

Effects of Exchange Rate Policy on Balance of Payments in Nigeria: A Machine Learning Approach

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Abstract

The effects of exchange rate policy on Balance of payments in Nigeria is a sensitive and significant issue because it examines how Nigeria's exchange rate policy influences external sector stability especially trade, capital flows, foreign reserves and overall balance of payments (BoP) outcomes and uses Machine Learning (ML) to capture effects that may be non-linear, delayed and regime dependent. It can provide timely, data-driven evidence for the Central Bank of Nigeria (CBN) and fiscal policy decisions than a purely conventional linear econometric approach. This study develops a hybrid-macro financial model that integrates the Mundell-Flemming open economy framework with machine learning techniques to analyze exchange-rate policy and balance-of-payments (BoP) dynamics in Nigeria. The theoretical structure follows the IS-LM-BP specification where the goods market (IS), money market (LM) and external balance (BP) jointly determine output, interest rates and the nominal exchange rate under alternative regimes (fixed, managed float, free float). Within this structure, key behavioral equations for net exports, capital flows and money demand are estimated using Nigerian data on output, inflation, interest rates, oil prices, foreign reserves and BoP components. To capture non-linearities, regime shifts and high-frequency dynamics that standard linear specifications miss, we employed Machine learning algorithms such as CatBoost, Ridge regression and SVR (RBF Kernel). Policy simulations examine how monetary policy shocks, fiscal expansions, oil price shocks and changes in exchange rate regime propagate through the model to affect output, inflation, reserves and the current and capital accounts. Results indicate that the hybrid Mundell-Flemming ML model outperforms purely linear IS-LM-BoP balances particularly during periods of policy regime changes and external shocks. The findings reveal that a managed-float regime complemented by rules-based interventions informed by ML-enhanced early-warning signals can improve external stability while preserving monetary policy effectiveness in Nigeria. This research demonstrates that Nigeria's current account balance can be predicted with meaningful accuracy from a small set of economically fundamental, same-year indicators, without resorting to time-series engineering. Ridge regression's outperformance over both a tree-based ensemble (CatBoost) and a kernel method (SVR) reflect the constraints of a genuinely small annual macro dataset — regularized linear models remain the most reliable choice at this scale.

Keywords: Machine learning, balance of payment (BoP), Exchange rate, inflation, output, model, current account

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1.0 Introduction

The Balance of Payments (BoP) is a systematic accounting record of all economic transactions between residents of a country and residents of the rest of the world over a specific period usually a quarter or a year (IMF, 2009; World Bank, 2025). A sustainable BoP position enhances a country's capacity to meet its international financial obligations, maintain adequate foreign exchange reserves, stabilize the domestic currency and support long-term economic growth (IMF 2023; World Bank, 2024). Conversely, persistent BoP deficits are often associated with exchange rate depreciation, rising inflation, depletion of foreign reserves and increased external vulnerability (Krugman et al, 2022).

In Nigeria, concerns about BoP sustainability have intensified in recent years due to the Country's heavy dependence on crude oil exports. Oil exports account for over 80 per cent of Nigeria's export earnings and more than half of government revenue making the external sector highly vulnerable to global oil price fluctuations (CBN, 2024; OPEC, 2023). For instance, the collapse of oil prices during the COVID-19 pandemic in 2020 followed by a sharp price volatility between 2021 and 2024 significantly weakened Nigeria's current account balance and foreign reserve position (World Bank, 2024; Adelegan & Abraham, 2022). Despite episodes of oil

price recovery, Nigeria's BoP position has remained fragile reflecting structural weaknesses in export diversification and external financing.

Recent macroeconomic developments have further complicated Nigeria's BoP dynamics. The persistent depreciation of the naira, particularly following exchange rate liberalization reforms between 2023 and 2024 has increased the cost of imports and external debt servicing thereby exerting additional pressure on the current account (CBN, 2024; Nwachukwu, 2021). Inflationary pressures driven by exchange rate pass-through effects, energy price shocks and supply-side constraints have also undermined external competitiveness and investor confidence (Bernard et al., 2024; IMF, 2023). These stylized facts suggest that Nigeria's BoP challenges extend beyond trade imbalances and are closely linked to broader macroeconomic conditions.

Within this context, Foreign direct investment (FDI) has been identified as a potentially stabilizing component of the BoP, particularly through its impact on capital and financial accounts. Unlike short-term capital flows, FDI provides relatively stable long-term financing that can support foreign reserve accumulation, ease balance of payment pressures and promote structural transformation (UNCTAD, 2024). However, Nigeria's FDI inflows have remained volatile and in recent years, relatively compared to other emerging economies reflecting concerns about macroeconomic instability, exchange rate uncertainty and policy inconsistency (Uguru, 2025, Adewole et al 2025). Specifically, between 2019 and 2024-Nigeria experienced a decline in net FDI inflows coinciding with heightened exchange rate volatility and rising inflation raising questions about the effectiveness of FDI in stabilizing the BoP.

The balance of payments can simply be compared to a country's profit and loss account regarding other countries. Statistical data on the balance of payments is reported in a closed account system with the so-called double entry bookkeeping where all economic transactions between domestic and foreign economic agents are registered. This account system consists of three parts: the current account, the capital account and the financial account. The capital account which includes capital transfers and the transfer of property rights has a modest scope in relation to other two components of the balance of payments.

A country's total exports and imports of goods and services, primary incomes and secondary incomes are registered in the current account. A surplus on the current account means that a country has a larger income than expenditure. The surplus thus becomes a positive financial account that can be used either for investments abroad or amortization of foreign debts.

The financial account in turn shows purchases and sales of financial assets and liabilities in relation to other countries. This and the current account can be regarded as two sides of the same coin and their total in theory should be zero. That is, a surplus on the current account must have a corresponding capital outflow in the financial account. Double entry bookkeeping means that each transaction in the balance of payments is entered into at least two different accounts-one as a debit and the other as a credit. In practice however, a residual item arises in the statistics which is often a considerable size. This is mainly because the sources of some of the statistics are not entirely comprehensive and more sub-items need to be estimated using statistical methods. The international investment position thus provides information on the country's financial assets and liabilities in relation to other countries broken down into financial instruments in the same way as the transactions in the final account.

