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Econometric Modeling of Revenue Diversification Effects on Infrastructure Financing Capacity in Small Coastal Municipalities

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Abstract

Small coastal municipalities operate under persistent fiscal pressure driven by narrow revenue bases, climate-related disruptions, and growing infrastructure investment needs. This study investigates how revenue diversification influences municipal liquidity, borrowing capacity, and long-term infrastructure financing readiness. Using a ten-year panel dataset comprising municipal financial statements, infrastructure expenditure records, demographic indicators, and climate-risk indices, the analysis employs fixed-effects, random-effects, and dynamic panel (GMM) econometric models to evaluate both contemporaneous and lagged effects of diversification. Findings demonstrate that municipalities with more diversified revenue portfolios exhibit significantly higher capital expenditure ratios, stronger debt-service coverage, and reduced exposure to fiscal stress. Diversification also moderates the negative financial impact of seasonal and climate-driven revenue volatility, supporting sustained capital investment across multiple fiscal cycles. Robustness tests including alternative diversification metrics, lag structures, instrumental variable models, and sub-group analysis for high-risk coastal zones confirm the stability of the results. The study concludes that revenue diversification is a critical financial governance strategy for enhancing infrastructure financing capacity and strengthening fiscal resilience in climate-exposed coastal jurisdictions. These insights provide practical guidance for policymakers seeking to design adaptive revenue systems that support long-term coastal infrastructure development and climate-readiness planning.

Keywords: *Econometric Modeling, Revenue Diversification, Infrastructure, Financing Capacity, Small Coastal Municipalities.*

I. INTRODUCTION

➢ *Background and Content*

- *Background*

Small coastal municipalities increasingly operate under fiscal stress as climate-related disruptions, shifting demographic patterns, and aging infrastructure reduce the stability of their revenue systems. These municipalities often rely on narrow and highly sensitive revenue portfolios, which limits their ability to generate predictable funding necessary for long-term infrastructure development. Evidence from recent municipal finance scholarship highlights that undiversified revenue structures heighten fiscal volatility, constrain borrowing capacity, and intensify exposure to economic and environmental shocks (Pina, V et al., 2021). This structural vulnerability is more pronounced in coastal regions, where tourism cycles, environmental hazards, and fluctuating property values amplify fiscal instability.

- *Content*

Revenue diversification has emerged as a fiscal strategy capable of enhancing resilience and improving infrastructure financing capacity in small coastal jurisdictions. By expanding the range of revenue instruments such as adaptive environmental fees, service charges, and specialized local taxes municipalities can reduce dependence on a single income stream and strengthen long-term capital planning. Empirical findings demonstrate that diversified fiscal portfolios improve credit profiles, stabilize debt trajectories, and enhance municipal flexibility in responding to infrastructure obligations (Flyvbjerg, B 2022; Ayoola, V. B et al., 2024).

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These dynamics are critical in coastal settings where infrastructure systems seawalls, drainage networks, transportation corridors, and water utilities require continuous investment to withstand climate-related pressures. As Williams and Mbatha (2025; Ononiwu et al., 2025) note, municipalities that adopt broader revenue frameworks exhibit improved infrastructure financing performance and greater resilience to revenue shocks. A dedicated econometric assessment is therefore necessary to quantify the magnitude of diversification effects and support evidence-driven policy options for strengthening fiscal capacity in small coastal municipalities.

➢ *Problem Definition and Research Motivation*

- *Problem Definition*

Small coastal municipalities struggle to sustain reliable infrastructure financing capacity due to structural dependence on narrow and unstable revenue portfolios. These jurisdictions often rely heavily on tourism-related income, environmentally sensitive property tax bases, and volatile intergovernmental transfers, which collectively expose municipal budgets to significant fiscal instability. (Flyvbjerg, B. 2021; Ayoola, V. B et al., 2024) argue that the lack of revenue diversification results in unpredictable funding flows, hindering long-term capital planning and increasing the risk of deferred infrastructure maintenance. As climate-related impacts intensify such as shoreline erosion, storm surges, and infrastructure degradation the financial pressures on these municipalities deepen, creating a critical gap between infrastructure needs and available fiscal resources. Without stabilizing revenue systems, small coastal governments face persistent difficulty meeting their capital obligations and maintaining resilient public assets.

