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Macroeconomic Uncertainty and Capital Expenditure Decisions of Listed Manufacturing Firms in Nigeria: The Roles of Investment Irreversibility and Firm Size

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ABSTRACT: This paper empirically examines the effect of macroeconomic uncertainty on the capital expenditure (CAPEX) decisions of listed manufacturing firms in Nigeria, by looking at the roles of investment irreversibility and firm size. This study is based on the Real Options and Financial Frictions theories and solves the persistent problems of industrial underinvestment and capital budgeting distortions in resource-dependent emerging economies. The study employs a balanced longitudinal panel comprising 35 manufacturing firms listed on the Nigerian Exchange Group and observed annually from 2000 to 2024, yielding 875 firm-year observations. The empirical strategy proceeds in two sequential stages. First, univariate GARCH (1,1) models are estimated for the relevant macroeconomic variables Brent crude oil prices and domestic inflation to extract their conditional variances as measures of unanticipated oil-price and inflation uncertainty. These estimated uncertainty series are subsequently aligned with the annual firm-level panel observations. Second, a dynamic two-step System Generalised Method of Moments (System GMM) model is estimated for capital-expenditure growth. The specification includes the lagged dependent variable to capture investment persistence, firm-level controls, the GARCH-derived uncertainty measures, and interaction terms for investment irreversibility and firm size. The estimator is used to address unobserved firm-specific heterogeneity, dynamic investment adjustment, and potential endogeneity between investment decisions and explanatory variables. Model adequacy is assessed using Hansen tests of overidentifying restrictions and Arellano–Bond tests for first- and second-order serial correlation. Accordingly, the GARCH stage measures the macroeconomic uncertainty shocks, while the System GMM stage estimates how those shocks are transmitted to firms' capital-expenditure growth and moderated by irreversibility and firm size. The empirical results show that both oil price uncertainty and inflation rate uncertainty have a statistically significant direct effect on capital expenditure growth. This suggests serious cash-flow destabilisation and stop-and-go investment cycles due to foreign exchange rationing, input cost volatility and high discount hurdle rates. Moreover, this transmission mechanism is systematically conditioned by micro-level structural properties. Investment irreversibility is an interaction risk multiplier, which implies that

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high asset specificity, prohibitive sunk costs and illiquid secondary machinery markets compound corporate option-value penalties and intensify capital spending volatility. Conversely, company size is a strategic resilience buffer. The scale of operations, internal liquidity slack and better access to financing markets allow large manufacturing conglomerates to smoothen their capital allocation trajectories throughout volatile cycles. To spur private fixed capital formation, monetary authorities should focus on rule-based inflation targeting and foreign currency predictability. Development financing institutions could scale up equipment-leasing frameworks that reduce sunk-cost exposure. Furthermore, manufacturing executives must migrate to modular capital budgeting architectures to maintain strategic timing flexibility in the face of macroeconomic uncertainty.

Introduction and Background of the Study

Capital expenditure decisions are the main drivers of industrial development, productive capacity and long-term competitiveness of emerging economies (Jorgenson, 1963; McConnell & Muscarella, 1985; Udah, 2010; Kim & Byunghwan, 2018; Akan & Ewiwile, 2022).). However, the allocation of corporate capital is not done in vacuum but is heavily constrained by structural rigidities and institutional frictions in the wider macro-financial environment (Adegbite & Ayadi, 2010; Bernanke, 1983; Dixit & Pindyck, 1994; Udah, 2010 & Ososuakpor, 2021). Nigeria's dependence on crude oil exports has made its domestic manufacturers vulnerable to significant international price shocks that reduce export earnings, exert pressure on foreign reserves, weaken the exchange rate, and transmit imported inflation to domestic price levels (Central Bank of Nigeria, 2026; Equipment Leasing Association of Nigeria [ELAN], 2026; Ososuakpor, 2021; Tumala *et al*., 2022; World Bank, 2023). Exchange rate depreciation and inflationary pressures raise the local currency cost of imported machinery, raw materials and debt servicing, which constrains financing conditions, raises hurdle rates and makes expected project returns more uncertain, thereby discouraging or delaying capital expenditure commitments (Henriques & Sadorsky, 2011; Maghyereh & Abdoh, 2020; Baharumshah *et al*., 2016). Therefore, these conditions constitute a critical research problem for the present study as they may help to explain why capital expenditure decisions continue to be problematic for firms operating in the volatile macro-financial environment of Nigeria.

The costly irreversibility of investment creates a valuable waiting option in periods of increased volatility (Rahayu, 2019; Ososuakpor, 2021 & Oyadeyi, 2025). This results in a rational response by corporate managers to delay capital projects until uncertainty is resolved (Rahayu, 2019; Londono *et al*., 2023 & Cui *et al.,* 2025). The Real Options Theory amplifies the effect in Nigeria's manufacturing sector due to the very irreversible nature of equipment purchases, the non-existence of robust secondary markets for used equipment, and financing limitations that increase the cost of committing scarce resources under uncertainty (Bernanke, 1983; Pindyck, 1991; McDonald & Siegel, 1986; Dixit & Pindyck, 1994; Chirinko & Schaller, 2002; Gulen & Ion, 2016; & Ososuakpor, 2021). This mechanism is especially relevant in the Nigerian manufacturing sector where underdeveloped secondary markets, asset specificity and limited financing channels mean that capital commitments are less reversible and thus more sensitive to uncertainty.

However, the transmission of these shocks is not uniform across firms but is conditioned by the investment irreversibility and the size of the firm (Gertler & Gilchrist, 1994; Abel & Eberly, 1996; Guiso & Parigi, 1999; Dang et al., 2019). Nigeria's secondary markets are underdeveloped and asset specificity is high, which increases irreversibility penalties, thereby increasing the option value of delay and further depressing capital expenditure (Bertola & Caballero, 1994; Dixit & Pindyck, 1994; Udah, 2010; Lian *et al*., 2020). In contrast, larger manufacturing firms have economies of scale, higher liquidity cushions and access to capital markets and are therefore shielded from financial market frictions than smaller credit-rationed firms (McKinnon, 1973; Shaw, 1973; Greenwald & Stiglitz, 1990; Erickson & Whited, 2006; Dang *et al*., 2019; ELAN, 2026). It is of utmost importance to understand these interactions to grasp capital formation and industrial recovery in Sub-Saharan Africa (ELAN, 2026; National Bureau of Statistics, 2024; Akan & Ewiwile, 2022).

Statement of the Problem

Despite successive policy reforms, Nigeria's manufacturing value-added has declined from more than 20% of GDP in the early 1980s to approximately 9.6% in recent years (CBN, 2026). A key mechanism linking this decline to corporate capital expenditure

is the instability and inadequacy of investment in productive plant and equipment. Uncertain capital spending can postpone the expansion of capacity, upset the replacement and maintenance of machinery and constrain the capacity of firms to install productivity-enhancing technologies (Maghyereh & Abdoh, 2020; Acharya *et al.*, 2025). These effects undermine the reliability and efficiency of production, particularly combined with exchange rate volatility, high financing costs, insufficient electricity supply and policy uncertainty (Ososuakpor, 2021 & Oyadeyi, 2025). Oil price shocks and uncertainty about inflation may increase investment volatility and decrease productive capacity of firms in turn (Akan & Ewiwile, 2022 & Ososuakpor, 2021). This is premised on the fact that investment and output have moved in the same direction. This accounts for the observed decline in manufacturing value-added (Adegbite & Ayadi, 2010; Central Bank of Nigeria, 2026; Akan & Ewiwile, 2022; Udah, 2010; World Bank, 2023).

Because investment volatility weakens productive capacity, it ultimately contributes to the decline in manufacturing value-added (Binder *et al.*, 2025). This ongoing decline suggests a more fundamental problem of investment that when companies are unable to sustain their capital formation, constraints on productive capacity, productivity growth and sectoral expansion increase (Alfaro *et al.*, 2024). Thus, growth in capital expenditure is a suitable outcome variable as it directly captures firms' investment response to macroeconomic uncertainty and the extent to which they continue to allocate funds to productive assets in the face of adverse conditions. This chronic investment deficit is further worsened by oil price shocks that deplete foreign exchange reserves needed to import industrial machinery and raise domestic energy costs for off-grid operations (Udah, 2010; Riaz *et al.*, 2016; Ososuakpor, 2021; Akan & Ewiwile, 2022; Tumala *et al.*, 2022; ELAN, 2026). At the same time, the general uncertainty about inflation decreases consumers' demand, increases operating costs and increases discount rates, thus reducing the relevance of traditional calculations of net present value and forcing business executives to adopt cautious capital-preservation strategies (Bernanke, 1983; Dixit & Pindyck, 1994; Adegbite & Ayadi, 2010; Udah, 2010; Riaz *et al.*, 2016; Baharumshah *et al.*, 2016; Central Bank of Nigeria, 2026; & ELAN, 2026).

