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Sensitivity and Scenario-Based Assessment of Petroleum Investment Resilience Under Nigeria's PIA 2021 Fiscal Regime

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ABSTRACT

The Nigeria Petroleum Industry Act (PIA) 2021 introduced a revised fiscal framework aimed at improving investment attractiveness and strengthening transparency and revenue generation in Nigeria's upstream petroleum sector. However, petroleum investment projects are exposed to uncertainties from market factors, economic, and operational conditions, creating the need to assess the upstream oil and gas petroleum investment resilience under the PIA 2021 fiscal regime. Using a Python-based Economic Evaluation and Investment Decision Support Tool (EEIDST) which was built by incorporating the fiscal provisions of PIA 2021, sensitivity and scenario-base analyses were conducted to examine the effects of varying the prices of crude oil and natural gas, hydrocarbon production, CAPEX, and OPEX on Net Present Value (NPV), Internal Rate of Return (IRR), Profitability Index (PI), Payback Period, and Government Take. The results from the sensitivity analysis showed that crude oil and hydrocarbon production are key drivers of project economic performance. At the base-case oil price of US\$70/bbl, the project generated an NPV of \$83.78 million, but at an oil price of \$80/bbl, the NPV increased to \$130.51 million, while it reduced to \$26.95 million at an oil price of \$60/bbl. Similarly, a 20% increase in the production relative to the base-case, generated a positive NPV of \$127.47 million, which decreased to \$30.73 million when production declined by 20%. The findings in this study indicate that the investment resilience of PIA 2021 is highly responsive to fluctuations in prices of crude oil and production. This study quantitatively evaluates the resilience of petroleum investment projects, which could be applied by stakeholders in the upstream oil and gas sector.

INTRODUCTION

Petroleum investment decisions are characterized by high budgetary and geological risks, long project implementation periods, volatile commodity prices, and uncertainties. The financial performance and feasibility of upstream petroleum projects could be greatly influenced by such factors. Fluctuations in crude oil and natural gas prices, production rate, capital expenditure (CAPEX) and operational expenditure (OPEX) would have a drastic effect on the cash flows and investment returns of a project. Deterministic base case assumption used in petroleum project evaluation might not be sufficient in evaluating investment risks under circumstances where there are a lot of uncertainties in the market and fiscal environment (Daniel *et al.* 2010). It is therefore important to utilize scenario and sensitivity analysis to examine the impact of fluctuations in key variables on investment returns and viability of petroleum projects in unfavorable times.

The economic performance of petroleum projects are influenced to a great extent by the fiscal regime responsible for managing the distribution of petroleum gains between the government of the host country and the investors. The distribution of petroleum rents, which affects the profit-making abilities of both the government and the investors, is based on petroleum fiscal regimes that utilize various fiscal measures like royalties, taxes, bonuses, cost recovery, allowances, etc. (Johnson, 2003;

Tordo, 2007). Therefore, an efficient fiscal regime should find a middle ground between two contrasting objectives: first, securing government's due share of revenue from the natural resources and second, keeping the interest of investors alive to invest in exploration and development. Decisions related to investments in countries producing oil and gas are greatly influenced by fiscal appeal, project risks, and anticipated profits (Sunday *et al.*, 2023; Tordo *et al.*, 2010).

Nigeria provides an important historical background against which such a study would be conducted; this is because of the strategic value of petroleum resources to the economic development of the nation along with the challenges posed by budgetary volatility, regulatory bureaucracy, and reduced attractiveness of investments. One of the objectives of the Petroleum Industry Act (PIA) 2021, is to revamp the petroleum sector of Nigeria through the development of a comprehensive legal, regulatory, governance, and fiscal regime (Illedare, 2022). This was statutorily provided for in Section 258 of the Act, to ensure progressivity, transparency and equity, increased government revenues, and investor returns (PIA, 2021).

The fiscal architecture introduced by the PIA 2021 influenced the economics of petroleum project. It sets up royalties based on price and production/terrain for onshore, offshore, and shallow water projects and added Hydrocarbon Tax aside from Companies Income Tax.

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The fiscal framework of the PIA impacts on the cash flow and key economic indicators such as NPV, IRR, PI, and payback period, which are essential for investment decisions. Government Take is affected too, because the proportion of the income of the petroleum project that goes to the government depends on taxes and royalties (PIA, 2021).

It has been demonstrated through empirical research that uncertainty analysis is important for the decision-making process of petroleum investment. For instance, Adeogun *et al.* (2018), used stochastic model to examine marginal oilfields in Nigeria, and the findings indicated that profit generation from such projects was greatly influenced by a number of variables, which included price of oil, cost of projects and economic environment among others. Osho *et al.* 2026 carried out research using real option valuation model and Monte Carlo Simulation to examine the effects of fiscal rigidity on the petroleum investment decisions in Nigeria prior to PIA 2021. The findings indicated that project economics could be negatively affected by higher government take and lower cost recovery. This empirical evidence supports the assertion that approaches to evaluate petroleum investment projects need to diversify beyond static economic analysis and incorporate a variety of market and project scenarios.

