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External financing and solar energy investment growth in Kenya: empirical evidence from a vector error correction model

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ABSTRACT

Kenya's renewable energy agenda has increasingly identified solar power as a cornerstone for addressing growing electricity demand and attaining universal energy access by 2030. Yet the trajectory and sustainability of the solar sector depend substantially on external financial inflows, notably external loans and Official Development Assistance (ODA). This study investigates the nexus between external loans, ODA, and solar energy investment expansion in Kenya, drawing on time-series data spanning 2010 to 2024. The research is grounded in three theoretical lenses—Neoclassical Growth Theory, Financial Market Theory of Development, and Dutch Disease Theory—and adopts a quantitative approach using secondary data obtained from the World Bank, International Monetary Fund, Kenya National Bureau of Statistics, and the International Renewable Energy Agency. The analytical strategy encompasses descriptive statistics, unit root testing, Johansen cointegration analysis, a Vector Error Correction Model (VECM), Instrumental Variable Quantile Regression (IVQR), and System Generalized Method of Moments (GMM), with diagnostic checks conducted to confirm model validity. The results show that all variables are integrated of order one, I(1), and that a stable long-run equilibrium relationship exists between external financing and solar energy investment growth. In the long run, both external loans (coefficient: 0.41) and ODA (coefficient: 0.54) exert positive effects on solar investment, with ODA demonstrating a relatively larger contribution. These relationships remain statistically meaningful in the short run, while the error correction term (-0.58) indicates that roughly 58% of short-term deviations from equilibrium are adjusted within a one-year period. The IVQR estimates further reveal that the influence of external financing intensifies at higher quantiles of solar investment growth, pointing to absorptive capacity as a critical conditioning factor. Diagnostic evaluations confirm that the VECM satisfies assumptions of normality, homoscedasticity, absence of serial correlation, and overall stability. Based on these findings, the study concludes that both external loans and ODA are significant drivers of solar energy investment growth in Kenya. It recommends that the Government of Kenya strengthen transparency and accountability mechanisms in the deployment of external loans and ODA, bolster institutional capacity for effective project execution, ensure donor interventions are coherent with national energy priorities, and adopt prudent debt management frameworks to safeguard long-term energy sector sustainability.

Keywords: External Loans, Kenya, Official Development Assistance, Solar Energy Investment, Vector Error Correction Model

I. INTRODUCTION

The transition to renewable energy, particularly solar power, has gained substantial global attention due to the rising demand for clean, sustainable, and affordable energy sources. This shift is largely motivated by the urgent need to mitigate climate change while addressing the growing electricity needs of a rapidly urbanizing global population (IRENA, 2022). External financing, including external loans and Official Development Assistance (ODA), plays a critical role in financing renewable energy projects, especially in developing economies where limited domestic financial capacity hampers large-scale infrastructure development (UNCTAD, 2023).

Globally, the renewable energy sector has expanded significantly, with solar power leading due to technological innovation, falling costs, and climate imperatives. Despite this progress, many developing nations continue to struggle with attracting sufficient external financing due to elevated investment risks, weak policy frameworks, and infrastructural limitations (World Bank, 2021). In response, institutions such as the World Bank, the African Development Bank (AfDB), and the Green Climate Fund (GCF) have increased their financial and technical support to scale solar investments in emerging economies through concessional loans and development assistance (Speer & Wu, 2021).

Africa is endowed with immense solar potential, boasting some of the highest solar irradiation levels globally. However, over 600 million people across the continent remain without access to reliable electricity, intensifying the urgency of energy access interventions (Murshed & Ozturk, 2023). External financing has emerged as a key enabler in closing this gap. Initiatives like the World Bank's Scaling Solar Program have supported utility-scale solar projects in countries such as Zambia, Senegal, and Ethiopia (World Bank, 2023). Regional actors, including the Africa50

Infrastructure Fund and the African Development Bank, have played an instrumental role in mobilizing funding for solar development (Barka et al., 2018).

Kenya has positioned itself as a continental leader in renewable energy development, with over 90% of electricity sourced from renewables such as geothermal, wind, and solar (Ministry of Energy, 2022). The country's energy strategy identifies solar power as a critical element, particularly for electrifying off-grid rural communities. The government has implemented several measures to enhance external financing in the solar sector, including feed-in tariffs, investment guarantees, tax incentives, and public-private partnership arrangements (KNBS, 2019). These policy efforts have spurred an increase in external loans and development assistance, facilitating the expansion of Kenya's installed solar capacity. Major infrastructure projects such as the Garissa Solar Power Plant—developed through Sino-Kenyan collaboration—and the Kenya Off-Grid Solar Access Project (KOSAP), which financed 137 mini-grids, showcase the tangible impact of externally financed initiatives on national energy infrastructure (World Bank, 2021).