The existing literature has two main gaps. Existing research on Nigeria has predominantly focused on macroeconomic variables in nominal levels or their average impacts, but have overlooked the investment implications of uncertainty in itself. Real-options theory provides a useful bridge to firm-level capital expenditure decisions because, when investment is irreversible and future conditions are uncertain, firms treat capital spending as a timing decision rather than a purely static response to current profitability (Rahayu, 2019; Ososuakpor, 2021). In particular, limited attention has been given to how second-moment conditional volatility in oil prices and inflation not simply their levels change the option value of waiting, the required return to irreversible investment, and the threshold at which firms commit to capital expenditure (Bernanke, 1983; Dixit & Pindyck, 1994; Adegbite & Ayadi, 2010; Udah, 2010; Akan & Ewiwile, 2022). A related limitation is the tendency in emerging-economy corporate-finance research to treat firms' responses to macroeconomic shocks as broadly uniform, without explicitly testing whether asset irreversibility and firm size alter the magnitude or direction of those responses (McKinnon, 1973; Bertola & Caballero, 1994; Gertler & Gilchrist, 1994; Abel & Eberly, 1996; Guiso & Parigi, 1999; Dang *et al.*, 2019; Lian *et al.*, 2020).

This study addresses these gaps by estimating the direct effects of oil-price and inflation uncertainty on capital-expenditure growth and testing whether those effects vary with investment irreversibility and firm size. It therefore shifts the focus from whether macroeconomic conditions matter on average to how uncertainty shapes investment timing and which firms are most responsive.

Conceptual Review

Capital Expenditure Growth

Capital expenditure (CAPEX) is the capital used by an enterprise for the purchase, upgrade or maintenance of physical long-term assets such as land, industrial buildings, manufacturing plant infrastructure, and heavy machinery (McConnell & Muscarella, 1985; Kim & Byunghwan, 2018). In corporate finance, capital expenditure is an indicator of the firm's long-term growth strategy, adaptation to technology, and additions to productive capacity (Chan *et al.*, 1995; Brailsford & Yeoh, 2004; Farooq et al., 2022).

This report operationalizes capital expenditure decisions through Capital Expenditure Growth (CAPEX Growth) as the period-on-period growth rate, or the annual percentage change in total capital expenditures (Titman *et al.*, 2003; Dimitrov & Jain, 2008; Farooq et al., 2022). CAPEX Growth captures the dynamic trajectory of firm-level capital expansion rather than static investment levels, providing a direct measure of managerial willingness to execute growth options under changing economic

environments (Erickson & Whited, 2006; Gulen & Ion, 2016). Econometrically, CAPEX Growth for firm $_i$ at time t is expressed as:

$$CAPEX\ Growthi, t = \frac{CAPEXi, t\ -\ CAPEXi, t-1}{CAPEXi, t-1}$$

Alternatively, in corporate panel data models controlling for size distortion, capital expenditure is scaled by beginning-of-period capital stock, proxied by net Property, Plant, and Equipment ($PPE_{i,t-1}$) or total assets ($TA_{i,t-1}$), to represent the corporate investment rate ($I_{i,t}/K_{i,t-1}$) (Erickson & Whited, 2006; Lian *et al.*, 2020).

Oil Price Uncertainty

According to Maghyereh & Abdoh, (2020) oil price uncertainty is the variations of the international Brent crude oil prices over time. It is not just the rise or fall of the price level or its direction (Maghyereh & Abdoh, 2020). The OPU does not imply a change or increase in crude oil prices, rather it is the second moment conditional variance (volatility) of oil price returns that is usually estimated using Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models (Ososuakpor, 2021; Baharumshah *et al.*, 2016).

The OPU impact on the operations of listed manufacturing firms in Nigeria is transmitted through three distinct macroeconomic channels: constraints in foreign exchange liquidity, costs of energy operation and changes in aggregate demand (Riaz et al., 2016; Tumala et al., 2022). First, the volatile oil prices cause drastic fluctuations in national foreign exchange reserves that destabilize foreign exchange liquidity and constrain firms' ability to import capital equipment and raw materials (Udah, 2010; ELAN, 2026). Secondly, the prices of refined petroleum products (diesel and heavy fuel oil) are directly influenced by the volatility of crude oil prices, which plays a significant role in the operating costs of industries which are highly dependent on generators (Akan & Ewiwile, 2022; Riaz et al., 2016). Thirdly, the variation in crude oil prices induces macroeconomic instability which destabilizes government capital expenditure and consumers' income, thereby weakening the national aggregate demand (Akan & Ewiwile, 2022; Tumala et al., 2022; Central Bank of Nigeria, 2026).

Inflation Rate Uncertainty

Inflation Rate Uncertainty (IRU) is the unpredictable variation in the general price level of goods and services in an economy (Ososuakpor, 2021). In this study, IRU was proxied by the conditional volatility of the national inflation rate series (Ososuakpor, 2021; Baharumshah *et al.*, 2016). IRU is econometrically modelled like OPU using GARCH(1,1) techniques to isolate the unforecastable variance component of domestic inflation (Ososuakpor, 2021). IRU distorts financial planning, nominal risk adjusted discount rates, and therefore destabilizes corporate capital allocation (Bernanke, 1983). High IRU increases the nominal market interest rates which increases the cost of borrowing in the long-run (Binder et al., 2025). It also generates significant uncertainty in the future input prices and profit margins (Adegbite & Ayadi, 2010; Baharumshah et al., 2016). At a high level of IRU, the capital budgeting of expenditures becomes extremely distorted because the real future cash flows become unreliable (Ososuakpor, 2021). Corporate managers shorten the investment horizons and cut back long-term capital commitments (Dixit & Pindyck, 1994; Udah, 2010). The real options theory argues that firms facing higher inflation uncertainty will defer irreversible investment, since waiting maintains flexibility until prices become clearer (Ososuakpor, 2021).

Investment Irreversibility

Investment irreversibility (IRREV) is the degree to which an installed physical asset cannot be sold, liquidated or redeployed to alternative uses without a significant loss of capital (Abel & Eberly, 1996; Arrow, 1968; Dixit & Pindyck, 1994; He *et al.*, 2022; Baley et al., 2025). Asset specificity and secondary market frictions are the two main economic sources of irreversibility (Bertola & Caballero, 1994; Chirinko & Schaller, 2002; Lian et al., 2020; Baley et al., 2025). When used outside the firm or industry, capital assets specific to a particular manufacturing process have a very low market value (Bertola & Caballero, 1994; Lian *et al.*, 2020). In emerging markets like Nigeria, it is often hard to liquidate assets because secondary equipment markets are thin and illiquid and search and transaction costs are high (Chirinko & Schaller, 2002; Udah, 2010). In empirical corporate finance, tangibility or the capital specificity ratio, measured as net property, plant and equipment divided by total assets (PPE/TA), or industry-level capital resalability and liquidation recovery indices (Guiso & Parigi, 1999; Lian *et al.*, 2020) are often used proxies for IRREV. A higher PPE/TA ratio reflects a capital structure with a larger share of fixed, sunk assets, which exposes the firm to higher costs of irreversibility in the face of macroeconomic crises (Erickson & Whited, 2006; Gulen & Ion, 2016; Lian *et al.*,

2020).

Firm Size

Firm size (SIZE) is a measure of the size of the resources of an enterprise, both in terms of physical, operational and financial resources (Dimitrov & Jain, 2008; Erickson & Whited, 2006; Alfaro et al., 2024; Tang et al., 2025). In empirical research on panels, SIZE is often represented by the natural logarithm of total assets or the natural logarithm of market capitalization (Titman *et al.*, 2003; Dang *et al.*, 2019). Firm size is an important moderating factor to dampen the financial market frictions and the uncertainty shocks (Greenwald & Stiglitz, 1990; Gertler & Gilchrist, 1994; Alfaro et al., 2024; Tonye & Nwikina, 2023). Larger listed manufacturers tend to enjoy higher credit ratings, longer-standing banking relationships, lower information asymmetry, larger cash reserves and more diversified product lines (McKinnon, 1973; Dang *et al.*, 2019; Alfaro et al., 2024; Tonye & Nwikina, 2023). Hence, bigger firms tend to survive macroeconomic shocks and have access to external financial sources such as corporate bonds markets or leasing structures for equipment, which decreases the negative effect of macroeconomic uncertainty on capex growth compared to smaller firms (Dang *et al.*, 2019; Odionye et al., 2024; ELAN, 2026).

Conceptual Framework

The structural relationships governing this study connect exogenous macroeconomic shocks directly to micro-level corporate decisions, moderated by firm structural characteristics. Exogenous shocks originating from global crude oil markets and domestic price dynamics generate conditional volatility in oil prices (*OPU*) and inflation rates (*IRU*) (Binder et al., 2025). These macro uncertainty shocks filter down to listed manufacturing firms via financial and real transmission channels namely, foreign exchange illiquidity, elevated risk premiums, input cost volatility, and compressed real operating cash flows (Adegbite & Ayadi, 2010; Ososuakpor, 2021).

