



Research Article

A Machine Learning Approach to Assessing Tax Cuts and Economic Growth in Ghana

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Abstract

This study investigates the impact of tax cuts on Ghana's economic growth using a machine-learning approach applied to thirty-five years of macroeconomic data. The analysis focuses on the corporate income tax (CIT) rate, the personal income tax (PIT) rate, foreign direct investment (FDI), inflation, and the sectoral contributions of oil, gold, and cocoa to gross domestic product (GDP). Three feature-engineering strategies namely original, first-differenced, and ratio-transformed variables were used to train and compare an Extreme Gradient Boosting (XGBoost) regression model. The model trained on ratio-transformed features achieved the strongest predictive performance, with a coefficient of determination (R^2) of 0.9737, a mean absolute percentage error (MAPE) of 4.12%, and a mean percentage error (MPE) of 0.0986%, substantially outperforming the models trained on the original and first-differenced features. SHapley Additive exPlanations (SHAP) were then applied to interpret the model's predictions. The SHAP analysis shows that higher CIT and PIT rates are consistently associated with lower GDP growth, while FDI inflows and commodity export revenues (particularly gold and oil) are associated with higher growth. These findings suggest that reducing corporate and personal income tax rates could support economic growth in Ghana, but that the benefits of such cuts are likely to be realized only alongside complementary policies that improve investment efficiency, strengthen tax compliance, and add value to commodity exports.

Keywords

Tax Cuts, Corporate Income Tax, Personal Income Tax, XGBoost, Machine Learning, SHAP Analysis, Ghana, Economic Growth

1. Introduction

Taxation is a fundamental instrument of government policy, serving as the primary source of revenue used to fund public services, infrastructure, and development projects [1]. In Ghana, taxes contribute significantly to national income and support key sectors such as education, healthcare, and transportation [1]. The structure and level of taxation can, however, influence economic growth in various ways, affecting business investment, consumer spending, and overall economic

activity [2]. Tax policy therefore plays a pivotal role in shaping a nation's economic landscape by influencing investment, consumption, and overall growth [3].

In Ghana, discussions surrounding tax cuts have gained prominence, especially in the context of recent economic challenges and political transitions [4, 5]. The country has experienced major economic difficulties in recent years, including currency depreciation, rising public debt, and inflation [5].

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These difficulties have been intensified by global shocks, such as the COVID-19 pandemic and the conflict in Ukraine, which disrupted supply chains and drove up commodity prices [6]. Tax policy has, as a result, become central to economic debates in Ghana, with particular attention on the advantages and disadvantages of tax cuts as a tool for stimulating economic activity [7].

Tax cuts, whether in corporate income tax or value-added tax are generally intended to stimulate growth [8]. The rationale is that lower tax burdens free up resources for businesses to expand, create jobs, and invest in innovation [9], while reduced personal income taxes raise household disposable income and increase demand for goods and services [10]. This study contributes to this discourse by providing data-driven insights that can help policymakers design tax strategies that foster sustainable economic development while maintaining fiscal responsibility.

1.1. Statement of the Problem

In response to Ghana's ongoing fiscal deficits, rising public debt, and currency depreciation, policymakers have proposed tax cuts as a means of promoting economic growth and reducing the tax burden on the population [11]. The efficacy of such tax reductions nevertheless remains a subject of debate, particularly concerning their potential to deepen existing fiscal problems if they are not accompanied by robust compliance measures [5]. In the first half of 2024, Ghana's total revenue and grants amounted to GH¢ 74.65 billion, representing 7.1% of GDP, a shortfall of 1.9% relative to the projected GH¢ 76.07 billion (7.2% of GDP).

Analysts caution that, while tax cuts can ease the financial strain on businesses and individuals, they may exacerbate fiscal challenges if they are not balanced with effective compliance enforcement and revenue-management strategies. Without addressing tax evasion and broadening the tax base, reductions in tax rates could lead to significant revenue losses and further strain public finances [12]. Critics further contend that tax cuts may reduce government revenue, widen budget deficits, and constrain public investment, potentially hindering long-term growth [13]. Given these complexities, there is a pressing need to empirically assess the impact of tax cuts on Ghana's economic performance. This study employs the XGBoost algorithm to examine how tax cuts have influenced Ghana's economic growth over time, and to identify the relative importance of tax policy alongside other macroeconomic drivers of growth.

1.2. Literature Review

Tax policy is central to economic development because it shapes investment, consumption, and government revenue [14]. Tax cuts are often used to stimulate growth by boosting private investment and disposable income [15], but their effects remain contested: critics argue that excessive tax cuts

can cause budget deficits, crowd out public investment, and create long-term fiscal instability [16].

1.2.1. Theoretical Framework: The Laffer Curve

The Laffer curve, introduced by the economist Arthur Laffer in the 1970s, is a foundational concept in tax policy and public finance [17]. It describes the relationship between tax rates and government revenue, illustrating that increasing tax rates beyond a certain point can lead to a decline in revenue collection, and that an optimal tax rate exists at which government revenue is maximized [18]. The curve is built on the premise that, at a 0% tax rate, government collects no revenue because no taxes are levied, while at a 100% tax rate government also collects little or no revenue because individuals and businesses lose the incentive to work, invest, or produce, leading to economic stagnation [19]. When tax rates are low, increasing them tends to raise government revenue, because individuals and businesses continue to operate largely as before [20].

1.2.2. Empirical Literature

Ferede and Dahlby analyzed Canadian provincial tax policy and found that corporate income tax (CIT) cuts significantly boost economic growth: a one-percentage-point CIT cut was found to increase annual growth by 0.1-0.2 percentage points, while the harmonization of sales taxes was found to promote investment and growth. Their use of comparable sub-national data avoided the pitfalls of heterogeneous cross-country studies; however, the study relied on statutory rather than effective tax rates, its aggregate data masked sectoral differences in investment, and its simulations may have overstated the benefits of tax cuts by ignoring tax competition and by capturing only temporary rather than permanent growth effects [21].

Lee and Gordon also analysed cross-country data for 1970-1997 and found that lower corporate tax rates promoted long-term economic growth, whereas personal income tax cuts had little effect; they reported a substantial negative correlation between statutory corporate tax rates and cross-sectional variation in average growth rates. Their study emphasised the importance of corporate taxation for investment but faced limitations, including data-comparability issues, measurement error, global shocks, and difficulties in establishing causality; it also overlooked informal-sector activity, sectoral differences, and regional variation. Although insightful, its findings should therefore be interpreted with caution [22].

Dladla and Khobai used an autoregressive distributed lag (ARDL) model to study taxation and economic growth in South Africa and found a negative relationship, with higher taxes reducing investment and productivity; however, the study's country-specific focus, its lack of disaggregation by tax type, and its difficulty in accounting for external shocks, data-quality issues, and potential reverse causality limit the generalizability of its findings [23].

Zandi assessed the macroeconomic effects of proposed tax cuts and argued for a balanced approach, noting that while tax

cuts can temporarily boost consumption and investment, their long-term effect on growth depends on the accompanying fiscal stance, and that growing deficits are a risk if tax cuts are not matched by equivalent spending reductions [24].