In recent studies, quantitative and comparative analysis have been carried out using simulations and cash flow model to examine the monetary impact of fiscal regimes on petroleum development projects. For instance, Benninger *et al.* (2024) applied simulation techniques and cash flow modeling to develop the quantitative models for petroleum fiscal regime analysis, facilitating an understanding of the effects of specific fiscal parameters on investment performance. In a related study, Echendu (2011) developed an economic model for the Gulf of Guinea. The study applied sensitivity and scenario-based analysis to simulate the performance of deepwater projects in the Gulf of Guinea. The study employed sensitivity and scenario-based analyses to simulate the performance of deepwater projects under different petroleum fiscal regimes. The research focused on the effects of these Front-Loadings on key economic performance indicators, including Government Take (GTake), Contractor Take (CTake), Net Present Value (NPV), Internal Rate of Return (IRR), Profitability Index (PI), Savings Index (SI), Return on Investment (ROI), Payout Time (POT), Effective Royalty Rate (ERR), Growth Rate of Return (GRR), Discounted Net Cash Flow (DNCF), and Front Loading Index (FLI). The work provided a useful framework which supports petroleum investment decision-making in the Gulf of Guinea.

More recent research has explored the impact of the PIA 2021 on investments. An economic model using the Excel spreadsheet was developed by Amina *et al.* 2023 to evaluate marginal fields investment using economic indicators such as Net Present Value (NPV), Internal Rate of Return (IRR), Government Take, and Net Cash Flow. From their study, conclusions were drawn indicating that

marginal fields investment would find the PIA 2021 fiscal provisions attractive. However, much of the Nigerian literature on the topic is based on the evaluation of PIA 2021 in legal, qualitative, comparative, or one-scenario basis. So far, the literature has shed light on the design and attractiveness of the fiscal regime, but there has been little attempt made to quantitatively evaluate how the PIA 2021 framework could support petroleum project economics in relation to concurrent changes in commodity price, production, CAPEX, and OPEX.

This limitation is crucial because it is impossible to get a reasonable inference of project resilience from just one economic base case scenario. Ideally, the NPV and IRR of the project would be positive. If the price of oil drops, the output level does not meet expectations, or there are high development and operation costs, the appeal of the project will go down significantly. At the same time, the economic realities of a project can be dramatically improved through higher prices of the commodity, better performance in terms of production and cost efficiency. The scenario approach provides for a much more thorough assessment of project behavior under coherent combinations of good and bad scenarios, and sensitivity analysis allows us to assess the importance of different variables.

Against this background, this study applies a Python-based Economic Evaluation and Investment Decision Support Tool (EEIDST) developed to evaluate petroleum project economic performance under Nigeria's PIA 2021 fiscal regime. By applying sensitivity and scenario base analysis the performance of the project will be measured using NPV, IRR, PI, Payback period, and Government Take by altering key economic and project parameters such as hydrocarbon prices, production, CAPEX, and OPEX. This helps us to measure the effect of changes in these key economic parameters on investor profits and government revenue, respectively.

The contribution of this study is presented in three categories. First, rather than relying solely on the deterministic base-case approach, it provides a quantitative assessment of the resilience of petroleum investments under the fiscal framework of the PIA 2021. Secondly, it demonstrates how the output, commodity prices, capital expenditure, and operational expenditure interact with the Nigerian fiscal system to influence investor return and government take. Finally, it demonstrates the approach to utilizing a localized digital decision-support technique to evaluate the impact of petroleum investments under various economic scenarios.

LITERATURE REVIEW

Petroleum Fiscal Regimes and Investment Economics

Petroleum fiscal regimes establish the monetary and institutional mechanisms that will allow the sharing of profits derived from oil resources between investors and governments. Examples of fiscal tools are royalties, hydrocarbon tax, company income tax, Niger Delta

Development Commission levies, Host Community Development Fund (HCDF), Tertiary Education Fund, etc. The flow of cash from the projects, the investor's returns, taxation, and the attraction of petroleum investments are all influenced by the design of these instruments. Fiscal systems should therefore provide a balance between the objective of the government to collect a reasonable share of the petroleum rents, and the objective of providing investors with sufficient return to compensate for the large amount of investment capital required for petroleum projects.

The economic implications of fiscal regime design are evaluated using commonly applied petroleum economic indicators, which includes Net Present Value (NPV), Internal Rate of Return (IRR), Profitability Index (PI), Payback Period, and Government Take. Net Present Value (NPV) refers to the residual value left after subtracting costs associated with investments and the value of money from a project, while Internal Rate of Return (IRR) is the discount rate at which NPV turns to zero. The Payback Period, also known as the capital recovery period, indicates the time required for a petroleum project to recover its initial investment, while the Government take is the proportion of the project's economic value that accrues to the government through royalties, taxes, and other government imposed fiscal payments. The investment attractiveness and fiscal effects of the investments can be determined through these metrics which could influence a project's investment decisions.

Coddou *et al.* (2018) for example, created a unified model for the analysis of cash flows of the fiscal system, including royalties, taxes, cost recovery provisions, and profit-oil splits. It was shown in their study, that even small variations in tax rates, royalty regimes, or cost recovery limits may have a significant influence on investors and state revenues due to the complexity of the interaction between various fiscal instruments. The findings indicated that standardization of fiscal models should be the most effective tool in ensuring transparency in the sector.