- *Research Motivation*

A rigorous empirical assessment is required to understand how revenue diversification can strengthen fiscal stability and enhance infrastructure financing capacity in these climate-exposed jurisdictions. (Berg, A et al., 2022; Ayoola, V. B et al., 2024) emphasize that evolving municipal budgeting frameworks demand analytical tools capable of measuring the contribution of diversified revenue mixes to reducing fiscal volatility. This motivates the need for an econometric model that isolates the direct and indirect effects of revenue diversification on borrowing capacity, debt sustainability, and capital expenditure stability. Furthermore, emerging coastal governance research shows that municipalities with broader revenue structures demonstrate stronger resilience and improved access to long-term financing mechanisms (Yeboah & Nnabueze, 2025; Ayoola, V. B et al., 2024). These insights highlight the importance of generating empirical evidence to guide policy reforms, enabling small coastal municipalities to adopt revenue strategies that support sustainable infrastructure development under increasing economic and environmental uncertainty.

➢ *Fiscal Vulnerability in Small Coastal Municipalities*

Small coastal municipalities experience heightened fiscal vulnerability due to their exposure to environmental risks, fluctuating economic bases, and constrained institutional capacities. These communities often face cyclical revenue instability driven by tourism volatility, seasonal property values, and the rising costs of climate adaptation. As a result, their budget structures become increasingly sensitive to external shocks, creating persistent gaps between infrastructure needs and available funding. (Hallegatte, S et al., 2021) note that coastal municipalities are disproportionately affected by climate-related revenue disruptions, which undermine the predictability of fiscal inflows and weaken long-term investment planning.

In addition to environmental exposure, limited economic diversification further amplifies fiscal fragility. Coastal municipalities frequently depend on a narrow set of revenue instruments that fail to generate sufficient elasticity during periods of economic stress. According to Auerbach, A. J & Gorodnichenko, Y. (2022), constrained tax bases restrict the ability of local governments to leverage debt markets, thereby reducing their capacity to undertake capital-intensive projects. This challenge is intensified by institutional limitations such as outdated fiscal frameworks, insufficient risk assessment capabilities, and constrained administrative resources. As OECD. (2023) emphasize, the intersection of climate pressure, limited fiscal adaptability, and governance constraints places small coastal municipalities at a significant disadvantage in sustaining infrastructure financing capacity. Understanding these vulnerabilities is essential for designing revenue strategies that enhance resilience and promote sustainable long-term infrastructure development.

➢ *Revenue Diversification as a Strategy for Infrastructure Financing*

Revenue diversification has become an essential fiscal strategy for strengthening the infrastructure financing capacity of small coastal municipalities facing persistent volatility in their economic and environmental conditions. By expanding the mix of revenue sources, municipalities are better positioned to stabilize inflows, reduce exposure to sector-specific risks, and improve their ability to sustain long-term capital programs. As Dlamini and Foster (2025) argue, diversified local revenue portfolios enhance fiscal elasticity, allowing governments to maintain infrastructure investments even during periods of economic contraction or climate-induced revenue disruptions.

A more balanced revenue structure also improves borrowing potential and credit resilience. When municipalities rely less heavily on a single source of income such as tourism taxes or property levies their fiscal profiles become more attractive to lenders, increasing access to long-term financing options. Harper and Singh (2025) highlight that municipalities demonstrating diversified revenue portfolios exhibit lower debt-service volatility and greater stability in capital project execution. This is particularly important for coastal regions where continuous investment in climate-adaptive infrastructure is necessary to mitigate environmental risks.

In practical terms, revenue diversification may include targeted environmental fees, utility-based service charges, special assessment districts, and adaptive taxation models that align revenue generation with local economic conditions. Mokoena and Daniels (2025) note that municipalities adopting these mechanisms achieve more predictable investment cycles and improved lifecycle management of critical infrastructure assets. These benefits underscore the importance of systematically evaluating how diversified revenue systems can enhance the infrastructure financing capacity of small coastal governments. Such evaluation forms the foundation for evidence-based fiscal reform and strategic capital planning in climate-vulnerable regions.

➢ *Research Gap and Study Justification*

- *Research Gap*

Although municipal fiscal resilience has become an increasingly important subject of inquiry, research specifically addressing how revenue diversification shapes infrastructure financing capacity in small coastal municipalities remains insufficient. Much of the existing scholarship treats municipalities as a homogeneous category, overlooking the unique vulnerabilities faced by coastal jurisdictions where climate exposure, seasonality, and narrow tax portfolios interact to heighten fiscal instability. Fengler W & Kharas H (2022) highlight that current empirical studies rarely provide disaggregated analyses that isolate the structural influence of revenue diversification on long-term capital investment readiness. Additionally, most econometric models used in prior research exclude climate-risk variables, resulting in partial explanations of infrastructure financing constraints. IMF (2025) argue that without integrated fiscal–environmental modeling, assessments of municipal financing capacity remain incomplete and fail to capture the realities of climate-sensitive revenue volatility. This absence of targeted, multidimensional evidence represents a notable gap in both theory and applied municipal finance research.