The BoP records a country's transactions with the rest of the world through the current account, capital account, financial account and a balancing item by construction, recorded credits and debit offset.

A useful macroeconomic representation is;

$$CA + KA + FA + EO = 0$$

Where CA=current account

KA=capital account

FA=Financial account

EO=Errors and omissions

1.1 Nexus Between Exchange Rates and Balance Of Payments (BoP)

The correlation between the Balance of Payments (BoP) and the exchange rate is not unequivocal and is affected by the time perspective and developments in other real economic variables for instance. Robert Mundell (1962) believes that policy effectiveness depends critically on whether exchange rate is fixed or floating and on international capital mobility. He believes that under floating rates, monetary policy has strong influence through the exchange rate but under fixed rates, monetary autonomy is sharply constrained, and fiscal policy is relatively more potent.

Rudi Dornbusch (1976) thinks that exchange rates are forward-looking asset prices while goods prices adjust more slowly. He also posits that monetary shocks can cause exchange rate overshooting: a currency may initially move beyond its long-run level, then partially reverse as domestic prices adjust.

Maurice Obstfeld (1993) submits that expectations themselves can trigger crisis under certain conditions-even a peg that appears viable can be attacked if investors expect devaluation and policymakers face a trade-off between defending the currency and domestic objectives

Similarly, Baldwin and Krugman (1989) feel that large exchange-rate movements may affect trade persistently because firms face entry, exit and other sunk costs submitting that depreciation does not always generate an immediate, symmetric trade response; exchange rate shocks can have dutiable effects on trade patterns and equilibrium exchange rates.

Modern intertemporal approach posit that the current account reflects saving, investment, expected future income, demographics, fiscal policy and access to global finance-not only merchandise trade, but a deficit can also be efficient when it finances productive investment or smooths consumption; its sustainability depends on how it is financed and whether future income can service external liabilities.

In the long run, it is reasonable to assume that it is real economic factors that determine the current account and thereby the financial account and exchange rate. Households and the public sector choose the desired level for financial saving according to income, preferences and demographic developments. There are other real economic factors that give rise to the opposite correlation. If demand and the price of Nigerian goods rise on the world market, net exports increase and the current account is strengthened. The demand for naira rises, which reinforces the exchange rate.

Trade Balance (Exports and Imports) is the main channel in which naira loses its value against major currencies like the USD, Euro and Pounds. It tends to make Nigerian exports cheaper for foreign buyers potentially boosting export volumes (especially non-oil exports like agricultural goods). It makes imports more expensive for Nigerians potentially reducing import volumes. In economic theory, this improves the current account balance if the Marshall-Lerner condition holds (i.e. demand for exports and imports is sufficiently elastic).

The change in the composition of savings can lead to capital flow within the financial account, which in the short term only affects the exchange rate but in the slightly longer term also affects the current account. Exchange rate policy in Nigeria significantly influences the country's balance of payments (BoP) primarily through its effect on the current account (especially trade balance) and the capital/financial account. Most studies find that exchange rate movements and the chosen regime (fixed, managed float or flexible) have measurable though sometimes fixed effects on BoP components.

In Nigeria's case, several studies report that exchange rate depreciation has often been associated with negative effect on the overall BoP partly because the economy is heavily import-dependent (especially for defined petroleum, machinery and consumer goods). Non-oil export capacity is limited, so depreciation does not always translate into significantly higher export volumes. Imported inflation and higher input costs can offset gains. Capital and Financial Account: Exchange rate policy also affects capital flows through stable and credible exchange rate regimes with clear rules and adequate reserves can attract foreign portfolio investment and FDI by reducing exchange rate risk and improving the financial account of the BoP.

Frequent devaluations, sharp depreciation or unclear policy can trigger capital flight as investors and firms move funds out to avoid currency losses, deter foreign investment due to higher perceived risk. It also worsens the capital/financial account and puts further pressure on reserves.

2.0 Literature Review

Studies on BOP-Exchange rate dynamics using machine learning models for analyzing the relationship and complexity between these two variables in Nigeria are almost nonexistent or rare, this is the gap the study seeks to fill.

There exists a plethora of econometric studies which we leverage our study on. Recent ARDL-based studies (covering up to the early 2020's) find a positive and significant relationship between exchange rate and Nigeria's BOP suggesting that under certain conditions and policy frameworks, depreciation can help improve BoP especially when accompanied by sound monetary and fiscal policies.

Our study adopts two theoretical frameworks that are most relevant to explaining the determinants of the balance of payments (BoP) in Nigeria given the country's macroeconomic structure and external sector peculiarities. These are the Mundell Flemming model and the Dutch disease theory. These are adopted because of their direct relevance to exchange rate dynamics, capital flows, foreign direct investment (FDI), oil dependence and balance of payments performance which constitute the core focus of this study.

Shafi, *et al.*, (2015) evaluated the comparative analysis of the impact of exchange rate, inflation rate and interest rate on balance of payments in India and Pakistan. It was revealed that the inflation rate and foreign exchange rate had positive effect on balance of payments while interest rate had negative effect on balance of payments. Abdullahi, *et al.*, (2016) assessed the causal effect of foreign exchange rate on balance of payments in Nigeria by employing secondary data which were obtained from Central Bank Statistical Bulletin and National Bureau of Statistics within the period of 1970-2014 analyzed with ordinary least squares regression technique and granger causality analysis. The results revealed that exchange rate and money supply have positive effect and significantly affect Nigeria balance of payments. Money supply, real gross domestic product, consumer price index and interest rate have negative effect but insignificant on Nigeria balance of payments.