Similarly, Amiesa *et al.* (2018) assessed the tax regimes for the petroleum sector in Nigeria using the deterministic royalty/tax cash flow model. In their study, the researchers noted that the economic attractiveness of petroleum investments depends on the interaction among the tax regime, applicable allowances, and cost-recovery mechanisms. They further found that changes in the fiscal regime can significantly affect the distribution of economic rent and the government's share of project revenues. They concluded that the fiscal competitiveness should be well calibrated to avoid discouraging investment. These studies clearly showed that fiscal environment within which an oil project operates is a key factor in assessing the resilience of such a project; this informed the investigation under this study. On the other hand, when there are changes in the basic economic and project environments, deterministic analysis based on one scenario cannot say anything about its resilience.

Nigeria's Petroleum Industry Act 2021 and Investment Attractiveness

The Petroleum Industry Act (PIA) 2021 represents a significant restructuring of the petroleum sector in Nigeria and provides a comprehensive framework for the administration, regulation, and control of petroleum revenue. From the sources examined, it is clear that one of the reasons for the enactment of the Act was to address the problems associated with the fiscal and regulatory environment surrounding the petroleum sector before the enactment of the law. The objective was to create an environment that would attract investments and generate revenue for the government.

Iwok and Daniel (2026) examined the PIA 2021 through the perspective of taxation, administration, and government revenue mobilisation. In their desk analytical approach, the study found that a much better framework, both fiscal and governance-related, is provided by the Act, which may result in increased investment and revenue from taxes for the government. However, they noted that there are still barriers to investor attraction regarding implementation, enforcement, transparency, institutional shortcomings, and certain budgetary aspects. It should be especially emphasized that this aspect is very important since despite having improved legislation on taxation, this will not guarantee profitability of petroleum investment projects under any market conditions.

Similarly, Adebisi & Ezebuio (2023) examined the wider implications of the PIA with respect to the areas of law, regulations, financing, and leadership. Though the Act enhances the governance of petroleum resources in Nigeria, their doctrinal analysis still revealed some weaknesses with regards to areas such as gas flaring, frontier exploration, and community financing. In another study, Idris (2025) examined the fiscal management of the PIA with particular focus on its management. The research adopted a qualitative methodology, utilizing case studies and stakeholders' discussions, alongside a comparative analysis of fiscal management and diversification strategies in Canada and Saudi Arabia. The study concluded that Nigeria must capitalize on the benefits of the PIA while aggressively pursuing economic diversification. The study concluded by recommending improved revenue management, then a transition into renewable energy.

Furthermore, Nwosi-Anele and Iledare (2024) assessed the fiscal framework of the PIA 2021 considering the country's drive towards zero carbon emissions, it not only stands out as progressive but is also attractive. The researchers found out that there should be more fiscal incentives and policies that would go hand in hand with low carbon investment objectives after carrying out an analysis of fiscal policy and performing qualitative evaluation. The study provided a good policy perspective although being qualitative, it cannot measure the influence of changing economic environment on petroleum investments.

More recently, Obakhume *et al.* (2026) applied scenario-

based fiscal modelling to onshore, shallow-water and deepwater projects under Joint Venture and Production Sharing Contract arrangements. Their analysis used a base oil price of US\$60/bbl and sensitivity analysis over a US\$40–100/bbl range. The study concluded that the PIA improved contractor economics and reduced Government Take across the asset classes considered, with these improvements remaining relatively robust across oil-price scenarios. This represents an important development in the literature because it explicitly introduces price scenarios into the assessment of PIA fiscal attractiveness.

While the above studies look at the PIA 2021 in terms of its regulatory provisions and fiscal attractiveness of petroleum projects, this study looks at investment resilience with the ability of petroleum project to remain economically viable in view of any positive or negative changes in the factors which make up its value proposition.

Uncertainty and Petroleum Investment Decisions

Petroleum investments, by nature, have a tendency towards uncertainty. There is plenty of margin for error in predicting how valuable the crude oil and natural gas will be in the future, the effectiveness of production compared to the expectations, and the actual cost incurred on fixed asset and operational expenditures. It is also possible that the cash flow from the project may be influenced by factors such as change in economic environment, production performance, and uncertainty about the geological conditions. For that reason, an investment that appears viable under a deterministic base case scenario can become marginal or economically nonprofitable when unfavorable events happen.

In their research, Adeogun *et al.* (2018) considered the viability of marginal oil fields under low oil prices based on the economic modeling and stochastic simulation techniques. Their research concluded that as crude oil prices declines, petroleum project investment reduces drastically. Also, the study showed that small oil fields need to be able to save costs and receive proper incentives to survive. Evaluations of the petroleum investment should not be made based on one assumed price of oil as presented by the results of (Adeogun *et al.*, 2018), because different factors, including the commodity prices, production, CAPEX and OPEX can affect the sustainability of petroleum investment. This study expands the analysis by considering their combined effects on petroleum project investment.

Sensitivity and Scenario Analysis in Petroleum Economic Evaluation

Sensitivity analysis is the tool extensively used in petroleum economics to measure the effect of changes in particular input variables on project performance. There are certain assumptions which can be changed, these include; oil price, gas price, production, CAPEX, and OPEX. As a result, it would be possible to identify the key factors

influencing the project economic performance and define its threshold of viability.