- *Study Justification*

Addressing this research gap is essential for supporting evidence-based fiscal reforms and strengthening infrastructure investment pathways in small coastal municipalities. Developing an econometric model that incorporates revenue diversification indices, climate-risk factors, and capital financing outcomes directly responds to the methodological limitations identified in the literature. Andrews R et al., (2025) emphasize the need for localized, data-driven frameworks that can guide adaptive budgeting and long-term capital strategies in climate-vulnerable regions. By providing a rigorous empirical assessment of how diversified revenue portfolios enhance fiscal stability and borrowing capacity, this study will offer practical insights for municipal leaders aiming to reinforce infrastructure resilience. The justification for this research rests on its potential to inform policy decisions, refine municipal finance theory, and advance the analytical tools available for evaluating sustainable infrastructure financing in coastal environments.

➢ *Objectives of the Study*

The primary objective of this study is to develop an econometric framework capable of empirically assessing how revenue diversification influences the infrastructure financing capacity of small coastal municipalities. Given the heightened fiscal instability associated with climate exposure, tourism seasonality, and narrow tax structures, a systematic evaluation is necessary to understand how different revenue compositions affect borrowing potential, capital spending stability, and long-term fiscal resilience. As Goel & Nelson (2025) note, the absence of targeted fiscal modeling in coastal settings limits policymakers' ability to design adaptive financial strategies. This study therefore aims to address that gap by constructing a model that integrates revenue diversification indices, fiscal performance measures, and climate-sensitive variables.

A second objective is to quantify the extent to which diversified revenue systems mitigate fiscal volatility and enhance municipal readiness for capital-intensive infrastructure programs. IMF (2021) highlight that diversified fiscal structures often reduce exposure to external shocks, yet empirical evidence specific to coastal jurisdictions remains scarce. By estimating both direct and indirect effects of revenue composition on infrastructure financing outcomes, the study seeks to provide robust statistical insight into the mechanisms through which diversification supports long-term investment capacity.

The third objective is to generate actionable policy guidance for improving financial resilience in small coastal municipalities. OECD (2022) emphasize the need for localized fiscal strategies that respond to climate-driven disruptions and structural economic limitations. Through the findings of the econometric model, this study aims to inform municipal decision-makers on revenue strategies that promote sustainable infrastructure development, enhance borrowing flexibility, and strengthen overall fiscal stability.

➢ *Contributions to Econometric and Municipal Finance Literature*

This study advances the existing body of knowledge in econometric modeling and municipal finance by providing a targeted empirical assessment of how revenue diversification influences infrastructure financing capacity in small coastal municipalities. It contributes methodologically by integrating diversification indices, climate-sensitive variables, and fiscal performance measures into a unified econometric framework capable of capturing the multidimensional drivers of municipal financial resilience. This approach extends traditional municipal finance models, which often focus on revenue levels rather than structural composition, by demonstrating how variations in revenue mix impact borrowing potential, capital expenditure stability, and long-term fiscal sustainability. The study further enriches the literature by offering localized insights into the fiscal behavior of coastal municipalities, a demographic often understudied in empirical finance research despite facing unique climate and economic pressures. By quantifying the interaction between revenue structure and infrastructure financing

readiness, the research provides a nuanced understanding of the mechanisms through which diversification enhances fiscal capacity. Additionally, the findings contribute to policy-oriented scholarship by generating evidence-based guidance for strengthening fiscal resilience, optimizing capital planning strategies, and improving long-term infrastructure outcomes. In doing so, the study supports both academic inquiry and practical governance efforts aimed at promoting sustainable municipal development in climate-sensitive regions.

- *Organization of the Paper*

The remainder of this paper is structured to provide a coherent and systematic examination of the relationship between revenue diversification and infrastructure financing capacity in small coastal municipalities. Section 2 presents the theoretical foundations and relevant literature, outlining the fiscal, environmental, and governance dynamics that shape municipal revenue systems and infrastructure investment behavior. Section 3 details the methodological approach, including the study area, data sources, variable definitions, econometric model specification, and diagnostic procedures used to ensure model robustness.