Similarly, Nwanosike, *et al.*, (2017) employed multivariate regression model to evaluate the effects of devaluation of domestic currency on balance of payments in Nigeria using Marshall-Lerner condition from 1970 to 2014. The result revealed that devaluation of exchange rate had negative effect on balance of payments (BOP) through balance of trade mechanism.

Delimus, *et al.*, (2018) examined the effect of exchange rate on balance of payments in Nigeria from 1999 to 2016 using Autoregressive Distributed Lag (ARDL) approach. Findings from the study revealed that nominal exchange rate had significant effect on Nigeria's balance of payments. Limbore and Moore (2019) examined the effect of exchange rates on balance of payments using secondary data from the RBI (Central Bank of India) covering the period of 2001 to 2018. Variables employed are export, import, trade account balance, current account balance and overall balance data which were analyzed using descriptive method. The study found that exchange rate was highly unstable which negatively influenced balance of payments.

On the other hand, Paul Krugman *et al* (2022) thinks that fixed pegs can become unsustainable when policy and reserves are inconsistent with the announced parity. A BoP/currency crisis occurs when defense of a peg exhausts reserves or borrowing capacity forcing devaluation or abandonment of a peg.

Ackay (2026) examines the political economy of Turkey's monetary policy experiment between 2018 and 2023 in the lens of policy coalitions, monetary unorthodoxy and external constraints. This seminal paper finds that sectorally differentiated monetary preferences reshaped the dominant social bloc giving rise to a coalition favouring low interest rates, credit expansion and discretionary state intervention. The study argues that conventional explanations centered on leadership preferences, institutional erosion or electoral opportunism cannot fully account for the persistence or timing of this unorthodox regime drawing on growth models perspective and critical state theory.

Furthermore, using a panel of G10 countries with monthly standardized data, Geldner (2025) finds that exchange rate depreciation initially worsens trade balances. Nevertheless, the impact varies across quantiles with significant heterogeneity between bilateral and effective exchange rates. This is the J-Curve effect which is one of the best documented phenomena in international economics. When a country's currency depreciates, the trade balance typically deteriorates first before improving later tracing a path that resembles the letter "J". The key insight is a timing mismatch because exchange rates and import prices adjust almost instantly but the volumes of goods traded respond only gradually.

Also, (Blecker, 2023; Geldner 2025) finds that exchange rate depreciation can engender improvements in current account balances by enhancing trade competitiveness. Exchange rate depreciation improves the current account balance through several interconnected channels rooted in the elasticity approach and the broader absorption approach through the relative price effect,

2.1 Mundell-Flemming Model (IS-LM-BP)

The IS-LM-BP model (also called the Mundell-Flemming model or IS-LM-BoP model) provides a core foundational framework for analyzing the interaction between monetary policy, exchange rates, interest rates and capital flows in an open economy. The model extends the closed economy IS-LM model to analyze a small open economy by adding the balance of payments (BP) as a third equilibrium condition. It shows how fiscal and monetary policies affect output and interest rates under different exchange rate regimes (fixed and flexible) and degree of capital mobility. Under a flexible exchange rate system, exchange rate adjustments play a central role in correcting external imbalances while in a fixed exchange rate regime, monetary policy and foreign reserve movements are used to stabilize the balance of payments.

A central result of the Mundell-Flemming model is that policy effectiveness depends on the exchange rate regime and capital mobility. Under fixed exchange rates, monetary policy becomes ineffective. Any attempt to change the money supply is offset by Central Bank intervention to maintain the peg (buying/selling reserves), so the LM curve cannot move independently. Fiscal policy becomes effective especially with high capital mobility: Expansionary fiscal policy shifts the IS curve to the right; to keep the exchange rate fixed, the Central Bank accommodates capital flows by adjusting reserves which shifts the LM curve and reinforces the output effect.

In sharp contrast, under a flexible (floating exchange rate), monetary policy becomes highly effective. An expansionary monetary shock shifts LM right lowering interest rates causing capital outflows and currency depreciation; depreciation boosts net exports shifting IS right and amplifying the output gain. Analogously, fiscal policy becomes weaker and fully ineffective with full capital mobility. Expansionary fiscal policy raises interest rates, attracts capital inflows, appreciates the currency and reduces net exports offsetting part or all the initial IS shift.

The importance of the Mundell-Flemming model to Nigeria lies in its emphasis on exchange rate volatility, interest rate movements and foreign capital flows particularly FDI. Existing evidence supports the notion that exchange rate instability in Nigeria has significantly influenced capital inflows and external sector performance. To buttress this, Adelegan and Abraham (2022) find that exchange rate policies in Nigeria directly affect the financial and capital accounts of the balance of payments by shaping foreign investors' expectations. Similarly, Ojunugwa (2024) argue that exchange rate management remains a critical tool for influencing trade balance and capital flows in Nigeria. It is also worth noting that the Mundell-Flemming model has certain constraints. One major criticism is the assumption of perfect or near perfect capital mobility which may not hold in developing countries like Nigeria currently plagued by policy uncertainty, somersault, institutional weaknesses and exposure to external shocks.

Machine learning (ML) is adopted here to augment the traditional Mundell-Flemming model since it is most valuable where traditional linear specifications are restrictive-for example when exchange rate responses depend on reserve adequacy, oil prices, global risk, capital mobility or mobility or policy-regime shift. Ridge Regression, CatBoost and SVR (RBF Kernel) is then employed to forecast exchange-rate changes using interest-rate differentials, money growth, fiscal variables, inflation, commodity prices, reserves and global risk indicators. This then helps to assess whether the estimated patterns align with Mundell-Flemming predictions.