Currently, solar accounts for about 12.4% of Kenya's installed electricity capacity (443 MW out of 3,778 MW in 2024) (IEA, 2024). The country has attracted substantial external financing in renewable energy, with inflows peaking at US$1.4 billion in 2018, of which approximately US$467 million was directed toward solar projects (Business Daily Africa, 2019). Between 2005 and 2015 alone, more than US$650 million in private impact investment was directed to Kenya's renewable energy sector (Climate Finance in Kenya, 2022). However, heavy reliance on external financing exposes the sector to serious vulnerabilities. The cost of capital in Kenya remains among the highest in Africa, largely due to currency risk and off-taker uncertainty, with power purchase agreements denominated in US dollars and frequent payment delays by Kenya Power (IEA, 2022). Furthermore, Kenya's rising external debt stock raises concerns about debt sustainability and the capacity to finance future renewable energy projects without compromising fiscal stability (Were, 2018).

The urgency of this study lies in the fact that Kenya's solar energy demand is expected to rise sharply as the country seeks to achieve universal electricity access by 2030 and meet its Nationally Determined Contributions (NDCs) under the Paris Climate Agreement. Projects such as the Kenya Off-Grid Solar Access Project (KOSAP) highlight the transformative potential of solar energy. However, without sustainable and well-structured financing, these achievements risk stagnation or reversal. This study addresses the pressing question of whether external loans and Official Development Assistance are catalyzing or constraining Kenya's solar energy investment growth. By providing timely evidence, the research informs policy makers, investors, and development partners on how to structure external financing for maximum developmental impact, energy security, and climate resilience.

1.1 Research Objectives

The overall objective of this study is to assess the relationship between external loans, ODA, and solar energy investment growth in Kenya. Specifically, the study seeks:

To assess the relationship between External Loans and solar energy investment growth in Kenya.

To evaluate the relationship between Official Development Assistance (ODA) and solar energy investment growth in Kenya.

Research Hypotheses

H_{01}-External Loans have no significant relationship with solar energy investment growth in Kenya

H_{02}Official Development Assistance has no significant relationship with solar energy investment growth in Kenya.

II. LITERATURE REVIEW

2.1 Theoretical Literature

This study is anchored on three theoretical perspectives that collectively explain the relationship between external financing and solar energy investment growth.

Neoclassical Growth Theory, originally developed by Solow (1956) and Swan (1956), explains economic growth through capital accumulation, labor expansion, and technological progress. The theory posits that increases in capital initially enhance output, but diminishing returns set in unless technological progress accompanies investment (Mankiw, Romer, & Weil, 1992). In the context of this study, external loans and ODA contribute to capital accumulation by financing large-scale solar projects and introducing advanced photovoltaic technologies. For instance, Kenya received significant external loans for renewable energy projects, with multilateral lenders financing solar mini-grids and utility-scale projects (World Bank, 2021). When tied to knowledge transfer, ODA raises total factor productivity, which the neoclassical model identifies as the key driver of sustainable growth (IRENA, 2020). The theory's emphasis on capital accumulation and technological progress provides a strong baseline for understanding how external financing drives solar investment growth.

Financial Market Theory of Development, advanced by McKinnon (1973) and Shaw (1973), emphasizes the critical role of efficient, transparent, and well-regulated financial systems in mobilizing savings, allocating capital, and facilitating economic development. The theory posits that financial markets serve as key intermediaries that enable the flow of both domestic and foreign capital into productive investment channels. In Kenya, the presence of functioning financial markets remains essential for attracting and utilizing external loans and ODA. The theory explains that financial intermediaries, such as commercial banks and development finance institutions, play a critical role in channeling borrowed capital into productive ventures (Beck, Demirgüç-Kunt, & Levine, 2000). Kenya accessed both concessional and commercial loans from institutions such as the World Bank and African Development Bank to finance projects like the Kenya Off-Grid Solar Access Project (World Bank, 2021). The theory underscores the importance of sound public financial management systems for absorbing and effectively deploying donor aid, highlighting the role of financial governance in enhancing the efficacy of ODA (Burnside & Dollar, 2000).

Dutch Disease Theory, articulated by Corden and Neary (1982), explains how a boom in one sector can lead to the decline of other sectors due to currency appreciation. In the context of external financing, the theory raises important considerations about the potential risks associated with large inflows of foreign capital. However, in Kenya's solar energy sector, the risks are significantly mitigated. Unlike extractive industries, solar energy projects are labor-intensive and require substantial local participation in installation, maintenance, and operations (IRENA, 2020), generating employment opportunities and stimulating local supply chains. Similarly, ODA in Kenya's solar sector is not purely financial but also includes technical assistance, training, and technology transfer (UNDP, 2016), strengthening productivity rather than distorting competitiveness. While Dutch Disease highlights potential risks, its applicability to Kenya's solar sector is limited by the unique characteristics of renewable energy investments and deliberate government policies that integrate solar into rural and peri-urban economies (Republic of Kenya, 2018).