To further analyze the effect of different variables in certain future conditions, the use of scenario analysis can be helpful along with sensitivity analysis. The scenario analysis allows avoiding the tedious process of adjustment of each variable independently. It uses a combination of optimistic and pessimistic assumptions of a project to understand how the project will perform under a best-case and worst-case scenarios. This approach is very helpful due to the multivariate nature of petroleum projects.

In their paper “Petroleum development projects; concept selection, taxation and recovery rate”, Osmundsen and Wittemann (2024) examined petroleum development projects through the analysis of the interaction between the choice of development concept, taxation, and recovery rate. Sensitivity analysis, cash flow analysis, and scenario comparisons were some of the methods of comparative economic modeling used by the authors. The study concludes that high recovery rates enhance value for investors and governments, and development concepts and fiscal parameters greatly influence the profitability of projects. The study further showed that fiscal factors alone are not the only determinants of economics of petroleum projects; rather, there is an interaction between technical and fiscal factors.

Similarly, Luo and Yan (2010) assessed fiscal terms through the application of scenario modeling and comparative studies on fiscal regimes. Their methodology considered multiple combinations of taxes, royalties, cost limitations, profit oil schemes, and contractor share in relation to rent distribution. In conclusion, the research showed that scenario modeling is an effective tool for analyzing possible impacts of alternative tax regimes on petroleum rent distribution.

Overall, the above-mentioned studies prove that scenario and sensitivity analysis are appropriate means for petroleum investments evaluation. Judging by the reviewed literature, such approach has been applied for the analysis of some particular investments, budgets or uncertainties. Nevertheless, there is a need to carry out a full-fledged assessment with the use of PIA 2021 economic model, which includes commodity prices, production, and costs.

Fiscal Modelling and Digital Approaches to Petroleum Investment Evaluation

Tools that will enable the translation of financial terms into economic impacts at the level of a project are critical due to the increasing complexity of the petroleum financial system. It is possible to construct cash flow models and calculate the investment criteria even through spreadsheet tools. In situations where complex fiscal systems consisting of numerous taxes, royalties, deductions, cost recovery, and other considerations are involved, it may be difficult to replicate spreadsheet techniques.

For instance, Danmadami *et al.* (2023) created an Excel model which was helpful in calculate the marginal profitability of the fields based on PIA 2021. This model calculated the NCF, NPV, IRR, and Government Take, among other considerations. This is an advancement quantitatively from qualitative analyses using the PIA, although models such as those in Excel may not be flexible in performing scenario and uncertainty analysis.

Coddou *et al.* (2018) addressed the broader need for an integrated cash flow theory for systematic modeling of the fiscal system. In their study, they built a unified fiscal system cash flow model that incorporates key instruments such as royalties, taxes, cost recovery rules, and profit oil splits. Then a comparative economic analysis was applied to evaluate NPV, IRR, and government take across varying fiscal parameters, which showed how each instrument shapes project economics. The study concludes that fiscal instruments interact in complex ways, and small changes in tax rates, royalty structures, or cost recovery limits can significantly alter both investor profitability and government revenue. A standardized modelling framework can therefore enhance fiscal-system evaluation, promote transparency in policy design, and support the calibration of fiscal terms to balance investment competitiveness with equitable revenue outcomes.

From the above studies, the economic models used for the analysis of the petroleum fiscal regime suffer from either being too rigid to reflect changes in tax regimes or does not provide the flexibility that is needed for a sensitivity or scenario-based analysis to understand the resilience of a petroleum project under the PIA 2021. The current research is conducted using a Python-based Economic Evaluation and Investment Decision Support Tool (EEIDST) that was developed and validated by Kalagbor *et al.* (2026).

Research Gap

The reviewed literature provides substantial evidence that petroleum fiscal regimes materially influence economics. Studies by Amiesa *et al.* (2018), Echendu *et al.* (2018), and Coddou *et al.* (2018) demonstrated that the fiscal instruments such as taxes royalties and cost recovery provisions influence NPV, IRR, Government Take and rent distribution.

Despite these contributions, three gaps were identified from existing literature. First, much of the post-PIA 2021 literature on Nigeria has concentrated on the Act's legal, regulatory, governance, and fiscal provisions, with relatively limited quantitative assessment of how petroleum project economics respond to changing market and project conditions. Another identified gap from literature is that existing quantitative studies have generally examined individual or selected dimensions of petroleum investment uncertainty, including oil-price fluctuations, marginal-field profitability, comparative fiscal regimes, or specific fiscal instruments. Consequently, there remains limited empirical analysis of how simultaneous changes

in key project drivers—particularly hydrocarbon prices, production, CAPEX, and OPEX—affect investment performance under the PIA 2021 fiscal regime. Lastly, relatively limited attention has been given to integrating PIA 2021 fiscal modelling with a digital decision-support framework capable of systematically combining sensitivity and scenario analyses to assess the resilience of petroleum investments.

The research gap, therefore, lies not in the absence of economic models of the PIA 2021 fiscal regime, but in the limited integration of fiscal modelling, multi-variable sensitivity analysis, and scenario-based assessment in the model framework for evaluating petroleum investment resilience. This paper therefore examines how changes in market, production, and cost variables collectively influence investor returns and government revenue under the PIA 2021 framework. The study addresses this gap by applying the Python-based Economic Evaluation and Investment Decision Support Tool (EEIDST) to a representative onshore petroleum project. The study evaluates the effects of changes in oil and gas prices, production, CAPEX, and OPEX on NPV, IRR, Profitability Index, Payback Period, and Government Take through complementary sensitivity and scenario analyses.