Ahmad et al., employed an ARDL model to analyses the short- and long-run effects of taxation on economic growth in Pakistan and found that higher tax rates negatively affect investment and economic expansion, discouraging both local and foreign investment. Their findings reinforce the argument that tax structures should be designed to enhance economic efficiency while maintaining adequate government revenue [25].

Romer and Romer challenge the view that tax cuts automatically lead to reduced government spending, arguing instead that tax cuts often increase government expenditure as political pressure mounts to sustain public services despite declining revenue [26].

Dowrick studied a sample of Organization for Economic Co-operation and Development (OECD) countries between 1960 and 1985 and found a strong negative effect of personal income taxation on growth, but no significant effect of corporate taxes [27].

Using the Marshallian macroeconomic model, Zellner and Ngoie investigated how tax rates affected economic growth in the United States between 1987 and 2008 and found that corporate taxes hinder economic expansion [28].

Stoilova examined the relationship between tax structure and economic growth across 28 European Union countries for 1996-2013 and found that personal income tax has a positive impact on growth, while corporate taxes have a negative impact. Although most of the theoretical and empirical literature points to a negative relationship between taxation and growth, some studies report a positive relationship [29].

Chigbu and Njoku examined how taxes affected the Nigerian economy between 1994 and 2012 and found a positive correlation between the dependent variables (unemployment and GDP) and the explanatory variables (corporate income tax, petroleum profit tax, and customs and excise duties) [30].

Ebiringa and Yadirichukwu, using a simple linear regression approach, examined the effects of different taxes on Nigeria's economic development between 1985 and 2011 and found a negative association between customs and excise taxes and economic growth, alongside a clear and substantial positive correlation between GDP and corporate income tax [31].

Okafor examined how tax revenue affected Nigeria's economic expansion between 1981 and 2007 using ordinary least squares (OLS) multiple regression, considering value-added tax, corporation tax, petroleum tax, and customs and excise duty revenue; the results showed a substantial and robust relationship between GDP and excise and customs taxes [32].

Shala evaluated value-added tax (VAT) revenue collected in Kosovo and its consequences for economic growth, using OLS and related econometric techniques to examine VAT collection patterns from 2005 to 2015. The study found that, although cross-border trade was important for VAT collection in Kosovo, revenue collection alone could not guarantee fiscal stability, and Kosovo's low VAT share of GDP suggested a relatively less developed economy [33].

2. Materials and Methods

This section describes the data sources, variable definitions, and the machine-learning methodology used to assess whether tax cuts have a positive or negative effect on Ghana's economic performance. An XGBoost regression model was trained on macroeconomic and fiscal data, and SHAP analysis was used to interpret the resulting predictions.

2.1. Data and Variables

The study uses thirty-five annual observations covering GDP growth and its macroeconomic and fiscal covariates. [Table 1](#) summarizes the source of each variable used in the analysis.

Table 1. Sources of Variables Used in the Study.

Variable	Source
GDP Growth (%)	World Bank Database
Corporate Income Tax (CIT) Rate	Ghana Revenue Authority (GRA)
Personal Income Tax (PIT) Rate	Ghana Revenue Authority (GRA)
Foreign Direct Investment (FDI)	World Bank Database
Inflation	World Bank Database
Policy Rate	Bank of Ghana Database
Oil Sector Share of GDP (%)	Ghana Statistical Service (GSS)
Gold Sector Share of GDP (%)	Ghana Chamber of Mines

Variable	Source
Cocoa Sector Share of GDP (%)	Ghana Cocoa Board
Trade Balance (% of GDP)	Trading Economics / WITS / UN Comtrade

Table 2 provides detailed definitions of each variable together with its hypothesized direction of impact on GDP growth.

Table 2. Detailed Variable Definitions, Sources, and Expected Impact on GDP.

Variable	Definition	Expected Impact on GDP
GDP Growth	Annual percentage growth rate of GDP.	Dependent variable; measures overall economic performance.
CIT Rate	Statutory tax rate applied to corporate profits.	Core policy variable; lower rates hypothesized to stimulate investment and growth.
PIT Rate	Top marginal tax rate applied to personal income.	Core policy variable; lower rates hypothesized to raise disposable income and consumption.
FDI	Net inflows of foreign direct investment.	Indicator of external confidence and a source of capital for growth.
Inflation	Annual percentage change in the consumer price index.	Indicator of macroeconomic stability; high inflation can deter investment and erode purchasing power.
Policy Rate	The central bank's primary monetary policy interest rate.	Influences the cost of borrowing, investment, and inflation.
Oil Revenue	Contribution of the oil sector to total GDP.	Ghana's key export commodity; affects fiscal space and foreign exchange.
Gold Revenue	Contribution of the gold sector to total GDP.	A traditional mainstay of Ghana's exports.
Cocoa Revenue	Contribution of the cocoa sector to total GDP.	A key agricultural export and source of rural income.
Trade Balance	Difference between the value of exports and imports.	Indicator of external-sector performance; a deficit implies more imports than exports.

2.2. Data Preprocessing and Feature Engineering

Three distinct feature-transformation strategies were used to model the relationship between the macroeconomic indicators and GDP growth:

- 1) Original features: variables used in their raw, untransformed state.
- 2) Differenced features: variables transformed by taking the first difference, $\Delta X_t = X_t - X_{t-1}$, to achieve stationarity and focus on short-term changes.
- 3) Ratio features: variables scaled as a percentage of GDP or otherwise normalized. This transformation stabilizes variance and captures the relative economic weight of each indicator, and proved to be the most effective transformation for the model.

2.3. SHAP Analysis

SHapley Additive exPlanations (SHAP) were employed to quantify the individual contribution of each macroeconomic indicator - particularly the tax variables - to predicted GDP growth. SHAP values were calculated for each observation in the test dataset, and the results were visualized using summary (beeswarm) plots to show global feature importance and waterfall plots to explain individual predictions.

Let the trained machine-learning model be denoted $f(x)$, where $x = (x_1, x_2, \dots, x_n)$ is the vector of input features. SHAP explains a prediction as shown in Equation (1):

$$f(x) = \phi_0 + \sum_{i=1}^n \phi_i \quad (1)$$

where $f(x)$ is the predicted value (e.g., GDP growth), ϕ_0 is the base value (the average model output over the dataset), and ϕ_i is the SHAP value of feature, representing its contribution to the prediction. The SHAP value ϕ_i for a feature x_i is computed as the average of its marginal contributions across all possible subsets S of features that exclude x_i , as shown in x_i Equation (2):

$$\phi_i = \sum_{S \subseteq N/\{i\}} \frac{|S|!(|N|-|S|-1)!}{|N|} [f_{S \cup \{i\}}(x_{S \cup \{i\}}) - f_S(x_S)] \quad (2)$$

where N is the set of all input features, $S \subseteq N/\{i\}$ denotes all subsets not containing feature x_i , $f_S(x_S)$ is the model's output when only the features in subset S are present, $f_{S \cup \{i\}}(x_{S \cup \{i\}})$ is the output when x_i is added to the subset, and the weighting term shown below ensures fairness in accordance with Shapley theory:

$$\frac{|S|!(|N|-|S|-1)!}{|N|}$$

Applied to this study, the predicted GDP growth decomposes as shown in Equation (3):

$$\text{Predicted GDP} = \phi_0 + \phi_{CIT_Rate} + \phi_{PIT_Rate} + \phi_{Inflation} + \phi_{FDI} \quad (3)$$

A positive SHAP value indicates that the corresponding feature increased the prediction relative to the base value, while a negative SHAP value indicates that it reduced the prediction. This approach provides both local and global interpretability, helping to clarify the economic significance of each variable in predicting growth.