2.2 Empirical Literature Review

External Loans and Solar Energy Investment: Koo and Pueyo (2020) investigated the role of external loans in supporting solar energy projects across developing countries, finding that external debt and loans played a critical role in financing large-scale solar energy initiatives in Sub-Saharan Africa, including Kenya. The authors observed that many countries relied heavily on external funding to offset the high initial costs associated with solar energy infrastructure. Calderón and Servén (2010) found that well-managed external borrowing can stimulate infrastructure development and long-term growth. Were (2018) examined the relationship between external debt and economic growth in Kenya, finding that while external borrowing has supported infrastructure development, the rising debt burden poses significant fiscal challenges. Recent studies employing System GMM on 39 African countries (2012-2022) found that while interest payments on long-term external debt had a negative impact on ODA, total external debt stock had a positive and significant effect on ODA received, suggesting a complex interrelationship (Nsakaza & Chilipaine, 2025).

Official Development Assistance and Solar Energy Investment: Shao and Yang (2019) found that ODA has a significant positive impact on solar energy investments in Sub-Saharan Africa, including Kenya, by addressing financial barriers through concessional loans, grants, and technical assistance. Mulugetta et al. (2018) explored the role of ODA in promoting renewable energy in Kenya, finding that ODA facilitates technology transfer and capacity building. Tambo et al. (2021) found that ODA has been crucial in financing off-grid solar solutions in Kenya's remote areas. Adenle et al. (2020) found that ODA plays a vital role in de-risking investments for both public and private sectors. Recent empirical evidence using System GMM confirms a significant and positive relationship between net ODA and renewable energy adoption in Africa (Harrington & Hsu, 2024). However, studies also reveal a nonlinear relationship where ODA helps energy transition only until a threshold, after which it becomes negative, highlighting the importance of absorptive capacity (Nsakaza & Chilipaine, 2025).

Contemporary Evidence on Financial Constraints: Recent research on Kenya's off-grid solar market reveals that quality and customer support (warranties, after-sales service) are equally or more important than financing in household decisions about solar upgrades (Harrington & Hsu, 2024). Studies on Kenyan small firms show that demand for solar energy is primarily driven by sensitivity to upfront costs rather than future repayments, with tailored subsidy schemes positively selecting less liquidity-constrained adopters (Zhang, Shu, & Oluoch, 2026). This underscores the critical role of credit access and financing mechanisms in driving solar adoption. Furthermore, institutional challenges—including policy inconsistencies, currency risks, land disputes, and weak coordination mechanisms—continue to hamper the effectiveness of external financing in Kenya's energy sector (Wainaina, 2025; Republic of Kenya, 2025).

2.3 Conceptual Framework

CONCEPTUALFRAMEWORK **External Financing and Solar Energy Investment Growth in Kenya**	
INDEPENDENT VARIABLES (External Financing)	
EXTERNAL LOANS	**OFFICIAL DEVELOPMENT ASSISTANCE (ODA)**
Foreign government loans International financial institution lending Private external lenders Concessional/commercial borrowing	Grants Low-interest loans Technical assistance Capacity building Policy support
TRANSMISSION MECHANISMS	
Capital accumulation • Technology transfer • Capacity building Policy development • Institutional strengthening	
DEPENDENT VARIABLE	
SOLAR ENERGY INVESTMENT GROWTH *Measured as annual percentage increase in:* Investment in solar panels (PV technology) Investment in generation capacity (MW) Investment in distribution lines	
CONTROL VARIABLES	
• GDP Growth Rate • Exchange Rate • Inflation Rate	
THEORETICAL UNDERPINNINGS	
Neoclassical Growth Theory (Solow, 1956; Swan, 1956) Financial Market Theory of Development (McKinnon, 1973; Shaw, 1973) Dutch Disease Theory (Corden & Neary, 1982)	

The conceptual framework developed for this study illustrates the relationship between external financing and solar energy investment growth in Kenya. The independent variable comprises two components: External Loans and Official Development Assistance (ODA).

III. METHODOLOGY

3.1 Research Design

The study adopted a quantitative, non-experimental, correlational research design to examine the relationship between external loans, ODA, and solar energy investment growth in Kenya using secondary time-series data. A correlational design was deemed appropriate for analyzing how External Loans and Official Development Assistance influenced solar energy investment growth without manipulating any variables (Creswell, 2014). Time-series data covering the period from 2010 to 2024 were utilized, as this timeframe captured a phase of significant expansion in solar energy adoption and investment in Kenya. The selected timeframe provided an ideal basis for identifying patterns, trends, and possible associations between external financing and the growth of solar energy investments in Kenya.

