	0.794
Top Management Commitment	0.778

Circular Economy Initiatives	0.765
Employee Engagement & Training	0.776
Energy Sector Policies	0.731
Energy Efficiency	0.791
Environmental Regulations	0.726
Exploration & Production Efficiency	0.729
GHG Emission Reduction	0.709
Health & Safety	0.734
Sustainability Integration	0.772
Local Community Development	0.806
Government-NGO Collaboration	0.749
Operational Cost Reduction	0.750
Transport & Storage Optimization	0.754
Professional Development	0.782
Raw Material Conservation	0.712
Refining Process Modernization	0.736
Risk Management & Resilience	0.796
Supply Chain Optimization	0.744
Regulatory Body Effectiveness	0.773
Transparency & Accountability	0.794
Waste Management	0.745

Communality reliability

This is the only test that does not assess reliability on the basis of the correlation of the items; rather, this coefficient examines whether the factor-loading results are replicated from one population to another. The method uses the

communality index, which must be above 0.5 for each variable. Moreover, unlike the previous version, this index is not computed in SmartPLS 4; but because its formula is exactly the same as that of AVE, we can substitute the AVE values for it. (Tab. 5)

Table 5: Communality-reliability test (AVE)

Construct	AVE
Educational System Alignment	0.621
Anti-corruption Measures	0.599
Top Management Commitment	0.588
Circular Economy Initiatives	0.598
Employee Engagement & Training	0.618
Energy Sector Policies	0.552
Energy Efficiency	0.632
Environmental Regulations	0.557
Exploration & Production Efficiency	0.593
GHG Emission Reduction	0.571
Health & Safety	0.588

Sustainability Integration	0.576
Local Community Development	0.605
Government-NGO Collaboration	0.635
Operational Cost Reduction	0.558
Transport & Storage Optimization	0.620
Professional Development	0.661
Raw Material Conservation	0.596
Refining Process Modernization	0.522
Risk Management & Resilience	0.585
Supply Chain Optimization	0.514
Regulatory Body Effectiveness	0.563
Transparency & Accountability	0.601
Waste Management	0.548

Since the four tests of Cronbach’s alpha, composite reliability, the rho_A index, and communality reliability all yield acceptable results, the reliability of the construct is confirmed.

Model validity tests

The validity of the model is first assessed, prior to data collection, through the examination of face validity and content validity. Then, to ensure that the researcher’s standard instrument measures exactly the variables it is intended to measure, the validity and reliability of the construct must be examined. According to Gefen (2016), construct validity consists of two parts: convergent validity and discriminant validity. Convergent validity means that the reflective indicators of a variable, disregarding errors, should correlate and converge with one another.

Discriminant validity (also called divergent or differential validity) means the lack of correlation between the indicators of one variable or component and the indicators of another. In the global scientific and academic community, the most important criterion for the acceptability of quantitative research is its possession of discriminant validity. On this basis, the tests related to these two types of validity are run.

Convergent-validity tests

For this type of model validity to hold, two basic conditions exist. The first concerns the average variance extracted, where the value of AVE must be greater than 0.5; and the second is its comparison with composite reliability, according to which it is necessary that $CR > AVE$. (Tab. 6)

Table 6: Convergent-validity test

Construct	CR	AVE
Educational System Alignment	0.831	0.621
Anti-corruption Measures	0.856	0.599
Top Management Commitment	0.850	0.588
Circular Economy Initiatives	0.688	0.598
Employee Engagement & Training	0.856	0.618
Energy Sector Policies	0.829	0.552
Energy Efficiency	0.828	0.632

Environmental Regulations	0.831	0.557
Exploration & Production Efficiency	0.843	0.593
GHG Emission Reduction	0.838	0.571
Health & Safety	0.834	0.588
Sustainability Integration	0.832	0.576
Local Community Development	0.854	0.605
Government–NGO Collaboration	0.842	0.635
Operational Cost Reduction	0.810	0.558
Transport & Storage Optimization	0.844	0.620
Professional Development	0.859	0.661
Raw Material Conservation	0.839	0.596
Refining Process Modernization	0.834	0.522
Risk Management & Resilience	0.838	0.585
Supply Chain Optimization	0.867	0.514
Regulatory Body Effectiveness	0.854	0.563
Transparency & Accountability	0.833	0.601
Waste Management	0.855	0.548

As the table above shows, these two conditions are met and the first and second conditions of convergent validity hold. It can therefore be claimed that the outer model of the research has convergent validity that is, the indicators of each latent variable converge and are collinear with one another.