2.4. XGBoost (Extreme Gradient Boosting)

XGBoost is an advanced ensemble-learning algorithm based on decision trees, designed for speed and predictive performance. It builds trees sequentially by optimizing a regularized objective function that uses both the gradient and the second-order derivative (Hessian) of the loss function. This allows the model to make precise corrections at each boosting stage while controlling for overfitting through shrinkage, column subsampling, and regularization.

Let the training data be defined as shown in Equation (4):

$$D = \{(x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)\} \quad (4)$$

where $x_i \in \mathbb{R}^m$ is the feature vector of dimension m , $y_i \in \mathbb{R}$ is the target variable, and n is the total number of

training samples.

The model begins with an initial constant prediction, typically the mean of the target values, as shown in Equation (5):

$$\hat{y}_i^{(0)} = \bar{y} = \frac{1}{n} \sum_{i=1}^n y_i \quad (5)$$

where $\hat{y}_i^{(0)}$ is the initial prediction for observation i and $\bar{y}$ is the mean of all target values.

At iteration t , the gradient and Hessian of the loss function L are computed as shown in Equation (6):

$$g = \frac{\partial L(y, \hat{y})}{\partial \hat{y}}, \quad h = \frac{\partial^2 L(y, \hat{y})}{\partial \hat{y}^2} \quad (6)$$

where g_i is the first-order gradient (loss sensitivity) and h_i is the second-order gradient (curvature, or confidence).

XGBoost uses a gain function to select the best split at each node, as shown in Equation (7):

$$= \frac{1}{2} \left[\frac{G_L^2}{H_L + \lambda} + \frac{G_R^2}{H_R + \lambda} - \frac{(G_L + G_R)^2}{H_L + H_R + \lambda} \right] - \gamma \quad (7)$$

where G_L and H_L are the sums of the gradients and Hessians of the observations in the left child node, G_R and H_R are the corresponding sums for the right child node, λ is the L_2 regularization term, and γ is the penalty for adding a new leaf (complexity control).

The optimal weight assigned to leaf j is given in Equation (8):

$$w_j = -\frac{G_j}{H_j + \lambda} \quad (8)$$

where G_j and H_j are the sums of the gradients and Hessians of the observations in leaf j .

At each boosting round, the prediction is updated as shown in Equation (9):

$$\hat{y}_t = \hat{y}_{t-1} + f_t(x_i) \quad (9)$$

where $f_t(x_i)$ is the prediction contributed by the new tree t .

The final XGBoost prediction is obtained by summing the outputs of all trees built during the boosting process, as shown in Equation (10):

$$\hat{y}_i = \sum_{t=1}^T f_t(x_i), \quad f_t \in F \quad (10)$$

where $\hat{y}_i$ is the predicted value for the i -th observation, T is the total number of boosting iterations (trees), $f_t(x_i)$ is the output of the t -th regression tree for input vector x_i , and F is the functional space of all possible regression trees. Each tree in the sequence is trained to minimize the residual errors of the combined previous trees using a gradient-based optimization approach.

2.5. Model Selection and Justification

The XGBoost regression model was selected as the most

appropriate algorithm for predicting GDP growth from key economic indicators tax rates, inflation, FDI inflows, and commodity prices - primarily because of its strong predictive performance and its ability to model complex, non-linear interactions among variables in macroeconomic data. Figure 1 shows the overall flow of the modelling process, from data preparation to final prediction and feature interpretation, and provides a clear outline of how the model was developed and evaluated at each step.

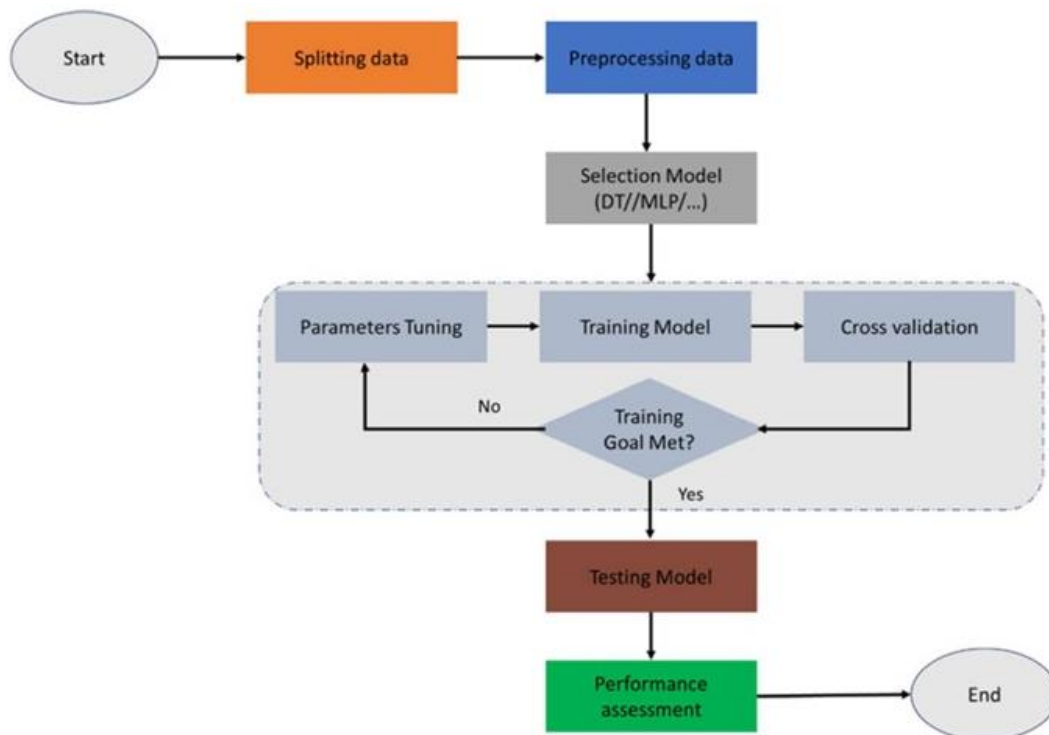


Figure 1. Flowchart of the XGBoost Modelling Process.

In summary, XGBoost was the most suitable choice for this study because of its robust performance, its ability to handle a comparatively small dataset, and its support for interpretable outputs through SHAP analysis.