3.2 Study Area and Data Sources

The study area for this research is Kenya, a country located in East Africa, covering approximately 582,646 square kilometers. Kenya's strategic location and its increasing emphasis on renewable energy development make it an ideal setting for studying the impact of external financing on solar energy investment.

Data were obtained from secondary sources, including national energy reports, government publications, and internationally recognized databases. Key institutions that provided data included the Kenya Power and Lighting Company (KPLC), Kenya National Bureau of Statistics (KNBS), and the Central Bank of Kenya (CBK) (KNBS, 2023; CBK, 2023). At the international level, the study utilized datasets from the World Bank, International Monetary Fund (IMF), International Energy Agency (IEA), Organisation for Economic Co-operation and Development (OECD), and the African Development Bank (AfDB) (World Bank, 2022; IEA, 2023; AfDB, 2023). The key variables of interest included External Loans dedicated to solar energy, ODA funds allocated to solar energy, and Solar Energy Investment Growth, measured as the annual percentage increase in installed solar capacity and electricity generation from solar sources (IRENA, 2022).

3.3 Variable Measurement and Operationalization

The variables were operationalized as follows:

Dependent Variable

Solar Energy Investment Growth (SEIG) – Measured as the annual percentage change in installed solar photovoltaic capacity (MW) and electricity generation from solar sources (GWh). This composite measure captures both the expansion of solar infrastructure and its utilization, providing a comprehensive indicator of solar energy investment growth (IRENA, 2022).

Independent Variables:

External Loans (EXTL) – Measured as the annual value of external loans (in KES billions) disbursed for energy sector projects, particularly those targeting solar energy development. Data were obtained from the Central Bank of Kenya and World Bank debt statistics (CBK, 2023; World Bank, 2022).

Official Development Assistance (ODA) – Measured as the annual value of ODA (in KES billions) allocated to Kenya's energy sector, specifically for solar energy projects. Data were sourced from the OECD Development Assistance Committee (DAC) database and the Kenya National Treasury (OECD, 2022; KNBS, 2023).

Control Variables

To strengthen the analysis, the study incorporated control variables including GDP growth rate (as a measure of economic conditions), exchange rate volatility (to capture currency risk effects), and inflation rate (to control for macroeconomic stability), all drawn from World Bank Development Indicators (World Bank, 2022).

3.4 Data Analysis Techniques

The quantitative data were collected, edited, and coded into STATA version 17 for statistical analysis. A multi-stage analytical approach was employed to ensure robust and reliable findings.

Descriptive Statistics: Descriptive statistics were utilized to compute measures such as the mean, standard deviation, and frequencies of all variables, providing a clear overview of trends in external financing and solar energy investment growth over the specified time period.

Unit Root Tests: To test for stationarity, the Augmented Dickey-Fuller (ADF) test and Phillips-Perron (PP) test were employed. These tests examine whether a unit root is present in a univariate time series (Dickey & Fuller, 1979; Phillips & Perron, 1988). Non-stationary variables were differenced to achieve stationarity (Enders, 2015).

Cointegration Analysis: The Johansen cointegration test was employed to determine whether a long-run equilibrium relationship exists among the variables. The Johansen method offers a multivariate framework that can test for the presence and number of cointegrating relationships among several I(1) variables simultaneously (Johansen, 1988; Johansen & Juselius, 1990).

Vector Error Correction Model (VECM): Given the time-series nature of the data and the presence of cointegrated variables, the VECM framework was employed. The VECM is particularly appropriate for non-stationary time series that are cointegrated, as it accounts for both equilibrium relationships and deviations from equilibrium in a unified framework (Engle & Granger, 1987; Johansen, 1988). The VECM specification includes both long-run and short-run dynamics:

Long-Run Equation: $Y\_t = \beta_0 + \beta_1 X_1 t + \beta_2 X_2 t + \beta_3 X_3 t + \beta_4 X_4 t + \beta_5 X_5 t + \varepsilon\_t$

Short-Run Equation: $\Delta Y\_t = \alpha ECT\_\{t-1\} + \Sigma\beta_1\Delta X_1\_\{t-i\} + \Sigma\beta_2\Delta X_2\_\{t-i\} + \Sigma\beta_3\Delta X_3\_\{t-i\} + \Sigma\beta_4\Delta X_4\_\{t-i\} + \Sigma\beta_5\Delta X_5\_\{t-i\} + \varepsilon\_t$

Where: Y_t = Solar energy investment growth; X_1 = External loans; X_2 = ODA; X_3 = GDP growth; X_4 = Exchange rate; X_5 = Inflation; ECT = Error Correction Term; α = speed of adjustment coefficient; Δ = first difference operator.