Accordingly, the study moves beyond assessing whether a petroleum investment is economically attractive under a single set of assumptions and examines how resilient the investment will remain when key market, production, and cost assumptions change under the PIA 2021 fiscal regime.

MATERIALS AND METHODS

This study adopts a quantitative economic evaluation approach to assess the resilience of an onshore petroleum investment under Nigeria's Petroleum Industry Act (PIA) 2021 fiscal regime. The methodology involves the development and application of a Python-based Economic Evaluation and Investment Decision Support Tool (EEIDST) to model project cash flows and evaluate investment performance under deterministic, sensitivity, and scenario-based conditions.

The methodological procedure consists of four main stages. First, production, development, economic, and fiscal data representing an onshore petroleum project in the Niger Delta were compiled. Second, the production profile, capital expenditure (CAPEX), and operating expenditure (OPEX) were incorporated into the EEIDST. Third, the project economic indicators were calculated under the base-case assumptions. Finally, sensitivity and scenario analyses were performed by varying selected technical, economic, and project parameters to examine their effects on project profitability and government revenue.

Project performance was evaluated using Net Present Value (NPV), Internal Rate of Return (IRR), Profitability Index (PI), Payback Period, and Government The study utilized production and development data

representing a representative onshore petroleum project in the Niger Delta. The project data comprised the technical and economic parameters required to establish the production profile and develop the project cash-flow model. These parameters included oil and gas production data, project development period, production life, capital expenditure, operating expenditure, oil and gas prices, and other relevant economic assumptions.

Additional fiscal and economic parameters required for the application of the PIA 2021 fiscal regime were obtained from relevant regulatory and industry sources, including the Nigerian Upstream Regulatory Commission (NUPRC), As well as other applicable petroleum industry and economic data sources.

The collected data were reviewed, organized, and converted into the input format required by the EEIDST. The input parameters were categorized into production,

economic, cost, and fiscal variables to facilitate their incorporation into the economic evaluation model.

RESULTS AND DISCUSSION

Sensitivity Analysis

Sensitivity analysis was employed to determine the effect of changing key economic indicators on onshore petroleum development project performance. The analysis focuses on the principal variables capable of influencing petroleum project economics, namely crude oil and natural gas price, hydrocarbon production performance, CAPEX, and OPEX. Each variable is varied while others are held constant. The resulting changes in NPV, IRR, PI, Payback Period, and Government Take are compared with the base-case results. For example, the CAPEX sensitivity analysis evaluates the effect of reduction or an increase in the capital expenditure on the project economics.

Table 1: Oil Price Sensitivity Analysis

Oil Price (\$/bbl)	NPV (\$)	IRR (%)	Payback Period	Profitability Index (PI)	Government Take (\$)
60	26,949,980.34	11.4	8.6	1.17	2,099,302,098.55
65	56,876,714.63	12.9	8.1	1.36	2,310,264,523.31
70	83,776,811.00	14.17	7.7	1.53	2,526,291,706.13
75	108,285,489.43	15.31	7.5	1.69	2,751,309,460.27
80	130,512,149.93	16.32	7.3	1.83	2,981,983,897.12

A similar procedure is applied to hydrocarbon prices, production, and operating expenditure. Table 1 below presents the results of the Oil Price Sensitivity Analysis. Table 1 presents the results of the sensitivity analysis of the onshore petroleum development project's economic performance to variations in crude oil price, while all other economic factors held constant. The results demonstrate that project profitability is highly responsive to variations in oil price. At an oil price of US\$60/bbl, the project remained marginally positive, generating an NPV of US\$26.94 million, an IRR of 11.4%, payback period of 8.6years, with a PI of 1.17. The investment decision at this oil rate is classified as economically unacceptable because the assumed hurdle rate for the project is 12%. As the oil price increased to \$65/bbl, this substantially improved the project economics, increasing NPV to \$56.88 million, IRR increased to 12.9%, the payback period decreased to 8.1years, while the PI shows that for every \$1 dollar that is

invested on the project the project is expected to generate US\$1.36 dollar in present-value benefit, resulting in an economically viable investment. At the base-case oil price of \$70/bbl, the NPV increased further to \$83.78 million, with an IRR of 14.17% and a payback period of 7.7 years, the PI also showed that at this oil price, the project is still profitable since it gives a present-value benefit of \$1.56 for every dollar that is invested. The financial performance of the onshore project gets progressively better when the oil price increases from \$75/bbl to \$80/bbl. NPV increased from \$108.29 million to \$130.51 million, IRR also increased from 15.31% to 16.32%, payback period decreased from 7.5 to 7.3 years, while the PI increased from 1.69 to 1.83, respectively. Additionally, because of the increase in revenue due to the increase in the oil price, the Government Take, increased from \$2.10 billion at an oil price of \$60/bbl to \$2.98 billion when the oil was at a peak price of \$80/bbl. This sensitivity