2.6. Model Validation and Performance Metrics

Model performance was assessed using the following four metrics.

- 1) Root Mean Squared Error (RMSE), which measures the average magnitude of the difference between predicted and actual values:

$$RMSE = \sqrt{\frac{1}{n} \sum (y - \hat{y})^2}$$

- 2) Mean Absolute Percentage Error (MAPE), which expresses the average error as a percentage of the actual values:

$$MAPE = \frac{1}{n} \sum \left| \frac{\hat{y}_i - y_i}{y_i} \right| \times 100$$

- 3) Coefficient of Determination (R^2), which evaluates how much of the variation in the data is explained by the model:

$$R^2 = 1 - \frac{\sum (y_i - \hat{y}_i)^2}{\sum (y_i - \bar{y})^2}$$

- 4) Mean Percentage Error (MPE), which measures the average percentage error between the predicted values ($\hat{y}$) and the actual values (y):

$$= \frac{1}{n} \sum \left| \frac{\hat{y}_i - y_i}{y_i} \right| \times 100$$

where y_i denotes the actual values, $\hat{y}_i$ the predicted values, and n the number of observations. An MPE greater than zero indicates that, on average, the model underestimates the true values; an MPE less than zero indicates that the model, on average, overestimates the true values; and an MPE of zero indicates perfect prediction, which is unlikely in practice.

3. Results

3.1. Descriptive Statistics

Table 3 reports descriptive statistics for the study variables ($N = 35$).

Table 3. Descriptive Statistics of Study Variables ($N = 35$).

Variable	Mean	Std. Dev.	Min	Max	Obs.
GDP Growth (%)	5.17	2.44	0.51	14.05	35
Corporate Tax Rate (%)	31.26	5.99	25.00	45.00	35
Personal Income Tax Rate (%)	31.57	4.50	30.00	55.00	35
Inflation Rate (%)	20.38	12.99	4.90	59.50	35
FDI Net Inflow (% of GDP)	3.71	2.68	0.25	9.47	35
Policy Rate (%)	18.44	8.35	8.89	35.76	35
Oil Revenue (% of GDP)	1.73	1.88	0.05	5.30	35
Gold Revenue (% of GDP)	4.10	1.29	1.00	5.80	35
Cocoa Revenue (% of GDP)	4.72	1.96	1.20	9.00	35
Trade Balance (% of GDP)	-6.44	3.24	-11.00	0.50	35

The descriptive statistics reveal a period of substantial economic dynamism and volatility in Ghana. GDP growth was, on average, robust but highly variable, averaging 5.17% with a range of 0.51% to 14.05%. This occurred against a backdrop of high and volatile inflation (mean 20.38%, standard deviation 12.99), which prompted a consistently tight monetary-policy stance (mean policy rate 18.44%). The tax environment was comparatively stable, with corporate and personal income tax rates averaging 31.26% and 31.57%, respectively. The economy was further shaped by volatile contributions from

the oil, gold, and cocoa sectors, alongside a persistent trade deficit (mean -6.44% of GDP), while FDI inflows showed moderate variability (mean 3.71% of GDP), reflecting fluctuating international investor confidence.

3.2. Model Performance Comparison

Table 4 reports the full performance metrics for the three feature-engineering strategies, including training-set results alongside test-set results, to assess the potential for overfitting.

Table 4. Full Model Performance Metrics by Feature-Transformation Strategy.

Model (Features)	R ²	MSE	MAE	MAPE	MPE
Original	0.8201	0.4310	0.5471	0.1156	3.5596
Differenced	0.2955	5.0361	2.0047	2.0042	153.0912
Ratio	0.9737	0.0630	0.2122	0.0412	0.0986

The quantitative evaluation across all performance metrics

demonstrates the clear superiority of the model trained on ratio-transformed features. The ratio-based model significantly

outperformed the alternatives, achieving an R^2 of 0.9737, explaining over 97% of the variance in GDP growth together with the lowest MSE (0.0630), lowest MAE (0.2122), lowest MAPE (4.12%), and a near-zero MPE (0.0986%), indicating almost no systematic prediction bias. By comparison, the original-features model showed strong but weaker performance ($R^2 = 0.8201$) with a slight tendency to overestimate GDP

growth (MPE = 3.56%). The differenced-features model performed poorly, with a very low R^2 (0.2955), high error (MSE = 5.0361), and a substantial positive bias (MPE = 153.09%), confirming that it is an unreliable approach for this forecasting task. The ratio-based transformation is therefore identified as the most effective feature-engineering strategy for this analysis.