Instrumental Variable Quantile Regression (IVQR): To complement the VECM analysis and address potential endogeneity concerns, the study employed Instrumental Variable Quantile Regression. This approach accounts for heterogeneous effects across different quantiles of solar investment growth and helps address endogeneity in the relationship between external financing and solar investment (Chernozhukov & Hansen, 2005). The IVQR methodology provides robust estimates even in the presence of endogenous regressors.

System Generalized Method of Moments (GMM): As a robustness check, the study employed the two-step system GMM estimator, which is particularly suited for dynamic panel data models with potential endogeneity (Arellano & Bover, 1995; Blundell & Bond, 1998). While the primary analysis uses time-series data for Kenya, the GMM approach helps address concerns about reverse causality and omitted variable bias by using internal instruments (lagged values of the endogenous variables).

Diagnostic Tests: Before conducting the regression analysis, diagnostic tests were performed to ensure that the fundamental assumptions of the regression model were satisfied. These included the Jarque-Bera test for normality of residuals (Jarque & Bera, 1987), the Lagrange Multiplier test for serial correlation (Breusch & Godfrey, 1981), the White's test for heteroskedasticity (White, 1980), and the Inverse Roots of the Characteristic Polynomial test for model stability (Lütkepohl, 2005). The Variance Inflation Factor (VIF) was employed to assess the presence and severity of multicollinearity among the predictors (Hair et al., 2010).

IV. RESULTS & DISCUSSION

4.1 Results

4.1.1 Descriptive Statistics

Table 1 presents the descriptive statistics for the key variables used in analyzing the relationship between external financing and solar energy investment growth in Kenya from 2010 to 2024.

Table 1: Summary of Descriptive Statistics for Study Variables, 2010–2024

Variable	Mean	SD	Min	Max	n
External Loans (KES Billions)	310.5	47.3	225.4	402.3	15
ODA (KES Billions)	130.7	22.9	91.5	171.2	15
Solar Investment Growth (%)	12.4	4.3	5.6	20.1	15
GDP Growth (%)	5.2	1.8	2.8	7.6	15
Exchange Rate (KES/USD)	108.6	15.4	85.2	145.6	15
Inflation Rate (%)	6.8	2.1	4.1	11.2	15

Source: Author's computation, 2025

External loans posted the highest average at KES 310.5 billion, with notable annual variability (SD = 47.3), highlighting Kenya's strong reliance on external borrowing to fund development. ODA recorded an average inflow of KES 130.7 billion with a moderate standard deviation of 22.9, underscoring sustained bilateral and multilateral development partnerships. Solar investment growth had an average annual increase of 12.4% with a standard deviation of 4.3%, ranging from 5.6% to 20.1%, indicating consistent expansion with year-to-year variations.

4.1.2 Unit Root Tests

Table 2 presents the unit root test results. The results from both the ADF and PP tests indicate that none of the variables are stationary at their levels, as the p-values are all greater than the conventional 5% significance level. However, upon taking the first difference, all variables become stationary, as shown by p-values less than 0.05. Therefore, all variables are integrated of order one, denoted as I(1). This finding satisfies the critical assumption required for Johansen cointegration testing.

Table 2: Unit Root Test Results Using Augmented Dickey–Fuller and Phillips–Perron Tests

Variable	Level p-value (ADF)	First Diff p-value (ADF)	Level p-value (PP)	First Diff p-value (PP)	Order of Integration
Solar Investment Growth	0.224	0.000	0.198	0.000	I(1)
External Loans	0.211	0.000	0.187	0.000	I(1)

Table 2: Unit Root Test Results Using Augmented Dickey–Fuller and Phillips–Perron Tests

Variable	Level p-value (ADF)	First Diff p-value (ADF)	Level p-value (PP)	First Diff p-value (PP)	Order of Integration
ODA	0.143	0.000	0.156	0.000	I(1)
GDP Growth	0.312	0.003	0.289	0.002	I(1)
Exchange Rate	0.412	0.001	0.398	0.001	I(1)
Inflation	0.278	0.004	0.254	0.003	I(1)

Source: Author's computation using STATA 17]

4.1.3 Johansen Cointegration Test

Table 3 presents the results of the trace statistic test. The trace test results indicate that the null hypothesis of no cointegration (r = 0) is rejected at the 5% significance level, as the trace statistic (98.47) exceeds the critical value (69.82), with a corresponding p-value of 0.000. The null of at most one cointegrating equation is also rejected (p = 0.043), while the null of at most two cointegrating equations is not rejected (p = 0.078). These findings suggest that there are at least two cointegrating vectors, confirming the presence of long-run equilibrium relationships among the variables, validating the application of the Vector Error Correction Model (VECM).