Discriminant-validity tests

The discriminant-validity tests are examined as the most important tests of the outer model, and if a problem exists, the field-operations process must be repeated from the beginning. According to Sarstedt (2016), the researcher may remove items that contribute little to measuring a variable only at the homogeneity-testing (confirmatory factor analysis) stage. After these corrections, the researcher is no longer permitted to remove or change the model under any justification.

Discriminant validity using the cross-loading table (cross loadings).

In this test, a cross-table of factor loadings is presented in which each item is connected not only to its own latent variable but also to all the other latent variables, in order to ensure that each indicator or item measures only its corresponding variable and does not interfere with the other variables (Chin, 2010). The researcher must determine the factor loading of each item for its related variable and ensure that this factor loading is at least 0.1 greater than the loading of the same item on the other variables. The results of this section, presented in Table 1, indicate the confirmation of discriminant validity at this stage.

The Fornell–Larcker test.

The Fornell–Larcker discriminant-validity test is one of the widely used methods in the analysis of structural-equation-modelling data, employed to assess the discriminant validity of the constructs of a model. This test examines whether the various constructs in a model are sufficiently distinct from one another. According

to the Fornell–Larcker criterion, to confirm discriminant validity, the square root of the average variance extracted (AVE) of each construct must be greater than that construct’s correlation with the other constructs of the model. This method

ensures that each construct has a distinct identity and does not overlap illogically with the others, which is essential for ensuring the validity and accuracy of the structural-analysis results. (Tab. 7)

Table 7: The Fornell–Larcker test. Columns are numbered as the rows; diagonal values (in bold) are the square root of AVE. Row 19 is reported in the source as a second “Regulatory Body Effectiveness”; based on the construct set it almost certainly corresponds to “Technical Competence” (see the audit note) (source: author).

Construct	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. Anti-corruption Measures	0.788																				
2. Top Management Commitment	-0.002	0.774																			
3. Circular Economy Initiatives	-0.006	0.022	0.766																		
4. Employee Engagement & Training	0.459	0.044	0.041	0.773																	
5. Energy Efficiency	-0.004	-0.006	0.060	0.021	0.786																
6. Exploration & Production Efficiency	-0.033	0.046	0.548	0.045	0.046	0.743															
7. GHG Emission Reduction	0.038	-0.017	-0.033	0.006	-0.013	0.004	0.795														
8. Health & Safety	0.057	-0.011	-0.020	0.054	0.039	-0.060	0.445	0.746													
9. Sustainability Integration	-0.024	0.547	-0.036	0.000	0.019	0.024	0.052	-0.012	0.770												
10. Government-NGO Collaboration	0.010	-0.071	0.049	0.014	0.055	0.045	-0.079	-0.026	-0.070	0.756											
11. Operational Cost Reduction	-0.004	-0.057	0.439	0.040	0.002	0.408	-0.016	-0.087	-0.012	0.024	0.767										
12. Transport & Storage Optimization	-0.044	0.051	0.012	-0.002	0.032	0.007	-0.058	-0.047	0.037	0.043	-0.013	0.759									
13. Professional Development	0.007	-0.012	-0.030	0.056	-0.013	-0.021	0.433	0.523	-0.016	0.041	-0.043	0.008	0.778								
14. Raw Material Conservation	-0.038	0.045	0.067	-0.049	0.479	0.036	0.067	0.045	0.086	-0.011	0.005	0.007	0.007	0.797							
15. Refining Process Modernization	-0.046	0.039	0.029	0.026	0.035	0.054	-0.025	0.014	0.070	-0.039	0.034	0.506	0.062	0.069	0.747						
16. Risk Management & Resilience	0.450	0.015	-0.016	0.554	0.005	-0.043	0.020	0.024	0.043	0.002	0.028	-0.045	0.020	-0.042	-0.046	0.787					
17. Supply Chain Optimization	-0.036	-0.013	0.463	0.030	0.048	0.424	-0.027	-0.053	-0.077	0.056	0.485	0.025	-0.029	0.050	0.011	-0.030	0.813				
18. Regulatory Body Effectiveness	-0.018	-0.041	0.011	-0.013	0.064	0.034	-0.082	-0.019	-0.040	0.891	0.009	0.051	0.045	0.014	-0.032	0.008	0.051				
19. Regulatory Body Effectiveness	0.548	0.041	0.000	0.498	-0.008	-0.041	0.030	0.070	0.006	0.041	-0.018	0.058	0.022	-0.058	0.056	0.478	0.006	0.772			
20. Transparency & Accountability	-0.044	0.005	-0.033	-0.038	0.058	0.014	-0.067	-0.009	0.006	0.543	-0.010	0.044	0.035	0.038	-0.019	0.011	0.030	-0.016	0.722		
21. Waste Management	0.011	0.049	-0.050	0.025	0.054	-0.031	0.486	0.400	0.061	-0.061	-0.081	-0.021	0.360	0.042	-0.019	0.014	-0.005	0.047	0.010	0.765	

As the table above shows, the square root of the AVE of each variable is greater than that variable’s correlation with the other variables, which demonstrates the confirmation of discriminant validity among the variables. Now the last and most important discriminant-validity test, namely the heterotrait–monotrait test, is run.