2.2 The Dutch Disease Theory

The Dutch disease is an economic phenomenon where a boom in one sector-typically natural resources harms other parts of the economy especially manufacturing and agriculture making them less competitive. The theory explains how heavy dependence on natural resource exports can generate binding distortions in an economy and adversely affect balance of payments performance. The theory further iterates that resource booms such as oil exports lead to real exchange rate appreciation which reduces the competitiveness of non-resource sectors particularly manufacturing and agriculture. As these sectors decline, export diversification weakens, imports increase and the current account deteriorates thereby destabilizing the balance of payments. Nigeria represents a classic case for the application of the Dutch theory. The country's strong dependence on crude oil exports has exposed it to recurrent external shocks arising from global oil price volatility. Studies show that oil-driven foreign exchange inflows often lead to currency appreciation which undermines the competitiveness of non-oil exports and contributes to persistent trade imbalances (Ojunugwa et al 2024). The structural weakness has been a major factor behind Nigeria's recurring BoP challenges.

Nevertheless, the Dutch disease theory has been criticized for its deterministic outlook. Critics argue that resource dependence does not inevitably lead to balance of payments instability if appropriate macroeconomic and structural policies are implemented. Lucas et al (1989) further submits that global market conditions and

domestic policy choices play a critical role in shaping balance of payment outcomes beyond resource dependence alone. A substantial body of empirical evidence identifies exchange rate movements as a key determinant of Nigeria's Balance of payments (BoP). Using cointegration technique, Ojunugwa (2024) find that exchange rate fluctuations significantly influence Nigeria's trade balance with currency depreciation improving export competitiveness particularly in the non-oil sector. However, the study also emphasizes that oil volatility remains the dominant driver of Nigeria's external balance limiting the effectiveness of exchange rate adjustments.

Similarly, Uguru (2025) demonstrates that although exchange rate devaluation can improve trade balances in the short run, its long-term effectiveness in Nigeria is constrained by the inelastic demand for crude oil exports. This finding aligns with the Mundell-Fleming framework which highlights the importance of capital mobility and exchange rate regimes but also exposes its limitations in resource-dependent economies such as Nigeria. Also, Shobande (2018) documents that exchange rate policy is relevant for industrial outcomes using cointegration evidence implying that external competitiveness can be influenced through exchange rate related policy channels that ultimately shape and BoP performance.

Furthermore, Andohol (2020) evaluates J-curve dynamics for Nigeria between 1970 and 2018 and shows that structural breaks (e.g. policy regime shifts) can alter the adjustment path of the trade balance following exchange-rate movements, an important caution for interpreting exchange-rate effects on external balances without accounting for breaks. Several studies emphasize the role of FDI as a stabilizing component of the BoP particularly the financial account. Adelegan and Abraham (2022) using an Error Correction Model find that FDI inflows exert a positive short-run effect on Nigeria's financial account thereby contributing to BoP stabilization. However, they caution that the long-run impact of FDI remains uncertain due to exchange rate volatility and oil price fluctuations.

Bernard et al (2024) support this finding noting that FDI can alleviate BOP deficits when inflows are diversified across productive sectors of the economy. In contrast, when FDI is concentrated in the oil sector, its stabilizing impact on the BOP is often short-lived. Mugo et al (2023) further argue that FDI plays a critical role in financing Nigeria's current account deficits, especially in the presence of low domestic savings. Furthermore, Madueme (2016) emphasize reserve adequacy and external-sector management concerns, supporting the policy view that BOP sustainability requires buffers credible macroeconomic management.

Furthermore, oil price volatility has been consistently identified as a major source of BOP instability in Nigeria reflecting the country's heavy dependence on crude oil exports. Adekunle et al (2025) applying the ARDL bounds testing approach find that oil prices significantly influence Nigeria's Balance of Payments through both the trade and financial accounts. Their results indicate that increases in oil prices improve external balances while price declines exacerbate BOP deficits.

However, the effects of trade openness on Nigeria's BOP remains mixed. Adewole et al (2025) argue that trade openness enhances export competitiveness and supports current account stability. However, they acknowledge that Nigeria's reliance on oil exports and limited export diversification reduce the effectiveness of trade liberalization in improving the BOP. Nguyen et al (2023) similarly caution that the benefits of trade openness may be offset by inflationary pressures and increased import demand.

Furthermore, Pamogho et al (2023) similarly observe that positive oil price shocks strengthen Nigeria's financial account whereas negative shocks deteriorate the trade balance. Ullah and Nobanee (2025) find that oil price volatility affects the BOP through exchange rate adjustments and current account fluctuations. These findings strongly support the Dutch disease theory which explains how resource dependence exposes economies to persistent external sector vulnerabilities. Nigeria's external balance remains highly exposed to oil-market conditions. Using descriptive evidence, Emediegwu and Okeke (2017) show that oil dependency and oil price volatility are closely linked with unstable macro-outcomes reinforcing the view that external accounts are structurally fragile in oil-led phases. Also, Alonge, Adelokun and Omitogun (2018) apply ARDL between 1977 and 2015 and reports that oil price fluctuations are a significant long-run driver of Nigeria's current account implying that persistent oil shocks transmit directly into external balance outcomes.

Similarly, Azeez, Kolapo and Ajayi (2012) critically examined the link between exchange rate fluctuation and economic growth in the Nigerian economy from 1980 to 2010. The findings from this study validate the fact that real exchange rate and economic growth have a direct relationship. In another study, Hossain (2012) investigated how exchange rate volatility and performance of the Nigerian macroeconomic indicators are related between the periods of 1986 to 2010. It was established from the paper that a direct link existed between exchange rate and economic growth. However, Aderemi et al (2019) employed a vector error correction model to examine the

relationship between exchange rate volatility and foreign capital inflows in Nigeria from 1990 to 2016. The findings from the paper submitted that 32 percent of total disequilibrium due to external shock in the previous year is corrected in the current year. Also, FDI inflows increased exchange rate volatility in the short run, but the volatility dies away over time and remittances reduces exchange rate volatility while reverse was the case of external debt.