Table 2: Gas Price Sensitivity Analysis

Gas Price (\$/MMSCF)	NPV (\$)	IRR (%)	Payback Period	Profitability Index	Government Take (\$)
2.2	\$ 74,552,365.28	13.74	7.9	1.47	2,498,798,977.91
2.4	\$ 79,164,588.14	13.96	7.8	1.50	2,512,545,342.02
2.6	\$ 83,776,811.00	14.17	7.7	1.53	2,526,291,706.13
2.8	\$ 88,389,033.86	14.38	7.7	1.56	2,540,038,070.24
3.0	\$ 93,001,256.72	14.59	7.6	1.59	2,553,784,434.35

analysis showed that the project became more profitable as the oil price increased from \$60/bbl to \$80/bbl. These findings aligned with the study of Farimani *et al.* (2020) that investigated the economic implications of the Iranian petroleum contract. The sensitivity analysis conducted in their study showed that both governments take and NPV increased with increase in oil price. On the flip side, it simply implies that low oil price makes the project less attractive for investment. The findings indicate that prices of crude oil have a great impact on the resilience of projects under the PIA 2021 and that investing in petroleum may become even riskier when the market price approaches some threshold level.

The results in Table 2 demonstrate the sensitivity of the onshore petroleum development project's economic performance to variations in natural gas prices. In this analysis, the natural gas price was varied while other key economic factors were held constant. Though the impact is lesser compared to that of crude oil price, there is a substantial correlation between natural gas price and profitability of the project. At the initial gas price of 2.2\$/MMSCF, the project generated an NPV of \$74.55,

IRR of 13.74%, payback period of 7.9 years, with a PI of 1.47. The metrics shows that the project is profitable at this gas price, because the NPV is positive, the value of the IRR is higher than the hurdle rate of 12%, and the present-value benefit for every dollar invested on the project is \$1.47. As the prices of natural gas increased to \$2.4/MMSCF, there was marginal increase in the NPV, IRR, PI, and Government Take while the payback period reduced by one month. As the gas price is increased to \$2.6/MMSCF, \$2.8/MMSCF, and \$23.0/MMSCF all the economic metrics shows that the project gets progressively better with marginal increase in the NPV, IRR, PI, and Government Take, while the cost recovery period reduced in response to the price increase. It should be noted that the economic feasibility of the project does not depend on the gas price assumptions made, as the investment in question proves to be feasible under all tested gas price scenarios. Improvements in NPV, IRR, and capital recovery, nevertheless, illustrate the fact that the project economics benefit from higher gas prices while the investment returns are decreased by lower gas prices. The economic viability of the project is confirmed even

Table 3: Capital Expenditure (CAPEX) Sensitivity Analysis

CAPEX (\$)	CAPEX Assumption	NPV (\$)	IRR (%)	Payback Period	Profitability Index	Government Take (\$)
271.36	20% Cost Savings	132,234,851.7	17.71	7.0	2.05	2.56
305.28	10% Cost Savings	108,005,831.3	15.79	7.4	1.76	2.54
339.20	Base Case	83,776,811.0	14.17	7.7	1.53	2.53
373.12	10% Cost Overrun	59,247,993.9	12.76	8.1	1.34	2.52
407.04	20% Cost Overrun	30,877,657.4	11.35	8.6	1.16	2.51

under the scenario of low gas price; thus, the natural gas price is a rather positive influencer of project profitability in the considered range of variation.

From Table 3, it is evident that the onshore petroleum development project's economic performance is sensitive to variations in capital expenditure. The results demonstrate that project economics are sensitive to variations in capital expenditure (CAPEX). A 10% and 20% cost savings in the CAPEX increased the NPV from

the base case value of \$83.76 million to \$108.0 million and \$132.2 million, respectively, while the IRR increased from 14.17% (base case) to 15.79% and 17.71%, and the PI increased from 1.53 for the base-case to 1.76 and 2.05, respectively. But there was a decrease in the cost recovery period from 7.7 years (base-case) to 7.4 years (10% cost savings) and then 7.0 years (20% cost savings). Conversely, a 10% and 20% CAPEX overrun reduced the NPV from \$59.25 to \$30.88 million, IRR from 12.76%

Table 4: Operating Expenditure (OPEX) Sensitivity Analysis

OPEX (\$)	OPEX Assumptions	NPV (\$)	IRR (%)	Payback Period	Profitability Index	Government Take (\$)
359.20	20% Cost Savings	108,884,629.94	15.24	7.5	1.69	2.572
404.10	10% Cost Savings	97,551,695.00	14.75	7.6	1.62	2.542
449.00	Base Case	83,776,811.00	14.17	7.7	1.53	2.526
493.90	10% Cost Overrun	75,083,031.86	13.75	7.9	1.48	2.486
538.80	20% Cost Overrun	63,552,892.20	13.22	8.1	1.40	2.457