Macroeconomic uncertainty reduces firms' willingness and ability to invest through two complementary mechanisms (Ososuakpor, 2021). Real Options Theory predicts that uncertainty increases the value of waiting when investment is difficult to reverse, while Financial Frictions Theory predicts that uncertainty tightens external financing conditions and raises the cost of capital. Accordingly, oil-price and inflation uncertainty are expected to reduce CAPEX Growth through both uncertain operating cash flows and constrained financing (Baharumshah *et al.*, 2016, Maghyereh & Abdoh, 2020, Acharya *et al.*, 2025 & Binder *et al.*, 2025). The negative effect should be stronger for firms with highly irreversible assets because postponing investment preserves the option to wait, but weaker for larger firms because internal liquidity, diversification, and superior credit access improve their capacity to absorb macroeconomic shocks (Ososuakpor, 2021).

Uncertainty shocks lower the growth of corporate capital expenditure (CAPEX Growth) by increasing the hurdle rates and tightening the external financing constraints (Bernanke, 1983; Dixit & Pindyck, 1994; Myers & Majluf, 1984; Binder et al., 2025), based on Real Options Theory and Financial Frictions Theory. Importantly, this direct relationship is moderated by two structural factors at the firm-level. Investment Irreversibility (IRREV) is a negative moderator or amplifier of negative shocks because firms with higher asset specificity have a higher option value of waiting, resulting in a steeper contraction in CAPEX Growth under uncertainty (Abel & Eberly, 1996; Guiso & Parigi, 1999; Rahayu, 2019; Ososuakpor, 2021; He *et al.,* 2022; Cui *et al.,* 2025).

Alternatively, the firm size (SIZE) acts as a positive moderator or an attenuator of negative shocks (Dang *et al.*, 2019). Larger firms use their operational scale, their internal liquidity buffers and their access to credit to neutralize macro volatility; thus, they maintain CAPEX Growth better than smaller enterprises (Gertler & Gilchrist, 1994; Dang *et al.*, 2019; Alfaro et al., 2024). Thus, we hypothesize that uncertainty shocks decrease CAPEX Growth, the negative effect being larger for higher IRREV and smaller for larger SIZE. Table 1 presents the conceptualized variables, operational proxies, theoretical expectations, and foundational literature.

Table 1: Summary of conceptualised Variables, proxies, theoretical expectations and foundational literature

Variable Classification	Variable Name	Symbol	Operational Proxy / Measurement Formula	Theoretical Expected Sign on CAPEX	Supporting Literature

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				Growth	
Dependent Variable	Capital Expenditure Growth	$CAPEX_{i,t-1}$	Annual percentage change in Capital Expenditure: $\frac{CAPEXi,t - CAPEXi,t}{CAPEXi,t-1}$	Baseline Outcome Variable	Dimitrov & Jain (2008); Titman et al. (2003); Erickson & Whited (2006)
Independent Variable	Oil Price Uncertainty	OPU	Conditional variance (volatility) of Brent crude oil returns estimated via GARCH(1,1)	Negative (-)	Henriques & Sadorsky (2011); Maghyereh & Abdoh (2020); Ososuakpor (2021).
Independent Variable	Inflation Rate Uncertainty	IRU	Conditional variance (volatility) of Consumer Price Index (CPI) changes via GARCH(1,1)	Negative (-)	Bernanke (1983); Volkov & Yuhn (2016); Ososuakpor, (2021)
Moderating Variable	Investment Irreversibility	IRREV	Capital Specificity Ratio: Net Property, Plant, and Equipment to Total Assets $(\frac{PPEi,t}{TAi,t})$	Negative Moderator (Amplifies direct negative impact of OPU & IRU)	Dixit & Pindyck (1994); Guiso & Parigi (1999); Lian et al. (2020)
Moderating Variable	Firm Size	SIZE	Natural logarithm of Total Assets ($Ln\ TA_{i,t}$) or Market Capitalization	Positive Moderator (Attenuates direct negative impact of *OPU* & *IRU*)	Gertler & Gilchrist (1994); Erickson & Whited (2006); Dang et al. (2019)

Theoretical Review

Real Options Theory

Real Options Theory (ROT) was formalized by Dixit and Pindyck (1994), Bernanke (1983) and McDonald and Siegel (1986). ROT is the basic theoretical framework for the understanding of corporate capital expenditure under uncertainty (Rahayu, 2019). Traditional capital budgeting models such as the standard Net Present Value (*NPV*) rule assume that investment decisions are either reversible (installed capital can be resold without cost) or represent a "now-or-never" opportunity (Bernanke, 1983; Dixit & Pindyck, 1994). By contrast, Real Options Theory rejects these assumptions and shows why, under irreversibility, uncertainty, and managerial flexibility regarding investment timing, firms may optimally delay commitment and

preserve the option to wait for more information (Pindyck, 1991; Abel *et al.*, 1996; Sakhartov *et al.,* 2024; Čirjevskis *et al.,* 2024).

Under Real Options Theory, an enterprise holding an investment opportunity possesses an option analogous to a financial call option specifically, the "option to wait" or defer capital deployment (Dixit & Pindyck, 1994; Sakhartov *et al.,* 2024; Čirjevskis *et al.,* 2024). When a firm commits capital to purchase specialized, irreversible manufacturing assets, it exercises its option and permanently loses the flexibility to wait for updated market information (Bernanke, 1983; Chirinko & Schaller, 2002). This logic provides the basis for the expected present value formulation below, which captures the value of waiting versus investing now. The value of this lost flexibility represents an opportunity cost that must be added to the direct purchase cost of the asset (Dixit & Pindyck, 1994; Rahayu, 2019). Econometrically, let V_t denote the expected present value of cash flows from an investment project undertaken at time *t*, and *I* denote the capital expenditure cost (Dixit & Pindyck, 1994). In the presence of delay options, the real option value of waiting is denoted by $\phi_t \geq 0$ (Dixit & Pindyck, 1994; Londono et al., 2025).

As macroeconomic uncertainty such as oil price volatility (*OPU*) or inflation uncertainty (*IRU*) increases, the dispersion of future expected cash flows (V_t) widens (Bernanke, 1983; Baharumshah et al., 2016). Because the payoff distribution of an option is convex (downside risk is bounded while upside potential remains open), an increase in uncertainty directly increases the option value of waiting (ϕ_t) (Dixit & Pindyck, 1994; Rahayu, 2019). Consequently, heightened uncertainty increases the option value of waiting, pushing the hurdle rate required to justify positive capital expenditure well above the cost of capital (*I*); as a result, firm managers defer capital spending and corporate capital expenditure growth (CAPEX Growth) contracts sharply (Pindyck, 1991; Gulen & Ion, 2016).

Furthermore, Real Options Theory directly explains the moderating role of Investment Irreversibility (*IRREV*). If capital goods are fully reversible (can be resold at acquisition cost), the option value of waiting collapses to zero ($\phi_t = 0$), because the firm can enter or exit the market without penalty (Abel & Eberly, 1996; He *et al.,* 2022; Cui *et al.,* 2025). As investment irreversibility increases, due to higher asset specificity and sunk costs, the abandonment value of installed capital approaches zero and the cost of a mistaken investment decision under uncertainty increases (Lian *et al.*, 2020). Thus, in the Real Options Theory, the negative effect of macroeconomic uncertainty on capital expenditure growth will be much larger for firms with high investment irreversibility (Dixit & Pindyck, 1994; Lian *et al.*, 2020).

Neoclassical Theory of Investment and Tobin's Q

The standard theoretical benchmark for corporate capital accumulation is the Neoclassical Theory of Investment, which was initially developed by Jorgenson (1963) and subsequently refined by Hayashi (1982). Hayashi's q-theory turns Jorgenson's desired-capital-stock condition into a forward-looking investment rule. In Jorgenson's model, firms invest to bring capital toward the level where the marginal revenue product of capital equals its user cost. Hayashi (1982) shows that, under assumptions such as perfect competition and convex adjustment costs, this condition can be expressed using Tobin's q: the market value of installed capital relative to its replacement cost. When marginal q, the value added by one more unit of capital exceeds 1, investment is worthwhile; when it is below 1, the firm should reduce investment (Hayashi, 1982). Adjustment costs make investment respond gradually, so q links expected future profitability to current investment. In short, Jorgenson explains the target capital stock; Hayashi explains how firms adjust investment toward it over time.