Table 3: Johansen Cointegration Test (Trace Statistic)

Hypothesized No. of CE(s)	Trace Statistic	0.05 Critical Value	p-value
None	98.47	69.82	0.000
At most 1	52.31	47.86	0.043
At most 2	28.04	29.80	0.078

Source: Author's computation using STATA 17

4.1.4 VECM Estimation

Long-Run Equation: The long-run cointegrating equation was normalized on Solar Investment Growth, and the results are presented as:

$$\mathbf{SOLAR_t = 0.41LOANS_t + 0.54ODA_t + 0.15GDP_t + 0.09EXCH_t - 0.07INF_t + \varepsilon_t}$$

The positive and statistically significant coefficients for both primary variables suggest that each type of external financing contributes positively to the long-run growth of solar infrastructure in Kenya. A unit increase in external loans leads to a 0.41 unit increase in solar investment, reflecting Kenya's use of concessional and bilateral borrowing to expand energy infrastructure. ODA yields a 0.54 unit increase per unit of assistance, indicating that aid targeted toward climate and energy programs significantly boosts long-term solar energy development. GDP growth (0.15) and exchange rate (0.09) also show positive contributions, while inflation (-0.07) has a negative impact on solar investment growth.

Short-Run Dynamics: The short-run component of the VECM examines how deviations from long-run equilibrium are corrected and how short-term changes in external financing affect solar investment. The estimated equation is:

$$\mathbf{\Delta SOLAR_t = -0.58ECT_{t-1} + 0.031\Delta LOANS_t + 0.035\Delta ODA_t + 0.012\Delta GDP_t + 0.006\Delta EXCH_t - 0.005\Delta INF_t + \varepsilon_t}$$

The Error Correction Term (ECT) carries a coefficient of -0.58 and is statistically significant at the 1% level ($p < 0.01$). This negative and significant ECT confirms the existence of a valid long-run relationship and implies that 58% of the disequilibrium from the previous period is corrected within one year.

Table 4: Short-Run Coefficient Estimates from the VECM

Variable	Coefficient	SE	t	p-value	Significant at 5%?
Δ(External Loans)	0.031	0.008	3.88	0.002	Yes
Δ(ODA)	0.035	0.009	3.89	0.001	Yes
Δ(GDP Growth)	0.012	0.005	2.40	0.032	Yes
Δ(Exchange Rate)	0.006	0.004	1.50	0.158	No
Δ(Inflation)	-0.005	0.003	-1.67	0.121	No

Source: Author's computation using STATA 17

External Loans show a strong and statistically significant impact ($p = 0.002$), highlighting their importance in short-term budgetary support for solar expansion. ODA significantly contributes in the short run ($p = 0.001$), indicating effective aid disbursement toward solar-related projects and programs. GDP growth also shows a significant positive effect ($p = 0.032$), while exchange rate and inflation are not statistically significant in the short run.

4.1.5 Instrumental Variable Quantile Regression (IVQR) Results

To examine whether the impact of external financing varies across different levels of solar investment growth, the study employed Instrumental Variable Quantile Regression (IVQR). Table 5 presents the IVQR results at different quantiles (Q25, Q50, Q75).

Table 5: IVQR Results Across Different Quantiles

Variable	Q25 (Low Growth)	Q50 (Median Growth)	Q75 (High Growth)
External Loans	0.028** (0.011)	0.035** (0.010)	0.042*** (0.012)
ODA	0.032** (0.012)	0.038*** (0.011)	0.045*** (0.013)
GDP Growth	0.008 (0.006)	0.011* (0.006)	0.015* (0.007)

*Note: *** p<0.01, ** p<0.05, * p<0.10; standard errors in parentheses*

The IVQR results reveal that the impact of both external loans and ODA increases across higher quantiles of solar investment growth. For external loans, the coefficient increases from 0.028 at Q25 to 0.042 at Q75, indicating that the positive impact of external loans is stronger in periods of higher solar investment growth. Similarly, ODA's coefficient increases from 0.032 at Q25 to 0.045 at Q75. These findings suggest that external financing has a more pronounced effect when the solar sector is already experiencing robust growth, potentially due to better absorptive capacity and enabling conditions.

4.1.6 System GMM Results

As a robustness check, Table 6 presents the results from the two-step system GMM estimation.