to 11.35%, and the PI decreased from 1.34 to 1.16; while the Payback Period was extended from 8.1 to 8.6. The project had more revenue at 20% cost savings due to more taxes and royalties resulting to a Government Take of \$2.56 billion, but this amount dropped to \$2.51 billion when the cost overruns increased by 20%. These results also aligned with the sensitivity analysis conducted by Farimani *et al.* (2020) in their research to investigate the economic implications of the Iranian petroleum contract. Their study showed that an increase in the capital expenditure, when other key economic indicators are held constant, led to a decrease in the government take and NPVs. These results indicate that CAPEX uncertainty can materially affect the economic performance and investment resilience of the petroleum project. Although the project retains a positive NPV and a PI above unity across the assessed CAPEX scenarios, the substantial reduction in NPV under the cost overrun scenarios indicates the possibility of the project to be economically nonprofitable if the capital expenditure is not properly managed. According to the results shown in Table 4, the onshore petroleum development

project's economic performance responds significantly to variations in operating expenditure. From the results, 20% cost savings on the OPEX increased the NPV from the base-case value of \$83.76 million to \$108.88 million, IRR increased to 15.24% from 14.17%, and this increased the present-benefit of any dollar invested in the project from \$1.53 to \$1.69, while the payback period was reduced from 7.7 years in the base-case to 7.5 years. Conversely, a 20% OPEX cost overrun, reduced the NPV from the base-case value of \$83.78million to \$63.55 million, the IRR fell to 13.22% from 14.17%, and the payback period extended to 8.1 years from 7.7 years, while the PI reduced from 1.53 to 1.40. The Government Take for the project was highest (\$2.272 billion) at a 20% OPEX cost-savings, and it was lowest (2.457 billion) at 20% OPEX cost overrun. Indicating that when the OPEX is reduced the Government gets more taxes and revenue from the investor because of increase in revenue. But when the operating cost increases, the project makes less revenue a, so the Government Take also declined reflecting a reduced taxable income under the PIA fiscal framework. Although the project remains economically viable

Table 5: Production Sensitivity Analysis

Annual Cumulative Production	Oil Production Assumption	NPV (\$)	IRR (%)	Payback Period	Profitability Index	Government Take (\$) 109
43,530,624	20% Production Decline	30,730,614.88	11.61	8.3	1.20	1.84
48,971,952	10% Production Decline	58,893,668.73	12.99	8.1	1.37	2.24
54,413,280	Base Case	83,776,811.00	14.17	7.7	1.53	2.53
59,854,608	10% Production Increase	105,598,331.10	15.18	7.5	1.67	2.88
65,295,936	20% Production Increase	127,466,041.49	16.15	7.3	1.81	3.02

across all tested scenarios, the results demonstrate that increasing operating environments heighten sensitivity to OPEX fluctuations.

Lastly, Table 5 provides the production sensitivity analysis of the onshore petroleum development project, in which variations in the annual cumulative oil production is evaluated against changes in crude oil and natural gas prices, capital expenditure (CAPEX) and operation expenditures (OPEX). The results show that under a base-case annual cumulative production of 54.41 million barrels, the project generated a positive NPV of \$83.78 million, an IRR of 14.17% (which is greater than the assumed hurdle rate of 12%), payback period of 7.7 years, with a PI of 1.53. When hydrocarbon production declined by 10% and 20%, this led to a decrease in the NPV from \$58.89 million to \$30.73 million, the IRR dropped from 12.99% to 11.61%, the payback period extended from 8.1 years to 8.3years, while the PI decreased from 1.37 to 1.2. At a 10% production decline rate, the project was still economically viable as the NPV was positive and IRR was above the assumed hurdle rate. But at 20%

production decline rate, the project is no longer viable considering that the IRR is less than the hurdle rate with a long capital recovery period. Conversely, increasing the production by 20% from its base-case values, increased the NPV to \$127.47 million, the IRR increased to 16.15%, the payback period decreased from its base-case value of 7.7 years to 7.3 years, and the PI increased to 1.81 indicating that the present benefit of every dollar invested on the project is \$1.81. Additionally, the response of the Government take is proportional to the volume of hydrocarbon production. As the volume of crude oil declined the Government Take decrease from its base-case value of \$2.53 billion to \$1.84 billion, but as production volume increased by 20%, the Government Take also increased to \$3.02 billion. Overall, the result shows that production uncertainty has a great impact on the project economic performance, because as seen in the table, a 20% production decline decreased the value of the NPV by approximately 63% relative to the base-case, this shows the impact of an underperforming reserve on the project economics. Also, the Government Take

dropped by approximately 27% relative to the base-case, which shows the impact of drop in production in the project revenue and the associated cash flow under the PIA 2021 framework incorporated into the EEIDST. The analysis demonstrates that the volume of hydrocarbon production is an important factor which impacts on the project revenue and government take and it represents a source of uncertainty in evaluating the resilience of onshore petroleum projects.

Scenario-Base Analysis

While sensitivity analysis investigated the effect of each individual factor, scenario analysis in this study examined the effects of a combined change in key economic factors, such as commodity prices, production, CAPEX, and OPEX on the project. Best-Case, Base-Case, and Worst- Case scenarios were identified and used for the analysis. Increase in prices of oil and natural gas, improved production, and lower capital and operating costs of the project were among the elements in the Best-Case scenario. On the other hand, worst-case scenario includes low commodity prices, lower hydrocarbon production levels, and higher capital and operating cost of the project. The onshore project was developed under the reference economic environment, which is known as the Base Case.