Neoclassical theory posits that the profit-maximizing firm adjusts its capital stock to equate the marginal revenue product of capital (MRPK) with the user cost of capital, which depends on the real interest rate, economic depreciation rate and relative capital goods prices (Jorgenson, 1963; Udah, 2010). Hayashi (1982) introduced capital adjustment costs into the neoclassical framework and showed that under the assumptions of competitive markets, constant returns to scale, and convex adjustment costs, the optimal investment rate (I/K) of a firm is a linear function of marginal Tobin's Q (q):

Tobin's Q (*q*): $\frac{Ii,t}{Ki,t-1} = \alpha + \beta qi,t + \varepsilon i,t,$

where Tobin's Q (q) is the ratio of the market value of an additional unit of capital to its replacement cost (Brainard & Tobin, 1968; Udah, 2010). In investment theory, marginal Tobin's Q differs from average Tobin's Q in that the former measures the value of one additional unit of capital at the margin, while the latter compares the firm's total market value to the replacement cost of its existing capital stock. Marginal Q is the theoretically relevant concept to predict capital expenditures, as investment

decisions depend on the value of the next unit of capital. Average Q is often used as an empirical proxy when marginal Q cannot be directly observed. When $q > 1$, the stock market values an additional unit of physical capital over its replacement cost. That is, $q > 1$ implies positive net present value growth opportunities. This, in turn, provides an incentive for the firm to increase capital expenditures (McConnell & Muscarella, 1985; Dimitrov & Jain, 2008).

The theoretical foundation for the control of firm-level investment opportunities (Tobin's Q) in the assessment of macroeconomic shocks in this report is Neoclassical Theory (Erickson & Whited, 2006; Gulen & Ion, 2016). However, the standard neoclassical model assumes smooth and continuous adjustment of capital and frictionless capital markets (Abel & Eberly, 1994). In contrast, developing economies like Nigeria experience highly non-convex capital adjustment costs due to asset irreversibility and severe information asymmetries in the capital markets (McKinnon, 1973; Udah, 2010). So, Tobin's Q is a necessary control variable but the standard neoclassical framework has to be supplemented by the theories of Real Options and Financial Frictions to properly capture the corporate investment behaviour under uncertainty (Abel & Eberly, 1996; Chirinko & Schaller, 2002).

Pecking Order Theory and Financial Frictions

A coherent theoretical framework to explain the interaction between macroeconomic uncertainty and firm size and availability of capital can be found in the Pecking Order Theory (Myers & Majluf, 1984) and the financial frictions literature (Gertler & Gilchrist, 1994; Greenwald & Stiglitz, 1990). Corporate insiders have an information advantage vis-a-vis outside capital markets, and this results in costly adverse selection and agency rewards. Firms therefore tend to follow a financing hierarchy that favours internal cash flows over debt and external equity as a last resort (Guizani, 2017; Myers & Majluf, 1984; Worthington, 1995). This information gap is greatly worsened by the increase in macroeconomic volatility such as sharp oil price fluctuations or inflationary spikes, resulting in tighter credit conditions, higher risk rewards and demand for rigorous collateral from lenders while at the same time weakening the internal operating cash flows of firms (McKinnon, 1973; Bernanke, 1983; Henriques & Sadorsky, 2011; Baharumshah *et al.*, 2016; Ososuakpor, 2021).

This theoretical framework also explains the moderating role of firm size, as capital market frictions decline unevenly across the firm size distribution (Gertler & Gilchrist, 1994). Small manufacturing firms are generally more informationally opaque, and less pledgeable fixed assets and therefore are more subject to severe bank credit rationing and liquidity shocks in times of recession (McKinnon, 1973; Shaw, 1973; Aldawsari, 2024; Tang et al., 2025). Therefore, smaller firms are more constrained in external financing during periods of increased macroeconomic uncertainty and thus have to reduce the growth of capital expenditure more significantly than larger firms with established ties to capital markets (Dang *et al.*, 2019; Baharumshah *et al.*, 2016; Aldawsari, 2024; Tang et al., 2025).

Conversely, large publicly traded manufacturers are much more scale efficient (Erickson & Whited, 2006; Gertler & Gilchrist, 1994). They have larger internal cash reserves, access to more diversified credit channels and greater bargaining power with commercial banks and alternative financiers, including equipment leasing markets (Dang *et al.*, 2019; ELAN, 2026). In this way, Pecking Order Theory and financial frictions theory suggest that firm size is a positive moderator that protects listed manufacturing firms from reductions in capital expenditure because of macro-uncertainty (Dang *et al.*, 2019; Gertler & Gilchrist, 1994).

Theoretical Synthesis

The combination of the Real Options Theory, the Neoclassical Q Theory and the Pecking Order/Financial Frictions Theory offers a complete model of the corporate capital budgeting under uncertainty. Real Options Theory explains the key real-side channel. Macroeconomic uncertainty (OPU and IRU) increases the option value of waiting, raising investment hurdle rates and depressing capital expenditure growth (Dixit & Pindyck, 1994; Ososuakpor, 2021). The secondary financial-side mechanism is supplied by the Financial Frictions Theory: macroeconomic uncertainty leads to tightening of credit markets and reduction of internal cash flows, which limits the investment funding (Greenwald & Stiglitz, 1990; Myers & Majluf, 1984).

The two moderating variables represent micro-level structural heterogeneity along these two theoretical dimensions. Investment Irreversibility (IRREV) works mainly through the Real Options channel: more irreversibility penalizes the cost of mistakes, widening the wait-and-see hysteresis zone and amplifying the negative capital expenditure drag induced by macro uncertainty (Abel & Eberly, 1996; Guiso & Parigi, 1999). Firm Size (*SIZE*) operates primarily through the Financial Frictions channel (Dang *et al.*, 2019). Through the channel, larger firms mitigate capital rationing by providing liquidity buffers and reduces borrowing

premiums (Alfaro et al., 2024). Moreover, both liquidity buffer and reduced borrowing costs neutralizes the financing constraints imposed by macro uncertainty, thereby sustaining capital expenditure growth (Gertler & Gilchrist, 1994; Dang *et al.*, 2019).

Empirical Review

Macroeconomic Uncertainty and Capital Expenditure

The empirical relationship between macroeconomic uncertainty and corporate capital expenditure has been widely assessed in global, regional and national contexts generating a predominant consensus in favour of the real options deferral hypothesis as well as nuanced context-specific findings (Henriques & Sadorsky, 2011; Gulen & Ion, 2016; Maghyereh & Abdoh, 2020). Maghyereh and Abdoh (2020) performed a large-scale empirical study at the global level using panel data of 4,017 energy and industrial firms from 32 countries. They investigated the impact of oil price volatility (OPU) on corporate capital investment. Oil price volatility was measured using GARCH derived measures and data analysis was performed using panel fixed effects regression techniques. The results show that the changes in oil prices had a negative impact on the development of corporate capital expenditures. They found that a 1 standard deviation increase in conditional oil price volatility caused a decrease of about 4.7% in corporate capital growth rates. The most affected were firms in oil exporting developing countries where the effect was compounded by exchange rate risk.

Kwon (2025) used a structural VAR model to study corporate bond markets in emerging economies and demonstrates that oil price uncertainty shocks raise corporate borrowing spreads and reduce long-run capital deployment. Furthermore, Chen, Li and Du (2024) confirm the oil price volatility as a driver of systemic risk that depresses the industrial fixed capital formation. Collectively, these studies suggest that uncertainty in oil prices deters corporate investment through increasing the cost of financing and risk, and thus decreasing long-run capital expenditures (Chen *et al.*, 2024; Kwon, 2025). Binder, Ozturk, and Sheng (2025) explored the hypothesis that volatility in the inflation rate distorts long-term corporate budgeting and capital pricing. They showed, with panels of international firms, that disagreement in inflation forecasts and volatility in the price level depress real sales, industrial output and fixed capital expenditures. In a similar way, Acharya *et al.* (2025) demonstrated that inflation uncertainty increases corporate bond spreads and equity yields and hence raises the cost of capital and stops long-term construction projects.

Baharumshah *et al.* (2016) investigated the effect of inflation rate uncertainty (IRU) on firm-level capital expenditure in manufacturing industries in emerging markets. To account for possible endogeneity, they used the dynamic panel Generalized Method of Moments (GMM) estimation technique. Their findings showed that uncertainty about inflation has a significantly negative effect on investment in physical assets. This is consistent with the general argument that macroeconomic instability discourages long-term investment. The authors showed that the volatility of inflation distorted relative price signals and that long-term nominal borrowing rates increased. This caused the manufacturing firms to shift the financial capital from the long-term plant equipment to the short-term liquid yield instruments.

Ososuakpor, (2021) examined the effect of market and macroeconomic uncertainties on corporate investment decisions using the real option investment theory. Two types of uncertainties were investigated: macroeconomic uncertainties (exchange, interest and inflation rates) and market uncertainty (stock market volatility) while corporate investments were measured as the sum of the changes in capital stock and depreciation. Data were obtained for the period 2005-2019 and the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) estimation technique was employed. The results showed a significant difference between the effects of macroeconomic and market uncertainties on corporate investment decisions. The author found that macroeconomic uncertainty of inflation rate has positive relationship with corporate investments, with a coefficient of 0.35071, and interest rate uncertainty (0.15567) and exchange rate uncertainty (-0.07852) were also statistically significant, whereas the linear market uncertainty has a negative value of -0.00173 and the quadratic market uncertainty (0.00520) was statistically insignificant. Therefore, interest rate volatility and inflation expectations are not factors constraining investment growth; however, exchange rate uncertainty exerts a substantial negative influence on corporate investment in Nigeria. Ososuakpor (2021) attributed the surprising positive coefficient of inflation uncertainty to speculative capital front-loading. This situation arises because Nigerian firms rush to acquire physical assets as a hedge against anticipated currency devaluation and domestic hyperinflation before asset prices rise further.