In the same vein, Aliyu et al (2009) estimated the nexus between real exchange rate and manufacturing exports in Nigeria and the Republic of Benin. It was discovered from the study that the major obstacle to the process of economy recovery in both countries is overvaluation of exchange rates. The author recommended among others that currency devaluation, implementation of appropriate policy measures and the domestic prices of tradable products should be adjusted in way to restore exchange rate equilibrium and boost the economy performance of the countries. Furthermore, Benson and Victor (2012) concluded that depreciation of exchange rate orchestrated an increment in imports and reduction in exports in Nigeria. On the other hand, reverse is the case for depreciation of currency. Therefore, the researcher argued that in the long run there would be a shift of attention from imported commodities to items locally produced as result of exchange rate depreciation. The aftermath effect of this would be a drastic diversion of income from abroad to domestic economy through a shift in terms of trade. Eventually, a significant impact on the economic growth in export and importing countries will be felt concurrently in the long run.

Furthermore, it could be pinpointed from the above reviewed literature that the studies on exchange volatility in Nigeria is ongoing, and the literature is very scanty about the impact of this variable on trade balance in the country. Hence, the relevance of this study.

Furthermore, because Nigeria still runs a current account heavily influenced by oil exports, exchange rate policy therefore interacts with oil prices. This means that when oil prices are high, BoP is strong even with a relatively weak naira. When oil prices fall, exchange rate depreciation alone may not fully offset BoP deterioration unless non-oil exports and domestic production respond strongly. Persistent BoP deficits force the Central Bank of Nigeria (CBN) to use foreign reserves to defend the naira and impose import restrictions or multiple exchange rate windows which can distort the market and affect long-term BoP dynamics. The broad consensus is therefore that exchange rates are an adjustment mechanism, but they are not a standalone cure for BoP imbalances. Sustainable external adjustments usually require consistency among fiscal policy, monetary policy, domestic saving and investment, productivity, trade structure, capital flow management and adequate reserves as well as policy credibility.

3.0 Data and Methodology

This research builds a predictive model for Nigeria's Balance of Payments current account balance, sourced entirely from official Central Bank of Nigeria (CBN) publications and supplemented with global Brent crude oil price data. The study adopts a Ridge regression model, trained on six economically grounded features and validated through a chronological train/test split, deployed as an interactive Streamlit web application.

The research followed a full applied-research workflow: raw data extraction from CBN's Statistical Bulletin workbooks, dataset construction and cleaning, correlation-driven feature selection, comparative model training (Ridge, CatBoost, SVR), SHAP-based interpretability analysis, and finally packaging into a reusable, documented, production-style project structure.

Best model: Ridge regression, MAE = \$5,359 million, $R^2 = 0.701$ on a held-out 2018–2024 test period—a substantial improvement over the naive persistence baseline.

3.1 Data Collection from the Central Bank of Nigeria

All core data originates from the CBN Statistical Bulletin (2024 edition), Section D — External Sector Statistics — a publicly available Excel workbook published by the CBN Statistics Department. This bulletin compiles Nigeria's Balance of Payments, trade flows, exchange rates, and external reserves under three successive compilation methodologies used since 1981:

- 1981–1993: Analytical Statement format (legacy tables, split by Oil / Non-Oil / Total)
- 2005–2013: Pre-BPM6 Compilation (IMF's fifth Balance of Payments Manual)
- 2014–2024: BPM6 Compilation (IMF's sixth, current Balance of Payments Manual)

Because CBN's own Balance of Payments compilation changed methodology twice, the current account, trade, services, and income series were extracted separately from each regime's tables and reconciled into one consistent annual panel, with a categorical flag retained to mark which methodology produced each year's figures. Global Brent crude oil price data was added from the Federal Reserve Economic Data (FRED) database to capture the world oil price effect independently of Nigeria's own export volume.

3.2 Dataset Columns — An Economic Perspective

The Balance of Payments current account is defined by economic identity as the sum of four components: Goods (trade balance), Services, Primary Income, and Secondary Income. The table below explains each retained column in these economic terms.

Column	Economic Meaning
current_account_usd_mn	TARGET. Net result of Nigeria's transactions with the rest of the world — positive means Nigeria is a net lender abroad, negative a net borrower.
trade_balance_usd_mn	Exports minus imports of physical goods — the Goods component of the current account, and empirically its dominant driver.
exports_total_usd_mn / imports_total_usd_mn	Gross value of goods sold to / bought from the rest of the world.
oil_exports_usd_mn	Crude oil and petroleum export revenue — reflects Nigeria's structural dependence on hydrocarbon exports.
brent_oil_price_usd_bbl	The world price of oil, isolated from Nigeria's own export volume — captures the external price shock separately from domestic production.
secondary_income_balance_usd_mn	Net current transfers, dominated by workers' remittances — a stabilizing inflow that partly offsets trade and income deficits.

3.3 Feature engineering

Feature engineering in this project deliberately excludes time-series constructs such as lagged values, rolling statistics, or year-over-year change rates. Every predictor represents a same-year, point-in-time economic indicator, making this a cross-sectional regression problem rather than a sequential forecasting one. Two simple ratio features were derived: oil export share (oil exports ÷ total exports) and current account as a percentage of GDP, the latter used only for contextual analysis since it is mathematically derived from the target itself.

A known consequence of this feature set is exact multicollinearity between trade balance, total exports, and total imports, since trade balance is defined as their difference. This was addressed not by dropping any of the three, but by relying on model families that tolerate correlated inputs gracefully: Ridge's L2 penalty shrinks correlated coefficients rather than becoming unstable, while CatBoost's tree splits and SVR's kernel similarity are structurally insensitive to linear dependence between features.