Figure 1 below presents the results of the analysis of the potential outcomes in a Best-Case, Base-Case and Worst-Case scenarios, after the prices of crude oil, natural gas, capital expenditure (CAPEX), operating expenses (OPEX), and the onshore production profile were adjusted simultaneously to capture the desirable, expected and undesirable conditions for the project. Specifically, the project proved to be economically profitable in the best-case scenario, because in this test-scenario the project recorded a positive NPV and the IRR was

greater than the assumed threshold of 12%. The analysis generated an NPV of \$222.42 million, an IRR of 22.27%, a payback period of 6.3, PI of 2.77, and a government take of \$3.647. The increase in the NPV is associated with increase in the prices of crude oil and natural gas, a reduction of CAPEX and OPEX by 20% and an increase in production by 20%. On the flip side, that is, under the worst-case scenario, which includes a decline in the prices of crude oil and natural gas products, an overestimation of capital investment and operational expenditure by 20%, and a reduction in the production output by 20%, the project recorded a negative NPV -\$51.12 million, the IRR reduced to 7.62%, payback period extended to 10 years. Additionally, the PI for the project decreased to 0.73, indicating that for every \$1 dollar invested on the project generates only \$0.73 in discounted value. Also, the Government take decreased by 40.7% from the base-case scenario, indicating a reduction in the taxable income of the project. Government Take also declined from \$2.526 billion in the base case to \$1.497 billion under the Worst-Case scenario, representing a 40.7% reduction. This reduction reflects the adverse effect of lower production and commodity prices, together with higher project costs, on project revenues and the associated fiscal flows under the modeled PIA 2021 fiscal framework. Overall, the scenario analysis demonstrates that the economic performance of the representative onshore petroleum development project is highly sensitive to simultaneous changes in market, production, and cost conditions. While favourable conditions substantially enhance investor returns and government revenue, adverse conditions can erode project value to the point of negative NPV. These findings highlight the importance of assessing petroleum investment resilience under a range of interacting uncertainties rather than relying solely on a single base-case economic evaluation.

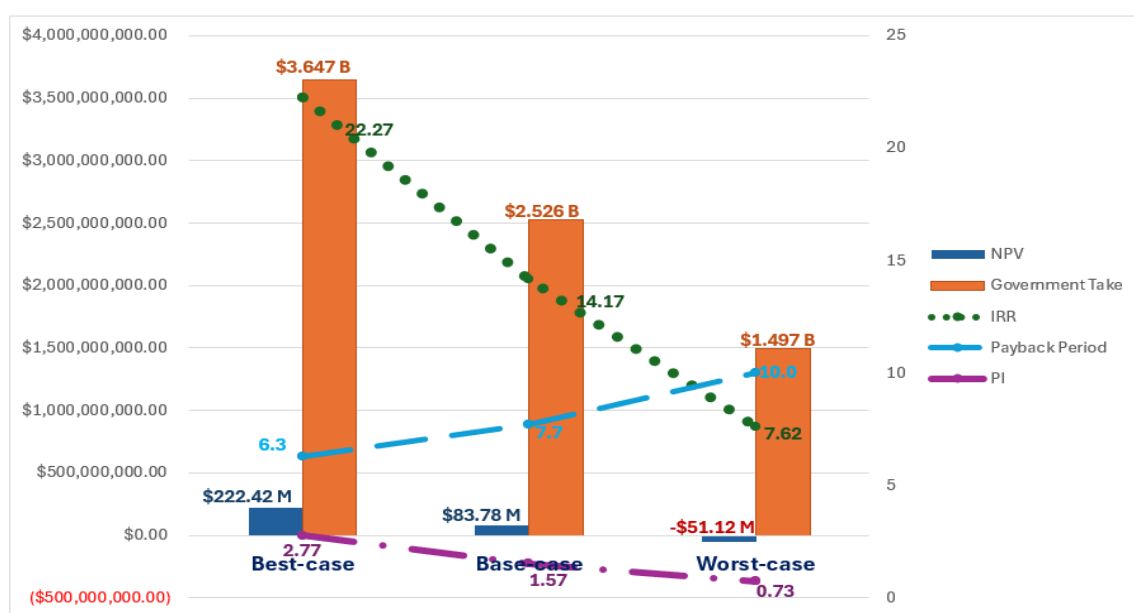


Figure 1: Onshore Petroleum Development Project Scenario-based Analysis

CONCLUSION

This study was able to show that uncertainty in the prices of crude oil and natural gas, volume of hydrocarbon production, CAPEX, and OPEX are critical determinants of the performance of investments in Nigeria under the PIA 2021 fiscal regime. From the sensitivity analysis, it is safe to say that the prices of crude oil and volume of hydrocarbon production are the key variables that heavily impacted on the onshore petroleum development project. Also, the scenario-based analysis showed that favorable conditions contribute to the success of a petroleum project, while unfavorable conditions impact negatively on the project revenue and government takes.

Furthermore, the findings in the study demonstrated that a positive base-case economic result does not, by itself, fully characterize the resilience of an upstream petroleum investment. The representative project remains economically viable under the individual sensitivity cases examined; however, the combined adverse conditions represented by the Worst-Case scenario can erode project value sufficiently to produce a negative NPV and an IRR below the assumed 12% hurdle rate. This finding emphasized the need for accessing petroleum investments under a range of varying economic and operational conditions rather than relying exclusively on a single deterministic base case.

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