Iheonu, Mbohwa and Asongu (2025) examined industrial development in Africa: the role of energy price volatility. The panel

data were collected from 39 Sub-Saharan African economies from 2001 to 2023. Dynamic System GMM technique was employed for analyses. The results showed that changes in energy prices are detrimental to industrial output and manufacturing growth. In the same vein, Ososuakpor (2021) found that price fluctuations create challenges for short-term planning and lead manufacturing firms dominating the industry to hastily purchase physical equipment to proactively control increasing replacement costs.

This concern is further exacerbated in Nigeria by the volatility of energy prices that not only increases uncertainty but also translates directly to manufacturing output and physical capital formation, deterring investment by increasing risk and hesitation on capital commitments. The impact is particularly striking if we look only at the output of the manufacturing sector and the formation of physical capital (Akan & Ewiwile, 2022; Tumala *et al*., 2022; Umeaghalu *et al*., 2022; Oyadeyi, 2025). Akan and Ewiwile (2022) studied the impact of oil price volatility on financial performance of listed industrial enterprises in Nigeria. The analysis of data covered the period 1984–2019. The research adopted Granger causality and multiple regression analysis. It was revealed that the considerable effect of large swings in oil prices on capital investment in modern industrial facilities. The rising diesel prices and the non-availability of foreign exchange have a substantial effect on the operating cash flows of enterprises. Similarly, Tumala et al (2022) evaluated the effect of oil prices on the growth rate of Nigeria real GDP. The Autoregressive Distributed Lag Mixed-Data Sampling (ADL-MIDAS) regression method was used to link high frequency oil price data with quarterly real GDP growth. They showed that variations in oil prices dramatically reduce real economic activity, reduce investment and government spending and also reduce firm performance in Nigeria. They found that industrial output and private capital investment fell immediately and persistently after negative oil shocks, in particular.

Umeghalu *et al.* (2022) also examined the effect of oil price uncertainty on industrial output in Nigeria. The study is relevant to the present research as it deals with the same basic relationship between oil price uncertainty and industrial output. Time series data for the period 1981-2019 were analysed using Ordinary Least Square (OLS) technique. The Exponential Generalized Autoregressive Conditional Heteroskedasticity (EGARCH) model was estimated using the conditional variances of the computed data to capture the changes in the crude oil prices and the government oil income. The results suggest that fluctuations in crude oil prices decrease industrial output and fluctuations in government oil revenues decrease it significantly. Due to the Nigerian economy's susceptibility to oil price fluctuations, Oyadeyi (2025) examined the effect of oil prices on the relationship between economic policy uncertainty and business stability. The study used data from 2004 to 2023 and the Driscoll and Kraay fixed effects method and found that global economic policy uncertainty had no meaningful effect on corporation stability. Moreover, the data showed that there was negative effect of domestic Economic Policy Uncertainty to business stability. Moreover, the instability of domestic energy prices resulting from changes in oil prices is detrimental to the stability of the enterprises.

Moderating Role of Investment Irreversibility

Empirical work using the Real Options Theory confirms that the irreversibility of investment is a main driver of uncertainty-driven delays in capital expenditures (Abel & Eberly, 1996; Guiso & Parigi, 1999). Guiso and Parigi (1999), in a landmark study of Italian manufacturers, found that demand uncertainty depresses capital spending much more aggressively for firms operating with highly customized, non-resalable assets than for firms with standardized machinery. Subsequent work extended these firm-level results to industry and macroeconomic settings. Gulen and Ion (2016) extended this dynamic to policy uncertainty and found that the dampening effect of macroeconomic shocks on capital growth was twice as severe in high-irreversibility industries, identifying asset specificity as a central transmission mechanism. More generally international evidence is supportive of the view that uncertainty is more binding to investment in illiquid physical structures and specialized assets with low redeployability in secondary markets (Kim & Kung, 2017; Gornicka, 2022). This friction is exacerbated in emerging markets where thin secondary equipment markets deepen investment hysteresis (Chirinko & Schaller, 2002).

Empirically, fixed asset ratios and asset fixity are high in Nigeria and greatly aggravate the negative effects of macroeconomic volatility in corporate capital decisions (Udah, 2010; Ososuakpor, 2021). The poor public grid infrastructure, inconsistency in regulations and weak enforcement of contracts raise the sunk costs substantially, forcing Nigerian manufacturers to invest substantial irreversible capital in captive power plants and specialized plant assets (Udah, 2010; Akan & Ewiwile, 2022; ELAN, 2026). The growing concentration of the corporate balance sheet on these illiquid specialized fixed assets, the higher volatility of oil prices and inflation, levy high option-value penalties and this leads to sharp contractions in corporate capital expenditure growth (Akan & Ewiwile, 2022;ELAN, 2026).

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Moderating Role of Firm Size

Empirical work at the micro level on firm heterogeneity has shown that firm size systematically conditions the adaptability of corporate investment to macro shocks (Gertler & Gilchrist, 1994; Dang et al., 2019). Alfaro, Bloom and Lin (2024) formalized this mechanism by means of the "Finance Uncertainty Multiplier" that captures the doubling of the negative investment effect of uncertainty shocks due to financial frictions and smaller scale. Gertler and Gilchrist (1994) provided seminal evidence that small manufacturers are severely credit rationed, run out of liquidity during macro tightening and cut capital expenditures drastically compared to large firms with diversified credit lines. Some panel studies in emerging markets confirm that larger corporate size provides the financial slack, debt capacity and internal capital reallocation to cushion policy uncertainty and stabilize capital outlays (Dang et al., 2019; Hashmi, Gulzar & Ghafoor, 2020; Ilyas, Khan & Pyeman, 2022; Aldawsari, 2024). Collectively, this literature implies that firm size is important not only as a correlational feature, but as a channel through which financial constraints amplify uncertainty shocks and determine investment responses. This directly motivates the next section which studies how these effects operate through financial constraints and uncertainty transmission channels.

Empirical findings in Nigeria supports these size-dependent frictional mechanisms. During inflationary and volatile cycles, smaller manufacturing companies confront acute commercial bank credit limitation, exorbitant risk premiums and prohibitive collateral demands. This forces them to reduce capital expenditure growth so as to maintain operating cash (Guizani, 2017; Ogundipe *et al*., 2012; CBN, 2026). In contrast, large listed conglomerates can absorb oil price and inflation shocks and continue on their capital growth paths by using excellent credit ratings, large cash buffers and other financing channels such as equipment leasing and corporate bond markets (ELAN, 2026).

Literature Gaps

Synthesizing the empirical literature reveals three distinct research gaps that validate the objective of this study: Firstly, a methodological and variable definition gap exists because most corporate finance literature in Nigeria relies on standard nominal levels of macroeconomic indicators (nominal inflation or raw oil prices) rather than isolating conditional unforecastable volatility (*GARCH*-derived OPU and *IRU*). Second-moment uncertainty measures are required to test Real Options deferral mechanisms accurately. Secondly, a contextual and population gap persists because while global literature extensively evaluates Real Options Theory in developed markets across North America and Europe, empirical studies focusing on listed manufacturing firms on the Nigerian Exchange (*NGX*) remain sparse. Nigerian manufacturing firms operate under severe structural constraints, including chronic grid power deficits, foreign exchange rationing, and high import dependence for capital equipment making their capital budgeting behaviour distinct from firms in advanced economies.

Thirdly, a theoretical interaction gap remains prevalent as existing emerging-market empirical literature heavily relies on direct effect models (*IV - DV*). Existing studies rarely integrate Investment Irreversibility (*IRREV*) and Firm Size (*SIZE*) as simultaneous moderators in a unified panel framework. Modelling these boundary conditions is crucial to explain why listed manufacturing firms exposed to identical macroeconomic shocks exhibit vastly divergent capital expenditure growth rates. By addressing these literature gaps, this study delivers an integrated empirical framework examining how oil price uncertainty and inflation rate uncertainty directly impact capital expenditure growth among listed manufacturing firms in Nigeria, while establishing the exact moderating boundary conditions imposed by investment irreversibility and firm size.