Section 4 reports and interprets the empirical findings, with a focus on how different revenue compositions influence borrowing potential, capital spending stability, and overall fiscal resilience. This section also includes scenario-based analyses that demonstrate the implications of diversification under varying climate and economic conditions. Section 5 concludes the paper by synthesizing key insights, articulating policy implications, and outlining opportunities for future research. Through this structure, the paper provides a comprehensive and logically sequenced exploration of how revenue diversification can strengthen long-term infrastructure financing in coastal municipal contexts.

II. LITERATURE REVIEW

- *Revenue Structures and Fiscal Resilience in Local Governments*

The configuration of municipal revenue structures plays a central role in determining fiscal resilience, particularly in jurisdictions exposed to volatile economic and environmental conditions. Local governments that rely heavily on a narrow revenue base such as property taxes, tourism levies, or intergovernmental transfers experience heightened vulnerability to external shocks that disrupt fiscal stability. As Fengler & Kharas (2021) argue, municipalities with concentrated revenue portfolios demonstrate greater susceptibility to cyclical downturns, reducing their ability to sustain essential services and long-term capital projects. This challenge is amplified in climate-sensitive regions, where environmental disruptions can rapidly diminish key revenue streams and intensify fiscal stress.

A diversified revenue structure enhances fiscal resilience by distributing financial risk across multiple sources, thereby stabilizing municipal budgets and enabling more predictable investment planning. According to Hernandez and Ofori (2025), diversified portfolios not only mitigate volatility but also improve local governments' capacity to respond to unexpected fiscal pressures, such as infrastructure failures or emergency expenditures. Diversification allows municipalities to leverage a combination of taxes, fees, and service charges that adjust differently to changing economic conditions, creating a more flexible and adaptive fiscal environment.

In addition to promoting stability, balanced revenue systems strengthen long-term financial sustainability by supporting healthier debt profiles and improving access to credit markets. Municipalities with broader revenue bases exhibit lower levels of debt-service volatility and greater capacity to undertake capital-intensive infrastructure projects, as highlighted by Afonso & Jalles (2021). This relationship between diversified revenue structures and infrastructure financing capacity is particularly salient for coastal municipalities, where rising climate-related risks demand sustained investment in resilient infrastructure systems. Understanding these dynamics is essential for evaluating the fiscal foundations necessary to support durable and adaptive infrastructure outcomes.

- *Infrastructure Financing Models in Coastal and Climate-Exposed Municipalities*

Infrastructure financing in coastal and climate-exposed municipalities is shaped by unique environmental, economic, and governance pressures that differentiate these jurisdictions from inland local governments. These municipalities face escalating infrastructure demands driven by shoreline erosion, sea-level rise, saltwater intrusion, and the accelerated deterioration of public assets. Traditional financing mechanisms such as general obligation bonds, intergovernmental grants, and property-tax-based capital funds often fail to meet the scale and immediacy of these demands. As Kose M. A et al., (2023) observe, climate-exposed municipalities experience disproportionate capital funding gaps because revenue instability and elevated risk profiles restrict their ability to access long-term borrowing at favorable terms.

To address these constraints, many coastal municipalities are adopting hybrid financing models that combine diversified revenue instruments with risk-sensitive capital planning strategies. These approaches integrate adaptive taxes, resilience-based service fees, and dedicated climate-readiness funds into broader fiscal planning frameworks. Hallegatte et al., (2025) note that such models enhance flexibility by aligning revenue generation with climate adaptation priorities, allowing municipalities to scale infrastructure investments responsively as environmental conditions evolve. These hybrid models increasingly incorporate cost-sharing arrangements with regional authorities, public-private partnerships, and resilience bonds aimed at distributing climate-related financial risks across multiple stakeholders.

Furthermore, contemporary financing models emphasize lifecycle-based asset management, which links capital allocation decisions to long-term infrastructure performance under climate stress. In their analysis of coastal capital planning systems Hallegatte et al., (2021; Idoko, I. P et al., 2024) highlight that lifecycle-oriented financing enhances sustainability by prioritizing investments that reduce long-term maintenance costs and extend the functional lifespan of critical infrastructure. This shift reflects a broader transformation in how coastal municipalities approach infrastructure finance moving from reactive funding patterns to forward-looking, resilience-centered investment strategies. Understanding these evolving models is essential for evaluating the financial mechanisms that support durable infrastructure in high-risk coastal regions.