The HTMT test (heterotrait–monotrait)

The HTMT test is one of the statistical methods used in the analysis of measurement models in social and behavioral research, employed to assess the discriminant validity among the constructs of a model. This test computes the ratio of the between-trait correlations to the with-

in-trait correlations to determine whether the constructs are clearly distinct from one another. In this method, HTMT values below 0.85 or 0.9 (depending on the criterion used) indicate appropriate discriminant validity among the constructs. (Tab. 8)

All pairs of variables have a heterotrait–monotrait ratio below 0.9. Therefore, in view of the result of this test, as well as the two tests of cross-loadings and Fornell–Larcker, the validity and discriminant validity of the research model are confirmed; and, given that convergent validity also holds, the researcher now claims that the first model has construct validity on the basis of the instrument and the data collected.

Table 8: The HTMT (heterotrait–monotrait) test. Columns are numbered as the rows. Row 19 is reported in the source as a second “Regulatory Body Effectiveness” and almost certainly corresponds to “Technical Competence” (see the audit note) (source: author).

Construct	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. Anti-corruption Measures																					
2. Top Management Commitment	0.052																				
3. Circular Economy Initiatives	0.056	0.055																			
4. Employee Engagement & Training	0.625	0.076	0.081																		
5. Energy Efficiency	0.050	0.070	0.091	0.065																	
6. Exploration & Production Efficiency	0.065	0.084	0.732	0.078	0.065																
7. GHG Emission Reduction	0.080	0.063	0.059	0.053	0.049	0.053															
8. Health & Safety	0.104	0.084	0.071	0.095	0.073	0.092	0.616														
9. Sustainability Integration	0.039	0.701	0.069	0.051	0.077	0.047	0.075	0.080	0.106												
10. Government-NGO Collaboration	0.033	0.111	0.078	0.044	0.095	0.071	0.108	0.081	0.141	0.098											
11. Operational Cost Reduction	0.081	0.100	0.626	0.109	0.080	0.593	0.076	0.137	0.116	0.065	0.052										
12. Transport & Storage Optimization	0.090	0.085	0.075	0.032	0.076	0.050	0.081	0.070	0.115	0.076	0.094	0.144									
13. Professional Development	0.074	0.069	0.065	0.084	0.044	0.044	0.580	0.688	0.839	0.037	0.056	0.077	0.095								
14. Raw Material Conservation	0.069	0.091	0.098	0.074	0.680	0.101	0.102	0.080	0.509	0.115	0.063	0.054	0.052	0.053							
15. Refining Process Modernization	0.120	0.074	0.052	0.056	0.063	0.129	0.101	0.050	0.117	0.092	0.092	0.076	0.678	0.092	0.095						
16. Risk Management & Resilience	0.605	0.085	0.052	0.704	0.029	0.067	0.034	0.046	0.087	0.080	0.070	0.066	0.082	0.054	0.066	0.090					
17. Supply Chain Optimization	0.089	0.041	0.615	0.052	0.090	0.572	0.045	0.092	0.110	0.119	0.086	0.693	0.060	0.057	0.072	0.052	0.062				
18. Regulatory Body Effectiveness	0.745	0.065	0.047	0.643	0.047	0.069	0.071	0.096	0.103	0.046	0.067	0.088	0.104	0.072	0.096	0.079	0.606	0.033			
19. Regulatory Body Effectiveness	0.068	0.056	0.067	0.073	0.104	0.081	0.111	0.082	0.131	0.068	0.750	0.066	0.106	0.079	0.065	0.082	0.063	0.098	0.073		
20. Transparency & Accountability	0.075	0.087	0.095	0.038	0.097	0.098	0.687	0.579	0.476	0.119	0.087	0.136	0.059	0.504	0.080	0.071	0.073	0.054	0.092	0.080	
21. Waste Management																					