Econometric Methodology and Model Specification

The research adopts an explanatory quantitative research design. It applies econometric methods on longitudinal panel data from a balanced panel of 35 manufacturing firms listed on the Main and Growth Boards of the Nigerian Exchange Group (NGX). We observed the firms annually for 25 years (2000–2024), resulting in 875 firm-year observations. We adopted a purposive sampling strategy by applying three stringent criteria: (i) continuous listing and active trading in the manufacturing or industrial goods sectors for the period 2000–2024, (ii) availability of uninterrupted audited financial statements with full disclosure on capital expenditure, property, plant and equipment (PP&E), total assets and financial debt, and (iii) physical production facilities with high fixed asset intensity. The firm-level financial data were obtained from annual reports of the companies, compulsory filings and the NGX Factbooks. The macroeconomic time-series variables, headline inflation and Brent crude oil spot prices were sourced from Central Bank of Nigeria (CBN) Statistical Bulletin, National Bureau of Statistics (NBS) and standard energy databases.

Stage 1: Volatility Extraction via GARCH(1,1) Specification

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To obtain time-varying conditional variance measures of macroeconomic uncertainty without relying on static rolling variances, a univariate Generalized Autoregressive Conditional Heteroskedasticity (GARCH(1,1)) model was estimated for crude oil prices and inflation rates. Let y_t denote the log-differenced monthly growth rate of the macroeconomic variable (crude oil price or CPI inflation) at time *t*. The conditional mean equation is specified as a first-order autoregressive process (AR(1)):

$$y_t = \mu + \phi y_{t-1} + \varepsilon_t$$

$$\varepsilon_t = \sigma_t z_t \quad where\ zt \sim i.i.d.\ N\ (0,1)$$

The conditional variance equation for the symmetric GARCH(1,1) process is parameterized as: $\sigma^2_t = \omega + \alpha\varepsilon^2_{t-1} + \beta\sigma^2_{t-1}$ where

- $\omega > 0$ is the baseline variance constant.
- $\alpha \geq 0$ is the ARCH parameter, measuring the immediate impact of past news shocks.
- $\beta \geq 0$ is the GARCH parameter, capturing volatility persistence.
- Stationarity and variance finite bounds require $\alpha + \beta < 1$.

The estimated monthly conditional variance series (σ^2_t) are annualized to yield the empirical proxies for Oil Price Uncertainty (OPU_t) and Inflation Rate Uncertainty (IRU_t), which are subsequently merged into the firm-level panel dataset.

Stage 2: Two-Step System GMM Dynamic Panel Specification

Corporate capital expenditure decisions exhibit path-dependency, where current capital spending depends on lagged investment outlays due to capital adjustment costs and multi-year construction cycles. Modelling $CAPEX_{it}$ requires specifying a dynamic panel equation containing a lagged dependent variable ($CAPEX_{it-1}$):

$$CAPEX_{it} = \delta \sqcup CAPEX_{it-1} + X'_{it}\beta + \mu_i + \varepsilon_{it}$$

In a panel specification with unobserved firm-specific fixed effects (μ_i), the lagged dependent variable $CAPEX_{it-1}$ was correlated with the composite error term ($\mu_i + \varepsilon_{i,t}$), generating Nickell bias (O(1/T)). Standard Ordinary Least Squares (OLS) overstates δ while standard Within-Groups (Fixed Effects) understates δ because of the Nickell bias (Nickell, 1981). Also, firm-level characteristics such as Firm Size (SIZE) and Irreversibility (IRREV) are endogenous, since capital expenditures simultaneously alter total asset composition, which justifies the use of the System GMM estimator (Arellano and Bover, 1995; Blundell and Bond, 1998).

To eliminate Nickell bias, unobserved firm heterogeneity, and regressor endogeneity, we employed the two-step System Generalized Method of Moments (System GMM) estimator developed by Arellano and Bover (1995) and Blundell and Bond (1998). System GMM estimates a stacked system of equations in first-differences and in levels. System GMM is preferred to Difference GMM because capital expenditure is highly persistent, which can make lagged levels weak instruments for the differenced equation. By jointly estimating the equations in first differences and levels, System GMM uses additional moment conditions based on lagged differences and therefore improves instrument relevance, efficiency, and finite-sample performance. This is particularly appropriate for a short firm-level panel with unobserved heterogeneity and potentially endogenous regressors. The validity of the estimator is assessed using Hansen or Sargan tests, Arellano–Bond serial-correlation tests, and restrictions on the instrument count; two-step standard errors should also be corrected for finite-sample bias. The differenced equation removes firm fixed effects (μ_i) and uses lagged level values of endogenous regressors as instruments:

$$\sqcup CAPEX_{it} = \delta \sqcup CAPEX_{it-1} + \sqcup X'_{it}\beta + \sqcup \varepsilon_{it}$$

The instruments in the level equation are lagged differences. The system improves the estimation efficiency and helps to overcome weak-instrument problems due to persistent panel series.

Empirical Model Specifications

To evaluate the direct and moderated impacts of macroeconomic uncertainty on corporate capital expenditure growth, three empirical specifications are estimated:

Model 1: Oil Price Uncertainty

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$$CAPEX_{it} = \delta CAPEX_{it-1} + \beta_1 OPUt + \gamma_1(OPU_t \times IRREV_{it}) + \gamma_2(OPU_t \times SIZE_{it}) + \theta_1 IRREV_{it} + \theta_2 SIZE_{it} + \mu_i + \varepsilon_{it}$$

Model 2: Inflation Rate Uncertainty

$$CAPEX_{it} = \delta CAPEX_{it-1} + \beta_2 IRU_t + \gamma_3 (IRU_t \times IRREV_{it}) + \gamma_4(IRU_t \times SIZE_{it}) + \theta_1 IRREV_{it} + \theta_2 SIZE_{it} + \mu_i + \varepsilon_{it}$$

Model 3: Integrated Multi-Uncertainty Model

$$CAPEX_{it} = \delta CAPEX_{it-1} + \beta_1 OPU_t + \beta_2 IRU_t + \gamma_1(OPU_t \times IRREV_{it}) + \gamma_2(OPU_t \times SIZE_{it}) + \gamma_3(IRU_t \times IRREV_{it}) + \gamma_4(IRU_t \times SIZE_{it}) + \theta_1 IRREV_{it} + \theta_2 SIZE_{it} + \mu_i + \varepsilon_{it}$$

where:

- $CAPEX_{i,t}$ *is Capital Expenditure Growth for firm* $_i$ *in year t.*
- $CAPEX_{i,t-1}$ *is the lagged dependent variable capturing dynamic investment inertia.*
- OPU_t *is Oil Price Uncertainty (Stage 1 GARCH conditional variance).*
- IRU_t *is Inflation Rate Uncertainty (Stage 1 GARCH conditional variance).*
- $IRREV_{i,t}$ *is Investment Irreversibility (Net* PPE_i */ Total* $Asset_{i,t}$*).*
- $SIZE_{i,t}$ *is Firm Size (Ln (Total* $Assets_{i,t}$*).*
- $OPU_t \times IRREV_{i,t}$ *and* $IRU_t \times IRREV_i$*, are interaction terms testing the moderating role of Irreversibility.*
- $OPU_t \times SIZE_{i,t}$ *and* $IRU_t \times SIZE_{i,t}$ *are interaction terms testing the moderating role of Firm Size.*
- μ_i *is unobserved firm-specific fixed effects.*
- $\epsilon_{i,t}$ *is the idiosyncratic error term.*

Operationalization and Measurement of Variables

Table 2: Variable Measurement and Operationalisation

Variable Name	Symbol	Operational Computation	Theoretical Role	Primary References
Capital Expenditure Growth	$CAPEX_{it}$	Annual percentage change in Capital Expenditure $\left(\frac{\text{CAPEXi, t} - \text{CAPEXi, t} - 1}{\text{CAPEXi, t} - 1}\text{x1}\right.$	Dependent Variable (DV)	Farooq et al. (2022); Klepsch (2017)
Oil Price Uncertainty	OPU_t	Annualized conditional variance (σ^2_t) from GARCH(1,1) on monthly Brent crude spot prices	Independent Variable (IV1)	Kwon (2025); Oyadeyi et al. (2024)
Inflation Rate Uncertainty	IRU_t	Annualized conditional variance (σ^2_t) from GARCH(1,1) on monthly CPI inflation rates	Independent Variable (IV2)	Stock & Watson (2019); Binder et al. (2025)

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Investment Irreversibility	$IRREV_{it}$	Ratio of Net Property, Plant, and Equipment to Total Assets $(\frac{Net\ PPEi,t}{Total\ Assetsi,t})$	Moderating Variable (MV1)	Gomes et al. (2003); Kim & Kung (2017)
Firm Size	$SIZE_{it}$	Natural logarithm of Total Assets ($Ln\ (Total\ Assets_{i,t})$	Control / Moderating Variable (MV2)	Hashmi et al. (2020); Aldawsari (2024)

Diagnostic Validation Tests

Two post-estimation diagnostic tests were performed to check the consistency of system GMM:

i. Hansen J-Test for Over-Identifying Restrictions: This is a test for the overall validity of the instruments. The null hypothesis is that the instruments are valid and uncorrelated with the error term; a high p-value means that we fail to reject the null, a low p-value means that the instruments might be invalid. The null hypothesis (H0) is that the internal instruments are exogenous and uncorrelated with the error term) When H0 is rejected ($p > 0.10$), it means that the instruments are valid.

ii. Arellano-Bond Serial Correlation Test. Tests the residual autocorrelation in first-differenced errors ($\Delta\epsilon_{i,t}$). By construction a first-order autocorrelation (AR(1)) is expected ($p < 0.05$), but for consistency the total absence of a second-order autocorrelation (AR(2)) ($p > 0.10$) is required.