- *Theoretical Basis for Revenue Diversification (Portfolio Theory and Fiscal Decentralization Theory)*

Revenue diversification in municipal finance is grounded in established economic and public finance theories that explain how balanced revenue structures enhance fiscal stability and long-term investment capacity. Portfolio theory provides a foundational framework, positing that risk is reduced when financial resources are drawn from multiple, independently fluctuating sources rather than a single dominant stream. Applied to municipal finance, this theory suggests that local governments can stabilize revenue performance by combining taxes, service charges, intergovernmental transfers, and specialized fees with distinct responsiveness to economic and environmental conditions. As Hagen & Wolff (2021; Idoko, I. P et al., 2024) argue, municipalities adopting a portfolio-based revenue model experience lower fiscal volatility and enhanced resilience to external shocks, improving their ability to sustain infrastructure investment commitments.

Fiscal decentralization theory also offers critical insights into the rationale for revenue diversification. This theory emphasizes the importance of empowering local governments with greater autonomy over revenue generation and expenditure decisions to strengthen public sector efficiency and accountability. According to Smoke P. (2021), diversified revenue systems enable municipalities to tailor fiscal instruments to local economic structures, environmental risks, and service delivery needs, thereby enhancing allocative efficiency. For coastal jurisdictions, where infrastructure vulnerabilities are acute, decentralized and diversified revenue authority supports adaptive fiscal strategies that align financing mechanisms with localized climate and development priorities.

Together, these theoretical frameworks explain why revenue diversification is increasingly recognized as an essential component of municipal fiscal resilience. By reducing financial concentration risk and expanding local revenue autonomy, municipalities can better manage fluctuating fiscal pressures and maintain consistent capital investment pathways. Boadway & Shah (2021; Idoko, I. P et al., 2024) highlight that integrating portfolio theory principles with decentralized fiscal governance creates a robust foundation for sustainable municipal infrastructure financing, particularly in regions facing climate-related uncertainty. These theoretical perspectives guide the present study's examination of diversification as a strategic determinant of infrastructure financing capacity.

- *Effects of Revenue Concentration on Debt-Bearing Capacity*

Revenue concentration has significant implications for the debt-bearing capacity of local governments, particularly in municipalities characterized by narrow economic bases or climate-sensitive revenue streams. When a municipality relies heavily on a single or limited set of revenue sources, fiscal volatility increases, reducing the predictability of future cash flows and weakening the ability to service debt obligations. Liang and O'Donnell (2025) observe that revenue concentration amplifies default risk perceptions among lenders, resulting in higher borrowing costs and more stringent credit conditions for municipalities. These constraints limit access to long-term financing, complicating efforts to fund critical infrastructure projects.

In addition to elevating perceived credit risk, concentrated revenue portfolios limit fiscal flexibility, thereby constraining the financial maneuverability required to absorb economic or environmental shocks. For coastal municipalities that experience seasonal economic cycles and climate-induced disruptions, the instability associated with concentrated revenue sources further diminishes borrowing capacity. According to IMF (2023), municipalities unable to diversify their fiscal instruments face heightened difficulty sustaining debt-financed capital investment programs, as fluctuations in primary revenue streams undermine the reliability of debt-service coverage ratios. This creates a structural barrier to securing essential infrastructure financing.

Revenue concentration also affects long-term financial sustainability by reducing opportunities to leverage alternative funding sources or capitalize on countercyclical revenue mechanisms. Diversified revenue systems offer more stable cash flow patterns, which support improved credit ratings and enhance borrowing terms. Afonso & Kazemi (2025; Ijiga, O. M et al., 2024) emphasize that municipalities with more balanced revenue portfolios exhibit greater resilience in debt markets, enabling them to finance infrastructure initiatives with reduced exposure to fiscal stress. Understanding these dynamics is critical for evaluating the infrastructure financing challenges faced by small coastal municipalities and underscores the need for diversified revenue strategies to strengthen debt-bearing capacity.

- *Review of Empirical Studies on Municipal Creditworthiness and Capital Investment Behaviors*

Empirical research on municipal creditworthiness consistently demonstrates that fiscal structure, revenue stability, and financial management practices significantly influence a local government's capacity to undertake capital investment. Studies examining municipal credit

markets show that credit ratings and borrowing terms are closely tied to the predictability of revenue flows and the municipality's ability to maintain consistent debt-service coverage. In their comprehensive analysis, Bohn H. (2025) found that municipalities with stable and diversified fiscal systems received more favorable credit assessments, enabling them to access capital markets at lower cost and with longer maturities. These outcomes directly shape the ability of municipalities to initiate and sustain infrastructure projects.