3.3. Predictive Accuracy

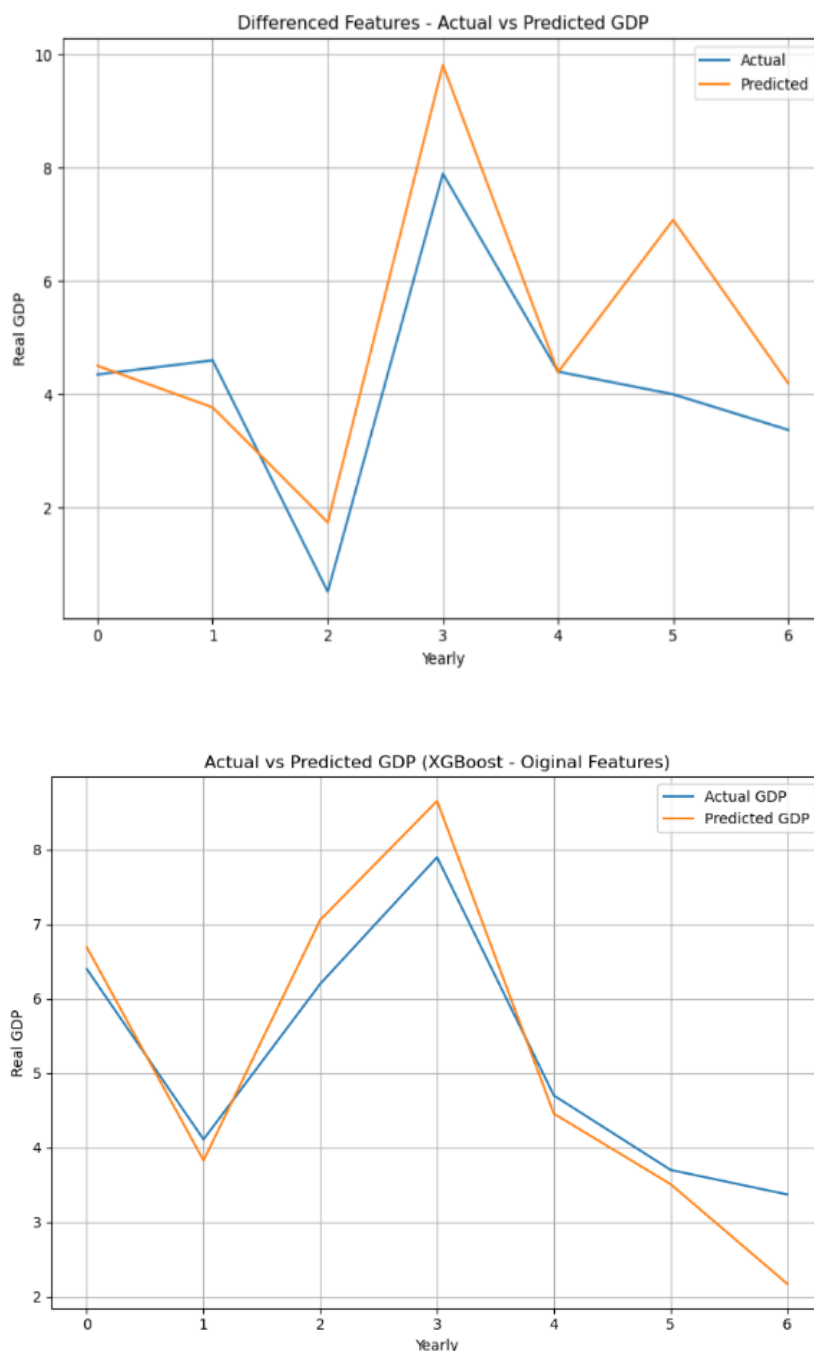


Figure 2. Actual versus Predicted GDP for All Model Variants (Original, Differenced, Ratio).

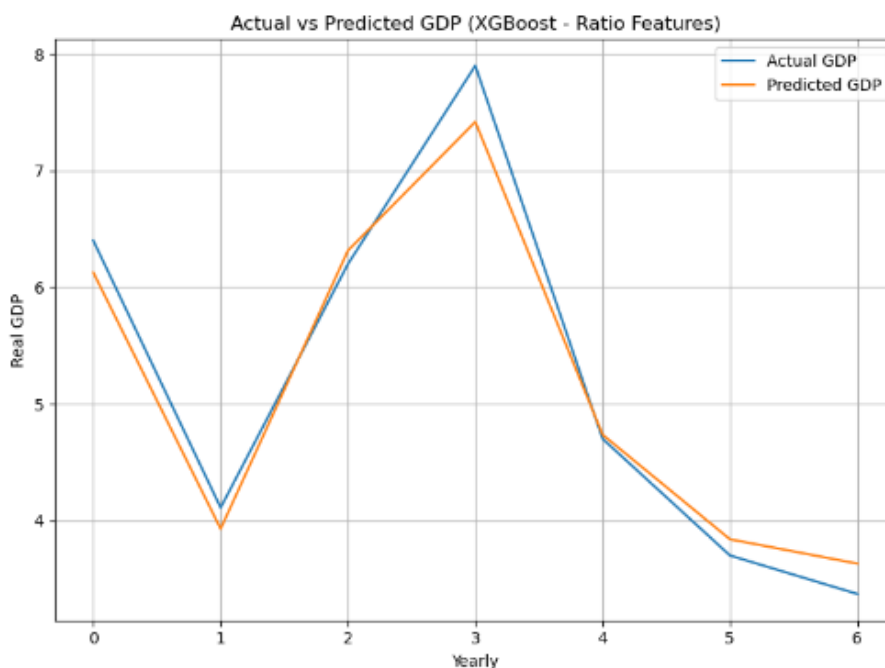


Figure 3. Comparative Predictive Accuracy of the Three XGBoost Models.

The comparison of the three XGBoost models trained on original, differenced, and ratio-transformed features confirms the ratio-based model as the optimal approach for modelling Ghana's GDP growth. While the original-features model demonstrated strong predictive capability ($R^2 = 0.8201$), the ratio-transformed model achieved superior performance, with near-perfect alignment to the actual data and outstanding met-

rics ($R^2 = 0.9737$, minimal error, and near-zero bias). By contrast, the differenced-features model performed poorly ($R^2 = 0.2955$) and exhibited severe overestimation, having removed essential long-term trend information from the data. The ratio-based model is therefore judged to be the most reliable for forecasting and for analyzing the impact of tax cuts and other macroeconomic indicators on economic growth.

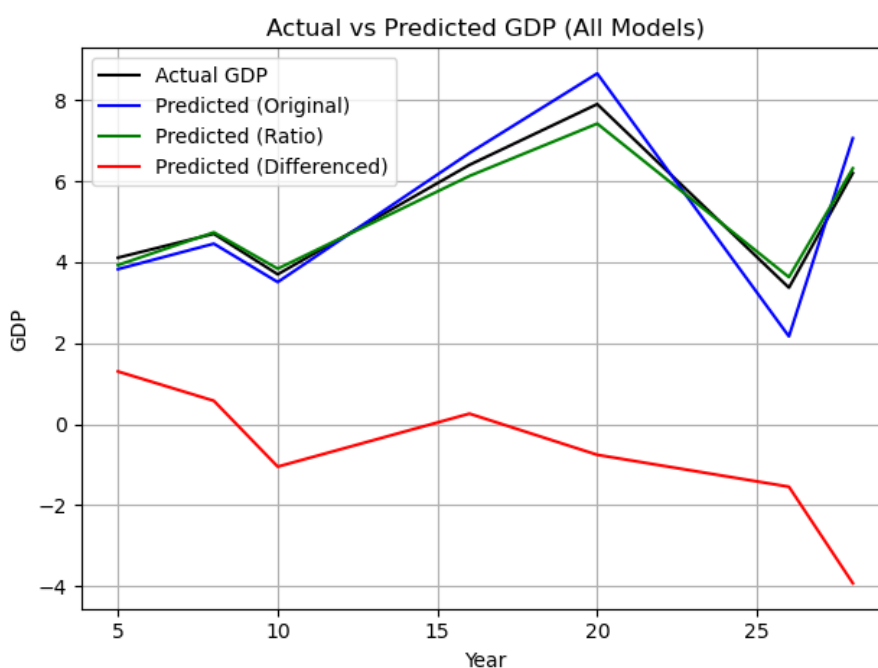
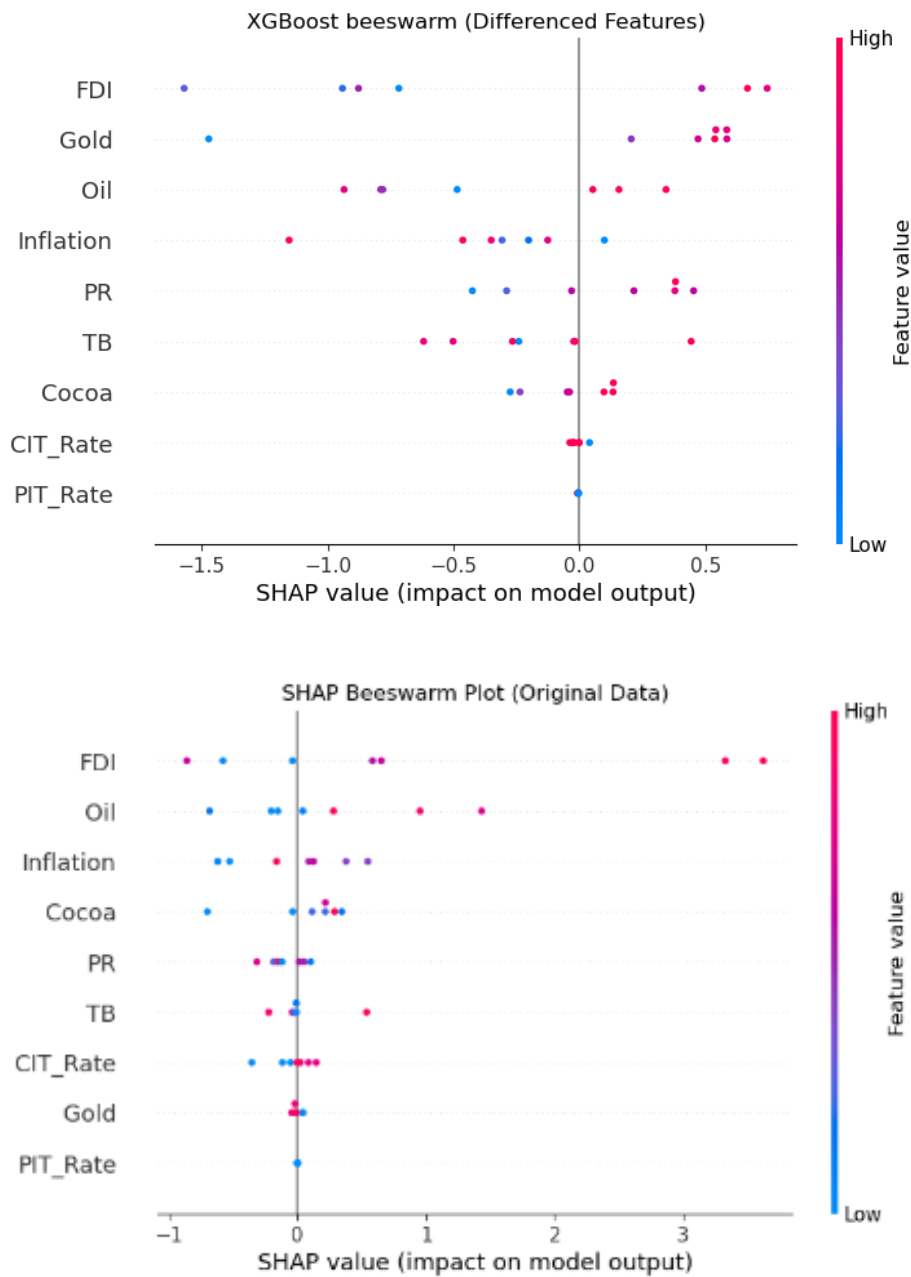