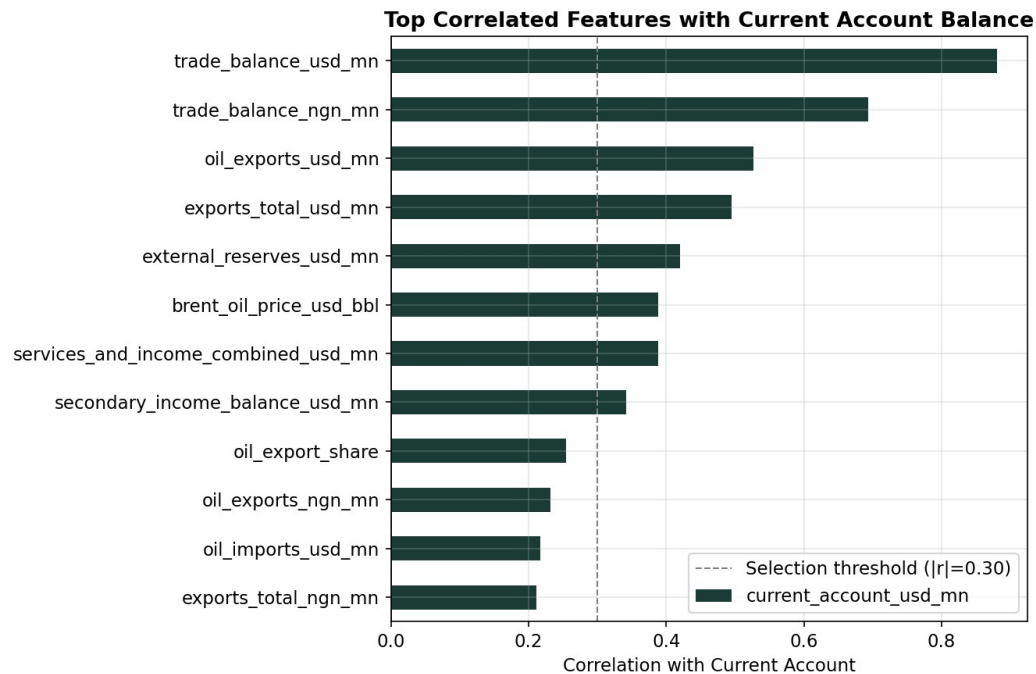
3.4 End-to-End Pipeline

- Extraction — parse CBN Excel workbooks (openpyxl) across three methodology regimes into one reconciled annual series.
- Cleaning — verify zero missing values in core columns; document and flag genuinely structural gaps (e.g. Brent price pre-1990).
- Feature engineering — derive oil export share and GDP-normalized ratios; no temporal transformations.
- Correlation analysis — rank all candidate columns against the target; visualize with a threshold-marked bar chart.
- Feature selection — retain $|r| \geq 0.30$ features plus economically essential imports.

- Model training — Ridge, CatBoost, SVR on an identical chronological 80/20 split.
- Evaluation — MAE, RMSE, R^2 per model; per-model and combined actual-vs-predicted plots.
- Interpretability — SHAP value analysis across all three model families.
- Deployment — model and scaler pickled; served through a Streamlit web interface.

3.5 Feature Selection

Candidate features were ranked by Pearson correlation against the target. Features clearing an absolute correlation threshold of 0.30 were retained; total imports were retained as an exception despite weaker raw correlation, since it is structurally embedded in the trade balance identity (trade balance = exports –



imports

Figure 1. Top 12 candidate features ranked by correlation with the current account balance. Only 6 of these were ultimately retained (see table below) Naira-denominated duplicates and external reserves were excluded for reasons detailed in Section 8.

Feature	Correlation (r)	Selection Basis
trade_balance_usd_mn	0.881	Dominant driver — retained
oil_exports_usd_mn	0.526	Above threshold — retained
exports_total_usd_mn	0.495	Above threshold — retained
brent_oil_price_usd_bbl	0.388	Above threshold — retained
secondary_income_balance_usd_mn	0.342	Above threshold — retained
imports_total_usd_mn	0.060	Below threshold — retained for economic completeness

The final dataset comprises 35 complete annual observations (1990–2024, constrained by Brent oil price availability) across 6 features — a samples-to-features ratio of 5.83:1, comfortably above the conventional 5:1 minimum guideline for stable linear model estimation.

3.6 Model Results

Three regression algorithms were trained and compared on an identical chronological 80/20 train/test split (train: 1990–2017; test: 2018–2024), avoiding any leakage of future information into model training.

Model	MAE (US\$ mn)	RMSE (US\$ mn)	R ²
Ridge Regression	5,358.6	6,043.3	0.701
CatBoost	6,794.3	7,805.2	0.502
SVR (RBF kernel)	8,543.4	9,888.9	0.200

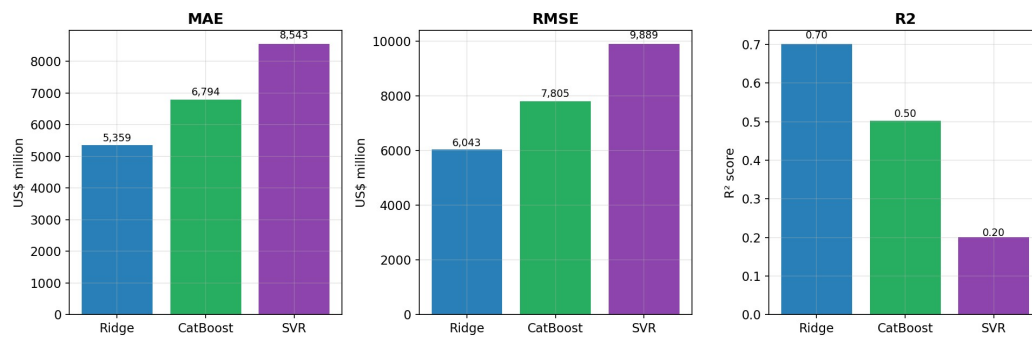


Figure 2. MAE, RMSE, and R² compared across all three models on the identical held-out test period.

Ridge regression was selected as the final production model, combining the lowest error and highest explanatory power, consistent with its L2 regularization being well suited to a small, moderately collinear feature set.