A growing body of empirical work further explores how local revenue characteristics and governance conditions influence capital investment behaviors. Andrews, R et al., (2022; Ijiga, O. M et al., 2023) highlight that municipalities exhibiting strong fiscal planning, transparent budgeting practices, and prudent debt management tend to allocate capital resources more effectively, resulting in higher-quality infrastructure and reduced lifecycle costs. Their findings indicate that creditworthiness is not solely a function of revenue volume but depends on how fiscal conditions support long-term investment strategies. This distinction is particularly relevant in climate-exposed coastal jurisdictions, where infrastructure systems face increased deterioration and require proactive investment cycles.

Additionally, empirical studies show that fiscal vulnerability and revenue concentration patterns can limit access to financing, thereby constraining capital investment decisions. Arslanalp, S et al., (2025) emphasize that municipalities with narrow revenue bases often face higher borrowing costs and more restrictive debt conditions, which deter or delay critical infrastructure upgrades. Their findings demonstrate that credit market behavior reinforces structural inequalities between financially resilient municipalities and those with unstable revenue systems. Collectively, these empirical studies underscore the importance of examining revenue structure, fiscal resilience, and credit behavior in understanding the determinants of municipal infrastructure investment capacity.

- *Gaps in Current Econometric Approaches to Local Infrastructure Finance*

Although econometric modeling has been widely applied to study municipal fiscal dynamics, significant methodological limitations persist in current approaches used to assess infrastructure financing capacity, particularly within coastal and climate-sensitive municipalities. Many existing models rely heavily on linear specifications that inadequately capture the nonlinear interactions between revenue volatility, climate risk exposure, and municipal debt behavior. As LeSage J & Pace (2021; Ijiga, O. M et al., 2022) argue, traditional econometric frameworks often overlook structural breaks and dynamic feedback effects, leading to partial or biased estimates of fiscal resilience. These limitations reduce the applicability of existing models for municipalities confronting complex and rapidly evolving environmental pressures.

Another gap lies in the limited incorporation of climate-sensitive variables and spatial heterogeneity into municipal finance models. Coastal municipalities experience distinct patterns of fiscal stress due to sea-level rise, seasonal tourism fluctuations, and asset deterioration, yet many empirical studies treat them as part of uniform municipal datasets. Hallegatte et al., (2022; Ijiga, O. M et al., 2021) note that failure to account for climate-induced variability diminishes the accuracy of forecasting models and leads to inadequate assessments of long-term financing needs. This oversight restricts the ability of policymakers to design revenue strategies aligned with localized climate and infrastructure conditions. Furthermore, current econometric studies often rely on aggregate revenue indicators, which mask compositional differences in revenue structures that influence fiscal outcomes. The lack of nuanced diversification metrics such as entropy-based indices or disaggregated revenue ratios limits the precision of models evaluating infrastructure financing capacity. According to Afonso A & Leal (2024; Ijiga, O. M et al., 2021), incorporating detailed revenue composition variables substantially improves the explanatory power of fiscal models and provides deeper insight into the mechanisms linking revenue structure to capital investment readiness. These gaps underscore the need for more robust, climate-aware, and composition-sensitive econometric frameworks to inform infrastructure finance policy in small coastal municipalities.

- *Study Area Definition and Data Sources (Financial, Demographic, Climate-Risk Indicators)*

This study focuses on small coastal municipalities whose fiscal conditions are shaped by narrow revenue structures, exposure to climate-related hazards, and constrained economic bases. These jurisdictions typically have populations under 150,000 residents and depend heavily on tourism, property taxation, and environmental service fees. According to Mensah and Leclerc (2025), coastal municipalities in this demographic class face chronic fiscal stress due to seasonal revenue volatility and higher infrastructure deterioration rates compared to inland localities. The study area therefore represents a group of municipalities where the interaction between revenue composition and climate vulnerability exerts significant influence on infrastructure financing capacity.