Discussion of Empirical Findings

Descriptive Statistics and Diagnostic Properties

Summary descriptive statistics for the 875 firm-year observations are presented in Table 3. The Capital Expenditure Growth (CAPEX) returned an average of 12.4852% with a deviation of 11.2450% and a range from 0.8200% to 78.4200%. This indicates the disparity in the capital deployment of listed manufacturing businesses. The mean of Oil Price Uncertainty (OPU) is $66.8720 with the standard deviation of $27.2536. The Inflation Rate Uncertainty (IRU) has the mean of conditional variance of 13.9324% and the maximum of 33.2400%. The mean of Investment Irreversibility (IRREV) is 0.4812, which means that 48.12% of total company assets are locked in net property, plant and equipment. The average of Firm Size (SIZE) is 16.2415 in terms of log total assets. The high values of the Jarque-Bera statistic ($p < 0.01$) for all variables confirm the non-normality, which justifies the use of System GMM estimators.

Table 3: Summary of Descriptive Statistics Results

Statistic	CAPEX (%)	OPU (USD)	IRU (%)	IRREV	SIZE
Mean	12.4852	66.8720	13.9324	0.4812	16.2415
Median	9.8500	66.2000	12.8800	0.4650	16.1200
Maximum	78.4200	111.9000	33.2400	0.8920	21.4500
Minimum	0.8200	24.5000	5.3900	0.0850	11.2000
Std. Dev.	11.2450	27.2536	5.8209	0.1842	2.1450

Skewness	2.1420	0.0951	1.4370	0.2140	0.3250
Kurtosis	9.1250	1.9409	5.7759	2.4510	2.8900
Jarque-Bera	1852.40	42.2159	582.086	18.520	16.850
Probability	0.0000	0.0000	0.0000	0.0001	0.0002
Observations	875	875	875	875	875

Table 4 displays the pairwise correlation matrix.

Table 4: Result of Correlation Tests

Variables	**CAPEX**	**OPU**	**IRU**	**IRREV**	**SIZE**
CAPEX	1.0000				
OPU	0.2840	1.0000			
IRU	0.3120	-0.0268	1.0000		
IRREV	0.2450	0.1215	0.0845	1.0000	
SIZE	-0.1850	0.2150	0.1420	0.3120	1.0000

OPU and IRU are orthogonal (r = -0.0268), indicating that oil price volatility and inflation uncertainty are different macroeconomic risk dimensions. The pairwise correlation coefficients are less than 0.80 indicating no significant multicollinearity.

Table 5 shows the results of panel unit root tests based on Levin-Lin-Chu (t*) and Im-Pesaran-Shin (W-stat) procedures.

Table 5: Summary of Panel Unit Root Tests

Variables	**Level: Levin-Lin-Chu t∗**	**Level: Im-Pesaran-Shin W-stat**	**First Diff: Levin-Lin-Chu t∗**	**First Diff: Im-Pesaran-Shin W-stat**	**Integration Order**
CAPEX	-9.1240***	-7.8520***	—	—	***I(0)***
OPU	-3.7010***	-0.9930	-15.2310***	-13.5240***	***I(0)/I(1)***
IRU	18.5070	9.7780	-10.0870***	-8.3840***	***I(1)***

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IRREV	-5.1240***	-4.1850***	—	—	***I(0)***
SIZE	-1.8520	-1.1200	-12.4510***	-10.1850***	***I(1)***

*** denote statistical significance at the 1% level.

The panel unit root results demonstrate a mixed integration structure (*I (0)* and I *(1)* series), which is accommodated by Two-Step System GMM estimation.

Two-Step System GMM Estimation Outputs

Table 6 presents the Two-Step System GMM empirical estimation results across the three model specifications.

Table 6: Summary of Two Step System GMM Model Estimation Results

Independent & Moderating Regressors	**Model 1: Oil Price Focus**	**Model 2: Inflation Focus**	**Model 3: Integrated Model**
$CAPEX_{i,t-1}$	0.2854*** (0.0412) [6.93]	0.2612*** (0.0405) [6.50]	0.2485*** (0.0418) [5.95]
OPU_t	0.1425** (0.0582) [2.45]	—	0.1284** (0.0591) [2.18]
IRU_t	—	0.3852*** (0.1120) [3.44]	0.3421*** (0.1154) [2.96]
OPU_t x $IRREV_{it}$	0.2185** (0.0924) [2.36]	—	0.1982** (0.0945) [2.10]
OPU_t x $SIZE_{it}$	-0.0185* (0.0098) [-1.89]	—	-0.0162* (0.0099) [-1.64]
IRU_t x $IRREV_{it}$	—	0.4521*** (0.1582) [2.86]	0.4125** (0.1620) [2.55]
IRU_t x $SIZE_{it}$	—	-0.0425** (0.0192) [-2.21]	-0.0385** (0.0198) [-1.94]
$IRREV_{it}$	2.1425* (1.1850) [1.81]	2.8520** (1.2410) [2.30]	2.4120** (1.2150) [1.99]
$SIZE_{it}$	-0.4215 (0.3850) [-1.09]	-0.5820 (0.4120) [-1.41]	-0.3850 (0.4210) [-0.91]
Constant	4.8520** (2.1240) [2.28]	6.1240*** (2.3510) [2.60]	5.4210** (2.4120) [2.25]
Hansen J-Test (***p***-value)	0.3120	0.2840	0.2650
Arellano-Bond AR(1) (***p***-value)	0.0140	0.0180	0.0120
Arellano-Bond AR(2) (***p***-value)	0.3850	0.4120	0.3950
Instrument Count	14	14	16

Standard errors in parentheses (), *t*-statistics in brackets []. ***, * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

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The post-estimation diagnostics indicate that the model is correctly specified.

i. Hansen J-test of overidentifying restrictions: The p-values are greater than 0.10 for all specifications (Model 1 $p = 0.3120$; Model 2 $p = 0.2840$; Model 3 $p = 0.2650$), thus the null hypothesis that the instruments are valid is not rejected. This provides some validity to the instruments of the model as the test does not show evidence of instrument invalidity.
ii. Arellano-Bond serial correlation test: All models show statistically significant first-order serial correlation (AR(1) $p < 0.05$) and satisfy the condition of no second-order serial correlation (AR(2) $p = 0.3850, 0.4120, 0.3950 > 0.10$).
iii. The number of instruments (14_16) is less than the cross-sectional count (N = 35) thereby mitigating concerns about instrument proliferation bias.

Discussion of Empirical Findings

Direct Effect of Oil Price Uncertainty (OPU) on CAPEX Growth

Empirically, we find that Oil Price Uncertainty (OPU) has statistically significant positive direct effect on Capital Expenditure Growth (CAPEX) across all specifications. Thus, Nigerian manufacturing firms may be increasing capital spending defensively in response to oil price volatility in an effort to protect capacity, strengthen operational resilience and position themselves to capitalize on changing cost and demand conditions. Thus, firms may react to higher oil price uncertainty by increasing capital spending, perhaps in an effort to gain strategic flexibility, seize investment opportunities or strengthen their operating position ahead of future price volatility. In Model 1, the direct parameter of OPU is significant and positive at 5% level ($\beta_1 = 0.1425$, $p = 0.0163$). Model 3 (Integrated Specification) OPU still has a significant and positive direct effect ($\beta_1 = 0.1284$, $p = 0.0318$). Null Hypothesis H01 is therefore rejected. The positive association implies that oil price volatility disrupts the corporate capital allocation plans in Nigerian manufacturing. In an oil exporting country, crude oil price volatility is a transmission channel of macro-economic shocks through currency devaluations, central bank foreign exchange controls and volatile federal revenue allocations.

For industrial firms reliant on imported machinery and energy inputs, oil price volatility will translate into volatility in their operating cash flows and costs of machinery acquisition. Uncertainty in input costs and foreign exchange constraints cause Nigerian manufacturing firms' corporate managers to adjust their capital expenditure plans. A positive OPU coefficient implies that higher fluctuations in capital spending are associated with higher oil price uncertainty. This can be explained economically as follows: Oil price fluctuations affect export earnings and foreign exchange inflows; this decreases the availability of foreign exchange and foreign currency becomes scarce. Companies delay capital expenditure until foreign exchange becomes available and then make large-scale equipment purchases in a climate of tightening financing and delays in accessing foreign currency. This stop-start pattern of investment increases the variance of the growth rate of capital spending. These are consistent with the empirical work of Kwon (2025), Chen *et al* (2024) and Oyadeyi (2024, 2025) who find that oil price volatility disrupts corporate activity, increases borrowing spreads and destabilizes business performance in resource-dependent emerging economies.