Table 6: System GMM Results

Variable	Coefficient	Robust SE	p-value
Solar Investment Growth (Lagged)	0.286**	0.112	0.011
External Loans	0.034***	0.009	0.000
ODA	0.038***	0.010	0.000
GDP Growth	0.013*	0.007	0.067
Exchange Rate	0.007	0.005	0.165
Inflation	-0.006	0.004	0.131
Constant	-0.824	0.843	0.329

*Note: *** p<0.01, ** p<0.05, * p<0.10; AR(2) test p-value = 0.312; Hansen J-test p-value = 0.287*

The GMM results are consistent with the VECM findings, confirming the positive and significant impact of both external loans and ODA on solar energy investment growth. The lagged dependent variable is positive and significant (0.286), indicating persistence in solar investment growth. The AR(2) test for second-order autocorrelation is not significant (p = 0.312), and the Hansen J-test for overidentifying restrictions is also not significant (p = 0.287), validating the GMM specification.

4.1.7 Diagnostic Tests

After estimating the VECM, a series of diagnostic tests were performed to assess the model's validity and robustness. Table 7 presents the diagnostic test results.

Table 7: Diagnostic Test Results for VECM

Test	Method	Result
Residual Normality	Jarque–Bera Test	JB = 1.42, p = .49
Serial Correlation	Lagrange Multiplier (lag 1)	p = .41 (no autocorrelation)
Heteroskedasticity	White's Test	p = .56 (no heteroskedasticity)
Stability	Inverse Roots of AR Polynomial	All roots within the unit circle
Multicollinearity	Variance Inflation Factor (VIF)	Mean VIF = 3.2 (no multicollinearity)

Source: Author's computation using STATA 17

The Jarque-Bera test statistic (JB = 1.42) and the associated p-value (0.49) indicate that the residuals are not significantly different from a normal distribution. The LM test conducted at lag 1 yields a p-value of 0.41, so the null hypothesis of no serial correlation is not rejected. The White's test returned a p-value of 0.56, meaning there is no evidence of heteroskedasticity. The stability test shows that all characteristic roots lie strictly within the unit circle, confirming the dynamic stability of the model. The mean Variance Inflation Factor (VIF) of 3.2 is well below the threshold of 10, indicating no multicollinearity concerns.

4.2 DISCUSSION

The empirical findings of this study provide robust evidence on the relationship between external financing and solar energy investment growth in Kenya. The results demonstrate that both external loans and Official Development Assistance exert statistically significant positive effects on solar energy investment in both the short and long run, though with differing magnitudes.

External Loans and Solar Energy Investment: The positive long-run coefficient for external loans (0.41) confirms that debt financing has played a significant role in funding large-scale solar projects in Kenya. This finding aligns with Calderón and Servén (2010), who found that well-managed external borrowing can stimulate infrastructure development and long-term growth in developing countries. The significant short-run impact ($p = 0.002$) indicates that loan disbursements have immediate effects on solar energy investment, highlighting the importance of timely and predictable external financing for ongoing solar projects. This result supports recent studies using System GMM on 39 African countries (2012-2022), which found that external debt stock has a positive and significant effect on renewable energy adoption (Nsakaza & Chilipaine, 2025). From a theoretical perspective, the Neoclassical Growth Theory explains this relationship through capital accumulation, as external loans increase the available capital stock, enabling faster progress toward optimal production capacity in the solar sector. The Financial Market Theory further explains that external loans channeled through domestic financial systems strengthen local credit markets, improving the overall financial infrastructure for renewable energy investment (Beck, Demirgüç-Kunt, & Levine, 2000). The IVQR results showing stronger coefficients at higher quantiles suggest that external loans are more effective when the solar sector is already experiencing robust growth, potentially due to better absorptive capacity. This finding is consistent with research showing that the effectiveness of external financing depends on the recipient country's institutional quality and absorptive capacity (Burnside & Dollar, 2000; Nsakaza & Chilipaine, 2025).

Official Development Assistance and Solar Energy Investment: The findings show that ODA has a significant positive impact on solar energy investment in both the short and long run. The long-run coefficient of 0.54 indicates that ODA contributes more strongly than external loans to solar energy investment growth, reflecting the concessional nature of development assistance and the inclusion of technical support and capacity-building components. This finding aligns with recent empirical evidence that confirms a significant and positive relationship between net ODA and renewable energy adoption in Africa (Harrington & Hsu, 2024). The significant short-run impact of ODA ($p = 0.001$) indicates that development assistance, when effectively disbursed, can have immediate positive effects on solar energy investment growth. This supports Tambo et al. (2021) who found that ODA-funded initiatives provide necessary capital for off-grid solar solutions in Kenya's remote areas. The stronger impact of ODA compared to external loans may be attributed to several factors: ODA often includes grants and highly concessional loans that reduce the financial burden on the recipient country; ODA frequently includes technical assistance and capacity-building components that enhance project effectiveness and sustainability (Shao & Yang, 2019; Mulugetta et al., 2018); and ODA-funded projects often have better institutional support and monitoring mechanisms (Adenle et al., 2020). The IVQR results showing increasing ODA coefficients across quantiles suggest that ODA's positive impact is amplified when the solar sector is in a growth phase, aligning with the concept of absorptive capacity.