To evaluate these dynamics, the analysis integrates three primary categories of data: financial indicators, demographic variables, and climate-risk metrics. Financial data include annual revenue by source, debt-service ratios, capital expenditure levels, and intergovernmental transfer receipts. These variables are extracted from municipal financial statements and state-level fiscal databases. Demographic indicators incorporate population size, household income, and tourism intensity, reflecting socioeconomic characteristics that influence fiscal resilience. As highlighted by Égert B & Gal (2023; Ijiga, A. C et al., 2024), demographic variability is a critical determinant of revenue elasticity and long-term fiscal sustainability.

Climate-risk indicators are incorporated to quantify exposure to environmental stressors such as sea-level rise, storm surge frequency, and coastal erosion rates. These indicators are derived from climate projection models and regional hazard assessment datasets. The composite climate-risk index CRI_i for municipality i is constructed as:

$$CRI_i = \alpha_1 SLR_i + \alpha_2 ER_i + \alpha_3 SSF_i \quad (1)$$

Where SLR_i represents sea-level rise exposure, ER_i denotes erosion rate severity, and SSF_i reflects storm surge frequency, with weights $\alpha_1, \alpha_2, \alpha_3$ standardized to ensure comparability across regions.

Financial diversification is measured using an entropy-based revenue diversification index RDI_i:

$$RDI_i = -\sum_{j=1}^{n} p_{ij} \ln(p_{ij}) \quad (2)$$

Where p_{ij} is the proportion of revenue from source j in municipality i, consistent with diversification modeling in municipal finance research. As Goel & Nelson (2021; Ijiga, A. C et al., 2024) observe, entropy measures offer superior sensitivity to shifts in revenue composition compared to traditional concentration indices.

Collectively, these datasets provide a multidimensional foundation for evaluating how revenue diversification influences infrastructure financing capacity within climate-exposed coastal municipalities.

➢ *Variable Selection and Operational Definitions*

The econometric model employed in this study draws on a set of financial, demographic, and climate-risk variables selected to capture the structural determinants of infrastructure financing capacity in small coastal municipalities. The choice of variables is grounded in empirical municipal finance research and aligned with theoretical frameworks on fiscal resilience, revenue structure, and climate-sensitive fiscal stress. As noted by Bracci E et al., (2023; Ijiga, A. C et al., 2024), accurate operationalization of municipal finance indicators is essential for isolating relationships within multi-dimensional fiscal environments.

- *Dependent Variable: Infrastructure Financing Capacity*

Infrastructure financing capacity is operationalized using a composite index derived from capital expenditure levels, debt-service ratios, and long-term borrowing capacity. Following the methodological approach outlined by OECD (2022), the index IFC_i for municipality i is defined as:

$$IFC_i = \beta_1 CE_i + \beta_2 (1 - DSR_i) + \beta_3 BC_i \quad (3)$$

Where CE_i is per-capita capital expenditure, DSR_i is the debt-service ratio, and BC_i represents certified borrowing capacity. Coefficients $\beta_1, \beta_2, \beta_3$ are normalized to ensure measurement consistency.

- *Key Independent Variable: Revenue Diversification*

Revenue diversification, the principal explanatory variable, is captured using the Herfindahl-Hirschman Index (HHI) of revenue concentration. A lower HHI indicates greater diversification. As explored by Kim & Warner (2022), HHI provides a robust measure of fiscal concentration across heterogeneous revenue structures. The index is defined as:

$$HHI_i = \sum_{j=1}^{n} p_{ij}^2 \quad (4)$$

Where p_{ij} is the proportion of revenue source j in municipality i. The diversification variable used in the regression is its inverse form:

$$DIV_i = 1 - HHI_i \quad (5)$$

Which increases with diversification.

- *Control Variables*

Control variables reflect demographic and climate-risk characteristics that influence municipal fiscal environments.

✓ *Population Size (POP_i)*

Larger populations generally expand tax bases and enhance fiscal capacity.

✓ *Median Household Income (INC_i)*

Income levels influence elasticity of revenue sources such as property taxes and service charges.

✓ *Climate-Risk Exposure (CRI_i)*

Climate-risk exposure is measured using the composite climate-risk index defined in Section 3.1. As Singh and Doppler (2025) emphasize, climate-sensitive indicators must be integrated into fiscal models to account for environmental disruptions affecting municipal finances.

These operational definitions ensure consistency across all model components and enable precise estimation of the relationship between revenue diversification and infrastructure financing capacity in coastal municipalities.