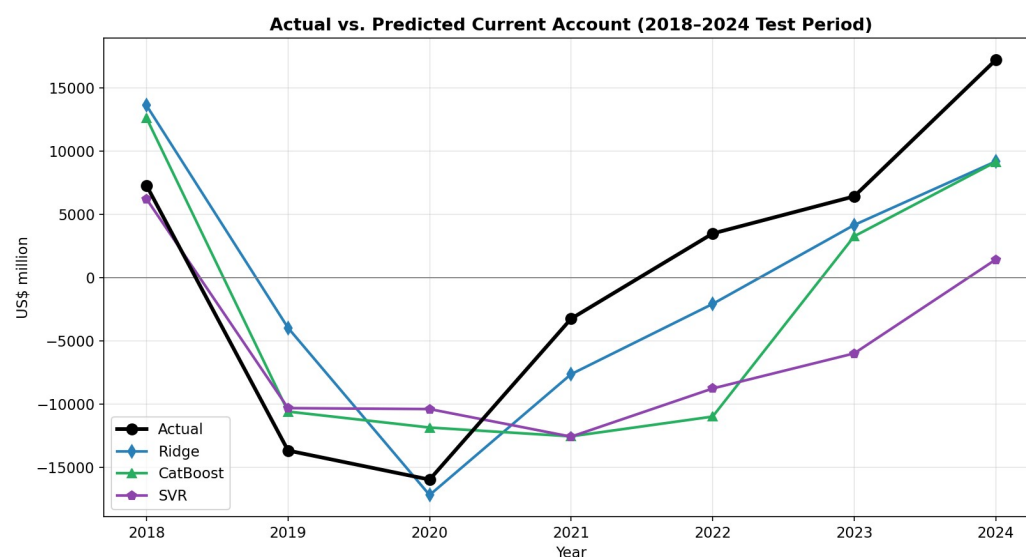


Figure 3. Actual vs. predicted current account for all three models over the 2018–2024 test period. Ridge tracks the overall shape most closely, including the 2020 downturn and the 2023–2024 recovery.

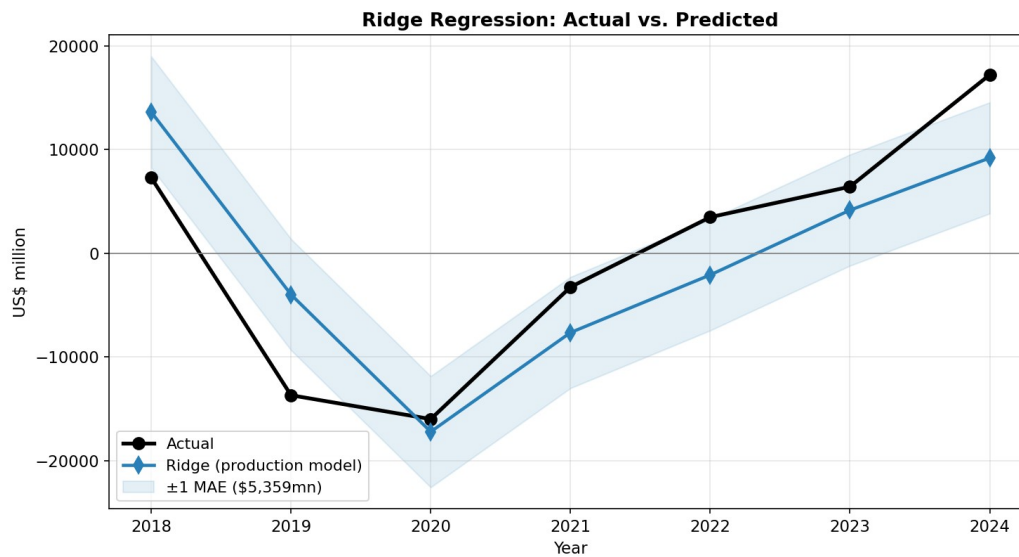


Figure 4. Ridge regression predictions with a ± 1 MAE uncertainty band — the production model's honest error margin, shown explicitly rather than presenting a single point estimate.

3.7 SHAP Interpretability Analysis

SHAP (SHapley Additive exPlanations) values were computed for the Ridge production model to verify economic plausibility beyond raw accuracy metrics. This method attributes each individual prediction to a contribution from every input feature, grounded in cooperative game theory.

Feature	Mean SHAP Value (US\$ mn)	Economic Interpretation
trade_balance_usd_mn	7,620.4 (1st)	Dominant contributor to every prediction, in agreement with the raw correlation analysis
imports_total_usd_mn	5,304.0 (2nd)	Ranks far higher in SHAP than its raw correlation ($r=0.060$) alone would suggest — a direct consequence of its multicollinearity with trade balance (Section 4). Ridge distributes explanatory weight across the linearly dependent trade features rather than assigning it all to one
secondary_income_balance_usd_mn	4,151.8 (3rd)	Remittances and transfers provide a consistent, moderate offsetting signal
brent_oil_price_usd_bbl	1,386.0 (4th)	Captures the global price effect distinctly from Nigeria's own export volume

Feature	Mean SHAP Value (US\$ mn)	Economic Interpretation
oil_exports_usd_mn	372.5 (5th)	A modest independent contribution once trade balance and Brent price already capture most of the oil-trade relationship
exports_total_usd_mn	4.4 (6th, lowest)	Negligible independent contribution — its information content is almost entirely captured by trade balance and imports together