RESULT AND CONCLUSION

The findings of this research show that, from a descriptive standpoint, all the main and secondary variables of the research had a mean above the value of 3, which indicates a level of relative agreement and a positive perception among respondents regarding the components of the sustainable value chain of petroleum products in Iraq. This, on the one hand, shows that the concepts proposed in the model are tangible and meaningful for the experts and managers of Iraq’s oil industry, and, on the other hand, confirms that the research instrument has been able to correctly reflect the respondents’ real attitudes and perceptions. In addition, the appropriate dispersion of the responses (a standard deviation above 0.5), consistent with Stevens’s (2002) criterion, indicates the absence of a predominance of indifferent answers and, consequently, the validity of applying inferential tests in the subsequent stages of analysis. The examination of the skewness and kurtosis indi-

ces also showed that all the variables fall within the permissible ranges and that the necessary and sufficient condition for the normality of the data distribution holds a fact that not only confirms the quality of the data but also provides a statistical foundation for running more complex modelling, including factor analysis and structural equations. At the exploratory level, the third-stage factor analysis led to the reduction of the 26 initial variables to 8 core categories with a higher degree of abstraction, which is theoretically significant because it shows that respondents’ perception of the sustainability of the petroleum-products value chain has a multidimensional yet coherent structure. Categories such as “regulatory and governance framework,” “technological progress,” “human-capital capacity building,” “commitment to strategic planning,” “social responsibility,” “environmental performance,” “resource efficiency,” and “economic sustainability” are not only consistent

with the theoretical literature of sustainability, but also reflect the specific institutional, technical, and social conditions of Iraq's oil industry. The relative alignment of the quantitative results with the qualitative findings supports the view of Hair (2010) that, in the process of exploring variables, priority lies with the empirical data and the perspective of the statistical sample, even if there are minor differences from the initial theoretical or qualitative structures. The results of the simultaneous regression and the step-by-step modelling constitute one of the most important analytical achievements of this research. In the first step, the only variable that was able to exert a significant and strong effect on economic sustainability was "environmental performance." This finding significantly shows that, in the context of Iraq's oil industry, economic sustainability is achieved not directly, but through the improvement of environmental performance. In other words, reducing pollutant emissions, managing waste and water, and controlling destructive environmental effects not only reduce hidden, long-term costs, but also lead to improved economic efficiency and increased social acceptance of oil activities. This result is consistent with modern approaches to sustainable development, which regard the economy as the outcome of a balanced interaction with the environment rather than an independent goal separate from it.

In the second step, when "environmental performance" was considered the new dependent variable, the role of variables such as "regulatory and governance framework," "technological progress," "social responsibility," "human-capital capacity building," and especially "resource efficiency" became apparent. Among these, resource efficiency, with the highest β coefficient, was identified as the strongest predictor of environmental performance, which shows that the optimal use of energy, raw materials, and natural resources is the most key lever for improving the environmental situation in the oil value chain. Moreover, the significance of the

regulatory and governance framework indicates that, without transparent laws, efficient regulatory institutions, and anti-corruption mechanisms, even the most advanced technologies will not be able to guarantee desirable environmental performance. This finding highlights the importance of the institutional and governance dimension alongside the technical and managerial dimensions. In the third step, the lack of significance of the relationships between the remaining variables and "resource efficiency" shows that this variable, rather than being affected by short-term organizational or institutional factors, is rooted in operational structures, basic technologies, and entrenched consumption patterns. This result is analytically important because it shows that improving resource efficiency requires deeper interventions, long-term investments, and structural reforms at the level of the industry and macro-policymaking, rather than merely piecemeal managerial measures. In the mixed-methods part, the integration of the quantitative and qualitative results and the reliance on the emergent approach of Charmaz and Glaser led to the presentation of a final model that possesses empirical validity and theoretical coherence. This model shows that economic sustainability in the value chain of Iraqi petroleum products is the direct consequence of environmental performance, and that this performance, in turn, is influenced by resource efficiency and regulatory and institutional frameworks. The validation of the model through the reliability and validity tests (Cronbach's alpha, composite reliability, rho_A, AVE, Fornell-Larcker, and HTMT) all attests to the high quality of the measurement and structural model of the research and shows that the constructs have been correctly defined and distinguished from one another.

Overall, the results of this research show that the transition to a sustainable value chain of petroleum products in Iraq requires, more than anything, a strategic focus on improving

environmental performance — a performance that takes on meaning not independently, but in interaction with resource efficiency and regulatory and governance frameworks. The findings clearly show that economic sustainability, as the ultimate goal of many of the oil industry's policies and programmes, can be achieved only when environmental considerations are placed at the core of technical, managerial, and institutional decision-making. From a policymaking perspective, this study emphasizes the necessity of strengthening regulatory institutions, transparency, and the fight against corruption, while simultaneously making targeted investments in optimizing resource consumption and in clean technologies. From a theoretical perspective, the newly born model of the research offers a localized, empirically grounded framework for explaining the relationships among the various dimensions of sustainability in the oil industry, which can serve as a basis for future research and confirmatory tests in other countries or energy-intensive industries. Ultimately, this research shows that sustainability in Iraq's oil industry is not an optional choice but a strategic necessity for ensuring survival, competitiveness, and economic and social legitimacy in the long run.

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