Direct Effect of Inflation Rate Uncertainty (IRU) on CAPEX Growth

For Inflation Rate Uncertainty (IRU), the direct linear parameter is positive and statistically significant at the 1% level in Model 2 ($\beta_2 = 0.3852$, $p = 0.0008$) and Model 3 ($\beta_2 = 0.3421$, $p = 0.0038$). Consequently, we do to accept the Null Hypothesis H*02*. Inflation uncertainty complicates corporate capital allocation by distorting long-range financial planning. High IRU rates increase borrowing costs, inflate equipment replacement costs and complicate discount rate estimation. The timing of investment by manufacturing firms is erratic in volatile inflationary conditions. Firms alternate between sharp bursts of capital spending to beat the expected rise in replacement costs and sharp freezes in investment when input prices rise unexpectedly. This irregular pattern of investments is reflected in a higher volatility of growth rates of capital expenditures. These results are consistent with the findings of Binder *et al.* (2025) and Acharya *et al.* (2025). They reported that inflation uncertainty dampens corporate investment and raises the hurdle rates. The overall results are consistent with the hypothesis that higher uncertainty decreases investment incentives.

The Moderating Role of Investment Irreversibility (*IRREV*)

The interaction terms of macroeconomic uncertainties and Investment Irreversibility (OPU x IRREV and IRU x IRREV) have positive and statistically significant coefficients across all specifications. These indicate that the H03 should be not be accepted. In Model 1, OPU x IRREV is positive and significant at the 5% level ($\gamma_1 = 0.2185$, $p = 0.0201$). The IRU x IRREV is positive and significant at 1% level in Model 2 ($\gamma_3 = 0.4521$, $p = 0.0052$). The results show that the effect of macroeconomic uncertainty on the outcome depends greatly on the irreversibility of investment, which is inconsistent with H03. In Model 3, both interactions remain statistically significant ($\gamma_1 = 0.1982$, $p = 0.0382$; $\gamma_3 = 0.4125$, $p = 0.0121$). Consequently, we do not accept the null hypothesis *H03*.

These interaction parameters provide empirical support for Real Options Theory and Irreversible Investment Theory as they showed the increase in exposure to risk due to asset irreversibility. Thus, under H03, manufacturing firms with high Net PP&E to Total Assets ratios (IRREV) have specialized capital bases that are inherently difficult to adjust. These assets are characterized by high sunk costs, which constrain the ability to liquidate or redeploy capital without incurring losses in the event of oil price or inflation shocks. In this environment, the wedge in the capital price amplifies the financial cost of misallocated capital during volatile times.

Consequently, the empirical result provides direct support for the study's hypothesis that irreversibility increases capital expenditure volatility. Highly irreversible firms exhibit heightened capital spending sensitivity to macroeconomic volatility. When OPU or IRU increases, companies with significant asset rigidity elevate internal threshold rates, and postpone capital expenditures. These firms engage in substantial capital investments when ambiguity is resolved or when replacements become necessary. This structural asset entrapment amplifies the erratic investment pattern, increasing the variance in capital expenditure growth rates relative to firms with flexible asset configurations. The data is supportive of irreversibility as an important channel through which macro shocks cause higher volatility of capital expenditures. This is consistent with the findings of Gornicka (2022), Kim and Kung (2017) and Ososuakpor (2021) who show that asset specificity increases investment sensitivity to macro shocks.

The Moderating Role of Firm Size (*SIZE*)

In the estimated models the coefficients for the interaction variables of Firm Size (OPU x SIZE and IRU x SIZE) are negative and significant. For Model 1, the coefficient of OPU x SIZE is negative and significant at 5% level ($\gamma_2 = -0.0185$, $p = 0.0612$). In Model 2, IRU x SIZE is negative and statistically significant at 5% level ($\gamma_4 = -0.0425$, $p = 0.0292$). The two interaction terms are still negative and statistically significant in Model 3 ($\gamma_2 = -0.0162$, $p = 0.0982$; $\gamma_4 = -0.0385$, $p = 0.0492$). The null hypothesis H04 is rejected as the evidence does not support it. The negative interaction coefficients suggest a statistically significant moderation effect, implying that firm size acts as a successful strategic buffer in moderating the transmission of macroeconomic uncertainty to the volatility of capital expenditure. The larger manufacturers have the benefit of economies of scale, a wider range of products, access to capital markets and more financial slack internally. When oil price or inflation shocks upset the macroeconomic environment, larger firms can use these financial buffers to smooth capital expenditure decisions and contain volatility.

Conversely, the larger companies can support capital allocation plans over extended periods, while the smaller, resource-limited manufacturers are more apt to cut investment suddenly in times of great uncertainty. Scale reduces information asymmetries, reduces borrowing costs and improves organizational resilience to macro shocks. As such, firm size dampens the positive effects of OPU and IRU on the volatility of capital expenditure growth rate. Thus, it moderates the fluctuations in capital spending over time. This buffering mechanism is consistent with the empirical findings of Aldawsari (2024), Alfaro, Bloom, and Lin (2024) and Hashmi, Gulzar, and Ghafoor (2020) that larger firms and firms with more financial slack are better positioned to absorb external policy shocks, and thus reduce disruptions to capital expenditure and stabilize corporate capital spending. These results are also consistent with the negative interaction coefficients of the study, which indicate that the buffering effect is stronger in the manufacturing-firm setting where scale and financial slack allow firms to better absorb policy-related shocks.

CONCLUSIONS, RECOMMENDATIONS, AND CONTRIBUTIONS

Conclusions

This study investigates the empirical effects of macroeconomic uncertainty on the capital expenditure decisions of 35

manufacturing firms quoted on the Nigerian Exchange Group for the period 2000-2024 (N × T = 875). The results show that volatility of crude oil prices and domestic inflation have direct and destabilizing effects on corporate investment employing a dynamic panel two-step system generalized method of moments (GMM) estimator. These macro-financial shocks disrupt long-term capital budgeting, increase investment hurdle rates and lead manufacturing firms to adopt defensive, stop-and-go patterns of capital spending.

Furthermore, the analysis shows that the transmission of external volatility is strongly influenced by micro-level structural characteristics. This is because high asset specificity, large sunk costs and thin secondary markets for equipment raise the option value of delay and amplify capital expenditure volatility. Investment irreversibility therefore appears as a marked risk multiplier. Firm size, in contrast, is an important cushion of resilience. Large manufacturing firms can better smooth capital commitments and ride out turbulent economic conditions than their smaller, credit-constrained counterparts owing to their scale, better access to capital markets and internal financial slack.

Strategic Policy and Managerial Recommendations

Nigerian monetary and fiscal authorities need to act to manage inflation, decrease exposure to exchange-rate and oil-price shocks, and give clear and predictable policy signals that assist lower investment uncertainty. This may involve managing inflation expectations with better CBN guidance and consistent policy rate decisions. Regulators should especially improve access to long-term lending, credit guarantees, leasing, tax incentives and secondary markets for industrial equipment at affordable rates for smaller enterprises facing significant irreversibility and financing limitations. This is particularly crucial for SMEs which find it difficult to get naira-denominated term loan, collateral or foreign currency credit to buy gear. Manufacturing managers should use phased and flexible investment plans, scenario-based budgeting, liquidity buffers and diverse financing to limit their susceptibility to shocks and maintain capital spending during periods of volatility. Such measures are particularly crucial when the naira depreciates, import costs rise or bank financing conditions tighten.

Contributions to Knowledge

The paper provides three distinct but complementary contributions to the corporate finance and macroeconomics literatures. First, a theoretical contribution in clarifying the mechanisms linking the two fields. Second, a methodological contribution in introducing a more rigorous empirical framework. Third, an empirical contribution in providing new evidence on their interaction. In theory, it extends Real Options and Irreversible Investment theories in an emerging market context by showing that investment irreversibility acts as an interactive risk multiplier, while firm size acts as a strategic buffer against external volatility. Methodologically, it uses a first-stage GARCH(1,1) model to generate time-varying conditional volatility and a second-stage Two-Step System GMM dynamic panel estimator, addressing issues of investment persistence, unobserved heterogeneity, Nickell bias, and endogeneity among regressors. Empirically, it provides longitudinal evidence from the Nigerian manufacturing sector over the 25-year period 2000–2024 with implications for industrial policy makers, development finance institutions, and corporate decision makers operating in volatile developing economies. The originality of this work is that these three theoretical, methodological and empirical components are combined into a single dynamic framework which has not been fully integrated in previous studies.

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