Figure 4. Predicted GDP for All Model Variants against Actual GDP.

Figure 4 compares actual GDP (black) with the predictions of the original (blue), ratio (green), and differenced (red) models. The ratio model shows the closest alignment with actual GDP, almost overlapping the true values and confirming its superior accuracy. The original-features model captures the general trend in GDP but shows noticeable deviations, particularly overestimating peaks and underestimating troughs. The

differenced-features model diverges markedly from the actual series, consistently underpredicting GDP and even producing negative values in later years. Overall, the ratio model provides the most reliable predictions, while the differenced model fails to capture long-term GDP dynamics.

3.4. Feature Importance: SHAP Analysis



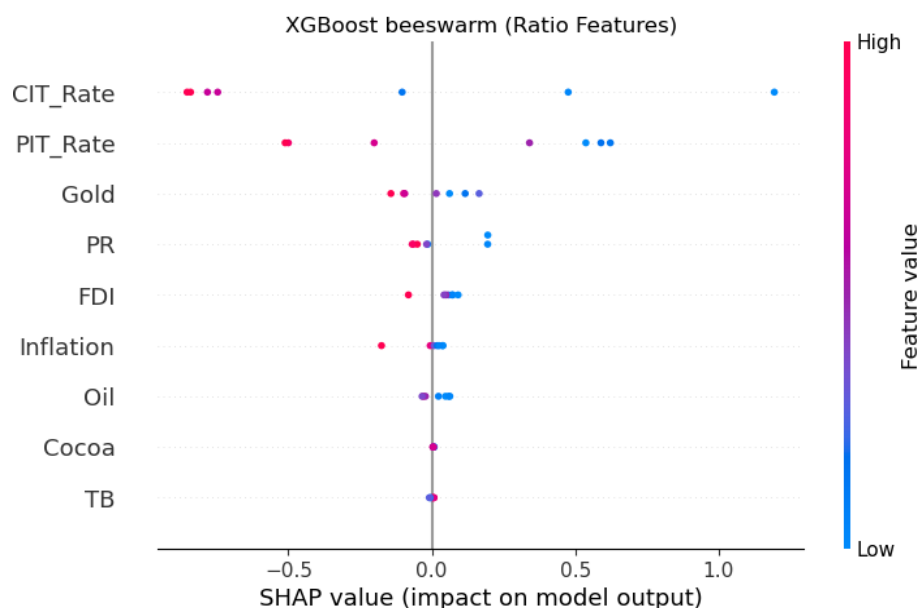
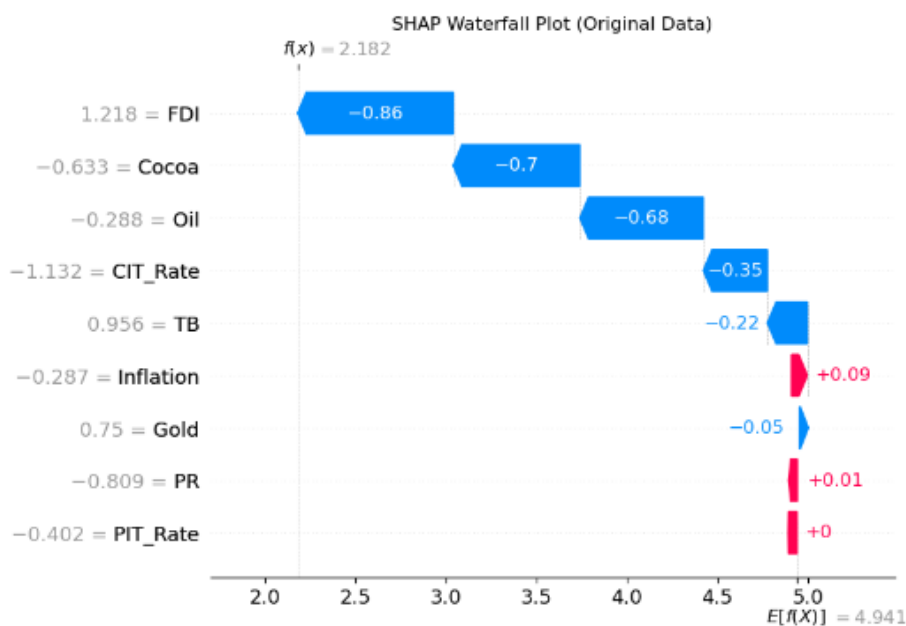


Figure 5. SHAP Summary (Beeswarm) Plots for the (a) Original, (b) Differenced, and (c) Ratio-Based Models.