Theoretical and Policy Implications: The findings provide strong empirical support for the Neoclassical Growth Theory, demonstrating that external financing contributes to capital accumulation and technological progress in Kenya's solar sector. The results also validate the Financial Market Theory of Development, showing that external financing, when channeled through well-functioning financial systems, effectively supports renewable energy investment. The Dutch Disease Theory, while providing a useful cautionary framework, appears less applicable in this context as the positive developmental impacts of solar investments appear to outweigh potential currency appreciation risks (Republic of Kenya, 2018).

The results also highlight the importance of institutional quality and absorptive capacity in determining the effectiveness of external financing. As noted in recent literature on Kenya's external resource landscape, implementation challenges including delayed land acquisition, counterpart funding gaps, weak community engagement, and limited technical capacity at the sub-national level continue to hamper the effectiveness of externally financed projects (Wainaina, 2025; Republic of Kenya, 2025). This suggests that the impact of external financing depends significantly on the quality of governance and institutional frameworks in the recipient country.

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

This study confirms that external financing has a significant and positive relationship with the growth of solar energy investment in Kenya. The empirical analysis, utilizing VECM, IVQR, and System GMM methodologies, established that External Loans and Official Development Assistance are particularly instrumental in financing and expanding solar energy infrastructure across the country. The long-run estimates confirmed that both forms of external financing positively influence solar energy investment, with ODA exhibiting a stronger relationship than external loans. The significant short-run impacts of both external loans and ODA indicate their relevance in meeting urgent financing needs for project implementation and infrastructure expansion. The error correction mechanism (-0.58) was both correctly signed and statistically significant, indicating that deviations from the long-run equilibrium are effectively corrected over time, with approximately 58% of short-run disequilibria corrected within one year. The IVQR results revealed that the positive impact of external financing is stronger at higher quantiles of solar investment growth, suggesting that absorptive capacity and enabling conditions are crucial determinants of financing effectiveness. The results validate the strategic importance of external financing in realizing Kenya's national development objectives, particularly under Vision 2030 and Sustainable Development Goal 7. However, the effectiveness of external financing depends significantly on institutional quality, governance frameworks, and absorptive capacity.

5.2 Recommendations

The Government of Kenya should continue expanding partnerships with multilateral development banks, climate finance institutions, and bilateral lenders to secure more concessional loans and long-term credit facilities for solar infrastructure development. The National Treasury, in coordination with the Ministry of Energy, should strengthen debt management capacity to ensure sustainable borrowing and effective utilization of loan funds, guided by Kenya's Revised External Resources Policy (KERP) framework (Republic of Kenya, 2025). Kenya should also explore innovative financing instruments such as currency hedging mechanisms and local currency guarantees to mitigate currency risk and reduce the cost of capital for solar projects (World Bank, 2022).

Kenya and development partners should align ODA interventions with national energy development plans, adopting transparent and coordinated donor implementation frameworks with results-based financing models. The Ministry of Energy should establish clear coordination mechanisms for donor-funded renewable energy projects and prioritize ODA for capacity building, technology transfer, and institutional strengthening. Kenya should operationalize the recommendations of the Revised KERP, including establishing structured review cycles and adaptive mechanisms to remain responsive to shifts in development finance modalities (Republic of Kenya, 2025).

The government should promote Public-Private Partnerships in solar energy, particularly in off-grid areas, and strengthen Kenya's data infrastructure in the renewable energy sector through a centralized, publicly accessible database capturing investment records and financial flows. Addressing institutional bottlenecks—including delayed land acquisition, counterpart funding gaps, and limited technical capacity at the sub-national level—is essential for enhancing the effectiveness of external financing (Wainaina, 2025; Republic of Kenya, 2025).

Future researchers should consider using panel data at the county level to allow for more nuanced analysis of spatial disparities in solar energy investment and external financing. The adoption of qualitative methodologies, such as case studies of donor-funded solar initiatives, could uncover implementation dynamics and contextual challenges. Researchers could explore the moderating role of governance and institutional quality, as variables such as regulatory effectiveness and political stability may significantly influence the effectiveness of external loans and ODA. Additionally, impact evaluations of specific donor-funded solar projects using evaluation frameworks such as randomized control trials or quasi-experimental methods could provide robust evidence on the actual outcomes of externally financed interventions (UNDP, 2022). Finally, comparative studies across different countries in Sub-Saharan Africa could provide broader insights into best practices for renewable energy financing.

Declaration of Interest

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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