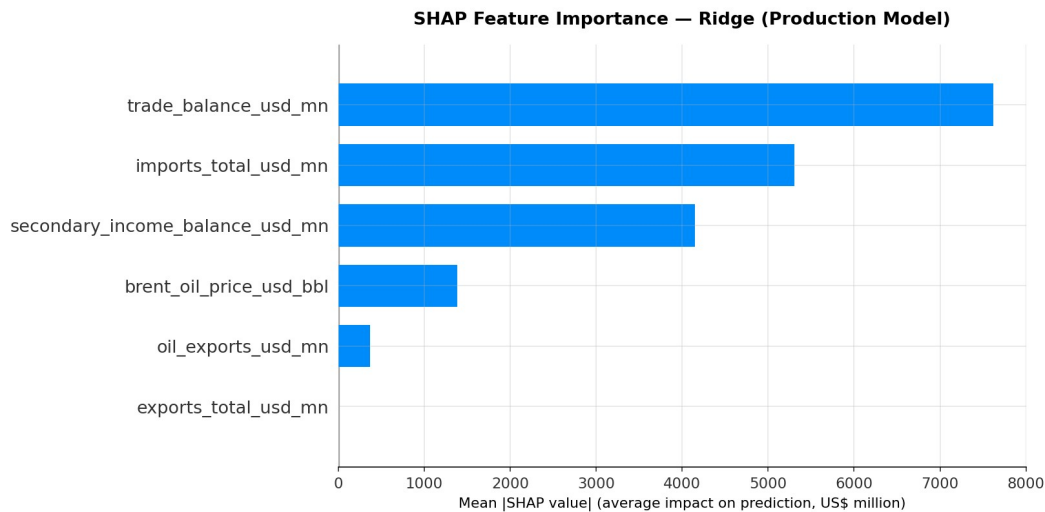


Figure 5. Mean absolute SHAP value per feature for the Ridge production model — the actual computed ranking, not a correlation-based approximation.

This ranking contains a genuinely important, non-obvious finding: total imports rank 2nd by SHAP despite having the weakest raw correlation with the target ($r=0.060$, Section 5). This is a direct signature of the multicollinearity flagged in Section 4 — because trade balance is mathematically exports minus imports, Ridge's regularized coefficients spread real explanatory weight across the trade-identity features rather than concentrating it entirely in trade balance alone. In other words, imports genuinely matter to the model's predictions; it simply does not show this through a simple linear correlation with the target in isolation.

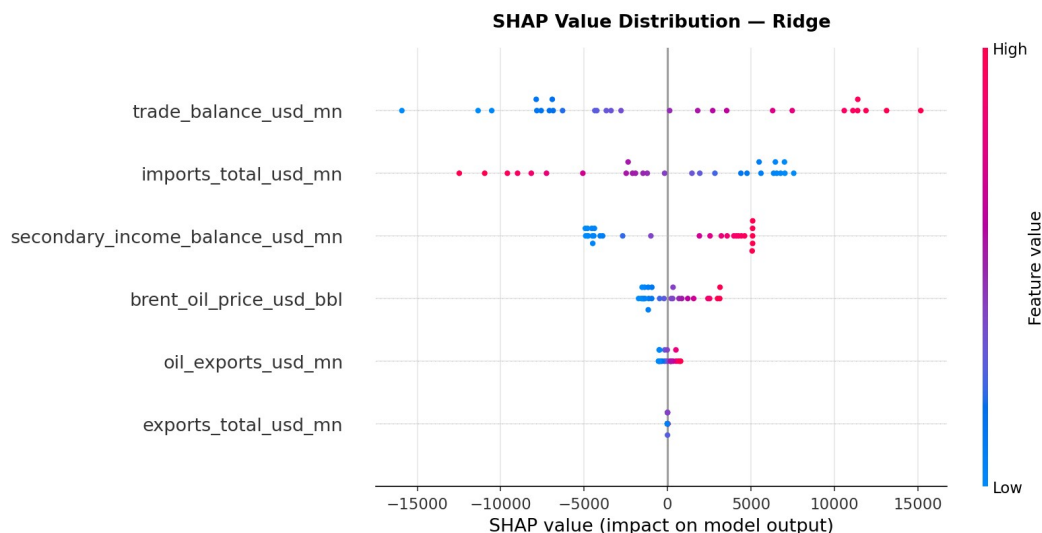


Figure 6. SHAP value distribution across all training observations — each point is one year, colored by that feature's value, showing both the direction and magnitude of each feature's influence.

3.8 Limitations

- Small sample size: 35 annual observations are limited by conventional machine learning standards, though typical for national-level annual macroeconomic series.
- Exact multicollinearity between trade balance, exports, and imports, mitigated but not eliminated by model choice.
- Brent oil price availability (from 1990 onward only) constrains the usable historical window, excluding 1981–1989 despite the target itself being available for those years.
- The model excludes services and primary income sub-components explicitly, since their earliest CBN compilation format does not separate them from other line items.

3.9 Conclusion

This research demonstrates that Nigeria's current account balance can be predicted with meaningful accuracy from a small set of economically fundamental, same-year indicators, without resorting to time-series engineering. Ridge regression's outperformance over both a tree-based ensemble (CatBoost) and a kernel method (SVR) reflect the constraints of a genuinely small annual macro dataset — regularized linear models remain the most reliable choice at this scale. The resulting model, packaged as a pickled artifact and served through a Streamlit interface, provides a transparent, reproducible, and economically interpretable tool for exploring how trade, oil, and remittance dynamics jointly shape Nigeria's external position.

Caveat: with 35 annual training observations, this model should be read as an order-of-magnitude analytical tool rather than a precision forecasting instrument. Extending the dataset with quarterly-frequency data remains the highest-value next step for improving both accuracy and confidence in future iterations.

3.9.1 Future research direction

A promising future research agenda is to move beyond predicting nominal exchange rate alone to developing early warning and policy simulation system for external sector stress. Can ML predict a sharp fall in international reserves? A large current account deterioration, a widening parallel market premium or a currency crisis in 1, 3, 6 and 12 months ahead?

This future research can specifically ask specific questions to examine if the development of new ML models can predict exchange-rate depreciation, exchange rate volatility or an exchange rate market pressure index more accurately than ARIMA, VAR/VECM, random walk and conventional early-warning models.

Future research can extend into modelling inflation heterogeneity using disaggregated CPI, nonlinear ARDL, local projections or VAR. Extensions can also be made to include fiscal-monetary interactions using threshold regression, SVAR or fiscal reaction functions to the study balance of payments and exchange rate dynamics.

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