The SHAP beeswarm plots across all three model variants consistently identify FDI and commodity exports (gold and oil) as primary positive drivers of GDP growth, while the CIT and PIT rates consistently exert negative effects, suggesting that tax cuts could stimulate the economy. In the original-features model, inflation and cocoa show context-dependent positive effects, while a higher policy rate has a mild dampening effect. The ratio-transformed model refines this picture, clarifying the strong negative impact of taxation and the positive role of

investment, though it shows that cocoa and the trade balance have a minimal or inconsistent influence. The differenced-features model highlights that short-term, year-on-year changes in commodities and monetary policy have a more immediate effect on GDP fluctuations than changes in tax rates, which operate over a longer time horizon. Collectively, the SHAP analysis provides robust, model-agnostic evidence that investment and exports are key growth catalysts, while taxation acts as a suppressant of growth.



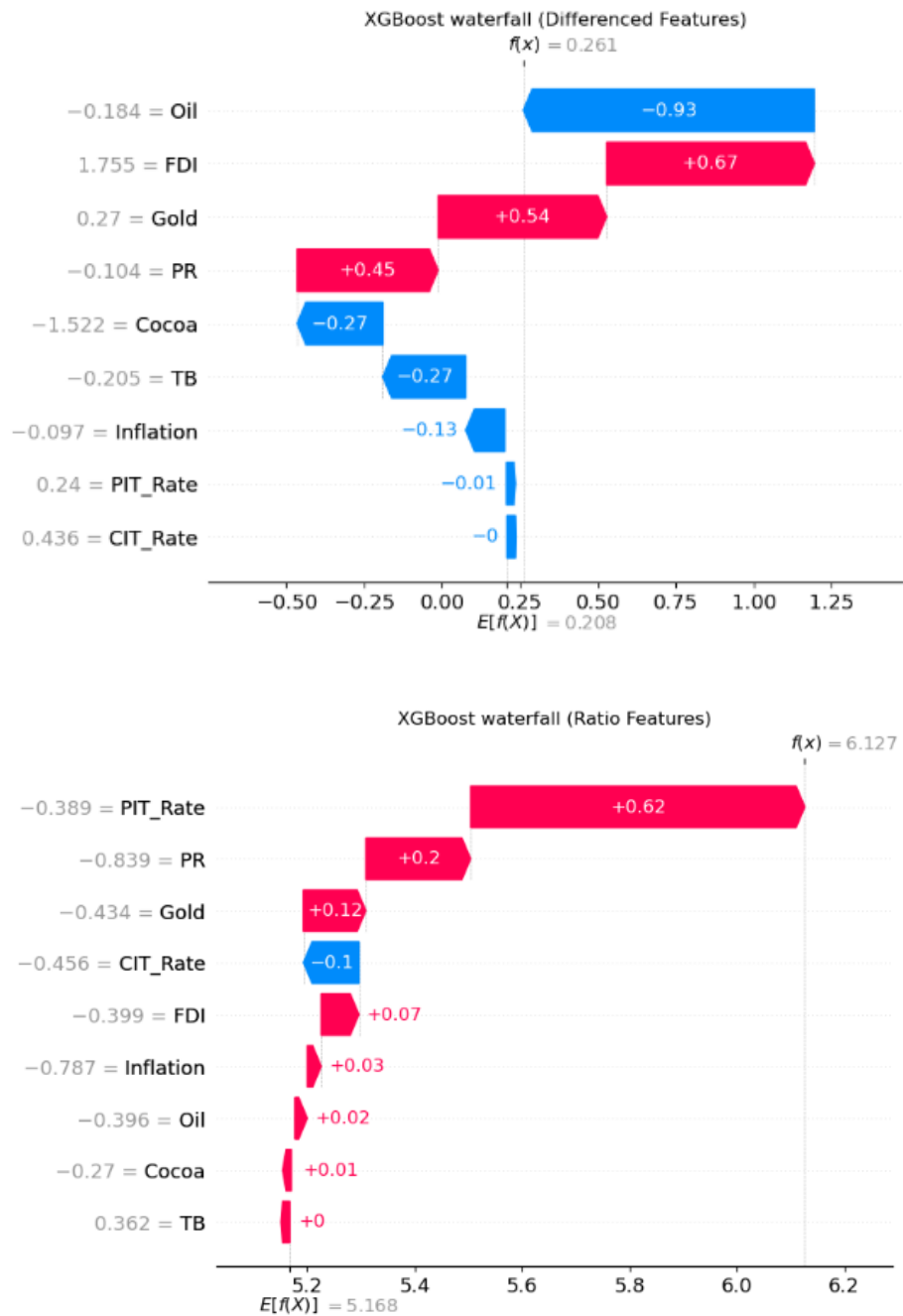


Figure 6. SHAP Waterfall Plots for Individual GDP Predictions across the Three Model Variants.

The SHAP waterfall plots illustrate how different features contributed to specific GDP predictions, highlighting context-dependent economic dynamics. In the original-features model, the prediction shown was dragged down primarily by negative contributions from FDI, cocoa, and oil suggesting issues such as poor capital allocation and commodity-price volatility with the CIT rate further reducing growth by discouraging investment. In the ratio-transformed model, a different period shows a more positive scenario, in which a higher PIT rate was the strongest positive driver, potentially reflecting robust tax com-

pliance and revenue, supported by a lower policy rate and contributions from gold and FDI; the CIT rate nonetheless remained a negative factor in this instance. The differenced-features model, focusing on short-term changes, shows oil and cocoa as significant negative drags due to export weakness, while FDI and gold are the primary positive drivers of growth. Collectively, these plots confirm that investment (FDI) and key exports (gold) are consistent growth catalysts, whereas taxation (CIT) and commodity-market volatility often act as suppressants, with the specific balance depending on the economic conditions and time horizon considered.

3.5. Hyperparameter Tuning

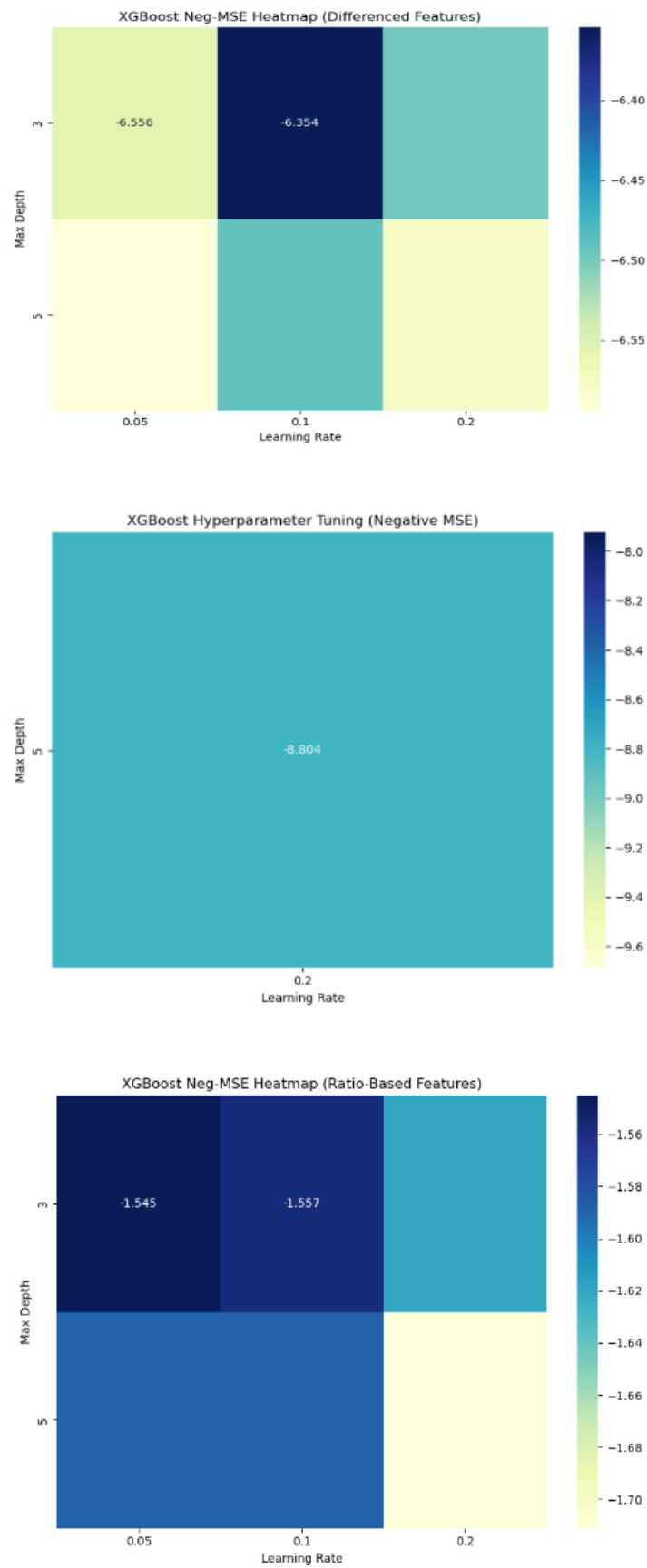


Figure 7. Hyperparameter Tuning (Grid-Search) Heatmaps for All Model Variants.

The grid-search results for key hyperparameters (e.g., learning rate, maximum tree depth) reveal further insights into model behavior and optimization. For the original-features model, FDI, cocoa, oil, and the CIT rate were the most influential but context-dependent features, with their impact on GDP predictions varying across time periods for instance, high values of FDI and cocoa sometimes negatively affected growth, highlighting the non-linear, complex relationships present in the economy. For the ratio-transformed model, hyperparameter tuning identified a learning rate of 0.05 and a maximum tree depth of 3 as the optimal configuration, balancing model complexity and generalization to achieve the best predictive accuracy (negative MSE = -1.545). Tuning of the differenced-features model likewise identified its best configuration, although its overall performance remained comparatively weak. Collectively, this analysis underscores that, while economic drivers such as investment and commodity exports are pivotal, their effects are not static, and careful model configuration is essential to capture these dynamics accurately.

4. Discussion

The results provide consistent, model-agnostic evidence that taxation - specifically the corporate and personal income tax rates act as a drag on Ghana's economic growth, while foreign direct investment and commodity exports (particularly gold and oil) act as growth catalysts. This finding is broadly consistent with the cross-country evidence of [21] and [22], both of which link lower corporate tax rates to stronger growth, and with the Ghana-specific concerns raised by [11] and [12] about the risk that revenue losses from tax cuts could destabilize public finances if not matched by improved compliance. It is also consistent with the Nigerian evidence of [30] and [31], which similarly finds a negative association between direct tax rates and growth outcomes in a comparable West African, oil- and commodity-exporting economy.

At the same time, the results should be read against the theoretical caution embedded in the Laffer-curve framework [17-20]: because the relationship between tax rates and government revenue is non-linear, a reduction in CIT or PIT rates does not mechanically translate into higher revenue or faster growth. [26] and [24] both note that tax cuts are frequently not matched by equivalent reductions in government spending, so that any growth benefit identified here needs to be weighed against the risk of a widening fiscal deficit, a risk that is especially salient given Ghana's current fiscal position, in which total revenue and grants have fallen short of projections.

The comparison of feature-engineering strategies is itself an important methodological finding. The substantially better performance of the ratio-transformed model ($R^2 = 0.9737$) relative to the model using original, untransformed features ($R^2 = 0.8201$) suggests that normalizing fiscal and macroeconomic variables to GDP shares removes scale effects that would otherwise obscure their true relationship with growth.

The poor performance of the differenced-features model ($R^2 = 0.2955$) further indicates that first-differencing removes economically meaningful long-run trend information that the model needs in order to predict GDP growth accurately; this is a useful methodological caution for future machine-learning applications in macroeconomic forecasting with a similarly small number of annual observations.

From a policy perspective, the SHAP results suggest that CIT and PIT cuts are more likely to translate into sustained growth when they are paired with policies that raise the productivity of investment and add value to Ghana's commodity exports, rather than being pursued in isolation. This is consistent with the view of [7] and [9] that the growth effects of tax cuts depend heavily on complementary structural conditions, and echoes the finding of [15] that the growth benefit of corporate tax cuts is sensitive to how firms respond to the changed incentives.

5. Conclusions

This study used an XGBoost regression model, combined with SHAP analysis, to examine the relationship between tax cuts and Ghana's economic growth using thirty-five years of macroeconomic data. The model trained on ratio-transformed features substantially outperformed the models trained on original and first-differenced features, achieving an R^2 of 0.9737 and a near-zero mean percentage error. SHAP analysis showed that higher corporate and personal income tax rates are consistently associated with lower GDP growth, while foreign direct investment and commodity export revenues particularly from gold and oil are associated with higher growth.

These findings suggest that tax cuts can support economic growth in Ghana, but that their effectiveness is likely to depend on complementary policies that improve the efficiency of investment, strengthen tax compliance and administration, and add value to commodity exports, rather than on tax cuts implemented in isolation. Future research should extend the analysis as additional years of data become available, incorporate effective (rather than only statutory) tax rates, and examine the distributional effects of tax cuts across different sectors of the Ghanaian economy.

Abbreviations

ARDL	Autoregressive Distributed Lag
CIT	Corporate Income Tax
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
MAE	Mean Absolute Error
MAPE	Mean Absolute Percentage Error
MPE	Mean Percentage Error
MSE	Mean Squared Error

OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Squares
PIT	Personal Income Tax
R ²	Coefficient of Determination
RMSE	Root Mean Squared Error
SHAP	SHapley Additive exPlanations
VAT	Value-Added Tax
XGBoost	Extreme Gradient Boosting

Author Contributions

Isaac Ampofi: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – original draft

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Conflicts of Interest

The authors declare no conflicts of interest.

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