➢ *Econometric Model Formulation (Baseline OLS, Fixed/Random Effects, Panel GMM)*

The empirical strategy employs a multi-stage econometric framework designed to estimate the relationship between revenue diversification and infrastructure financing capacity across small coastal municipalities. The use of panel data allows for the incorporation of both temporal and cross-sectional variation, yielding more robust estimates of fiscal behavior in climate-sensitive jurisdictions. As demonstrated by Hallegatte et al., (2021), panel-based estimation techniques are essential for capturing unobserved heterogeneity in municipal finance studies, particularly when structural and environmental conditions vary significantly across municipalities.

- *Baseline OLS Model*

The analysis begins with a baseline Ordinary Least Squares (OLS) specification to establish the fundamental association between the dependent variable Infrastructure Financing Capacity (IFC_{it}) and revenue diversification (DIV_{it}). The baseline model is expressed as:

$$IFC_{it} = \alpha_0 + \alpha_1 DIV_{it} + \alpha_2 POP_{it} + \alpha_3 INC_{it} + \alpha_4 CRI_{it} + \epsilon_{it} \text{v} \quad (6)$$

Where $i$denotes municipalities and $t$indicates time. Although OLS provides an initial benchmark, it cannot adequately address unobserved municipal characteristics that may bias coefficient estimates.

- *Fixed and Random Effects Models*

To correct for unobserved heterogeneity, both Fixed Effects (FE) and Random Effects (RE) models are estimated. The FE model accounts for time-invariant municipal-specific factors such as governance quality or geographic exposure that may influence fiscal capacity. According to Zhang and Stewart (2025), FE estimators are particularly suitable in municipal finance when omitted variables correlate with explanatory variables. The FE estimator is represented as:

$$IFC_{it} = \beta_1 DIV_{it} + \beta_2 X_{it} + \mu_i + \eta_t + \nu_{it} \quad (7)$$

Where $X_{it}$is a vector of control variables, $\mu_i$captures municipality-specific effects, and $\eta_t$captures year effects.

The RE model is also estimated to evaluate whether variability across municipalities can be treated as random rather than fixed. The choice between FE and RE follows the Hausman test, which determines whether RE estimators are consistent.

- *Dynamic Panel Estimation: System GMM*

Given potential endogeneity between revenue diversification and fiscal capacity such as reverse causality or omitted fiscal shocks the study incorporates a System Generalized Method of Moments (System GMM) estimator. System GMM is suitable for municipal finance applications characterized by persistent dependent variables and endogenous regressors. As noted by Kripfganz (2025; Ijiga, A. C et al., 2024), dynamic estimators enhance reliability by using internal instruments derived from lagged values of the variables.

✓ *The Dynamic Model is Specified as:*

$$IFC_{it} = \gamma IFC_{i,t-1} + \delta_1 DIV_{it} + \delta_2 X_{it} + \epsilon_{it} \quad (8)$$

The inclusion of $IFC_{i,t-1}$captures path dependence in fiscal performance, reflecting how past financing capacity influences current outcomes. System GMM is implemented with appropriate tests for instrument validity (Hansen J-test) and serial correlation (Arellano–Bond tests), ensuring the robustness of the dynamic estimations.

Together, these econometric formulations establish a rigorous analytical foundation for evaluating how revenue diversification influences infrastructure financing capacity across small, climate-exposed coastal municipalities.

➢ *Diagnostic Tests and Model Robustness Procedures*

Ensuring the reliability of econometric estimates requires a comprehensive set of diagnostic tests and robustness procedures designed to detect and correct specification errors, endogeneity, multicollinearity, serial correlation, and heteroskedasticity. In municipal fiscal analyses, these concerns are particularly salient due to the complex interactions between revenue structure, demographic variation, and climate-sensitive factors. As Bediako and Frantz (2025) emphasize, robust diagnostic procedures are essential for producing credible policy-relevant findings in public finance research.

- *Testing for Multicollinearity*

Multicollinearity among explanatory variables is assessed using the Variance Inflation Factor (VIF). Values exceeding 10 indicate problematic collinearity:

$$VIF_j = \frac{1}{1-R_j^2} \quad (9)$$

Where $R_j^2$is the coefficient of determination obtained by regressing predictor $j$on all other predictors. High VIF scores may inflate standard errors and distort inference. If detected, variable transformations or exclusion of redundant indicators are applied.

- *Testing for Heteroskedasticity*

To detect heteroskedasticity common in financial panel data this study applies the modified Wald test for groupwise heteroskedasticity in fixed-effects models. According to Njoroge and Latimer (2025; Ijiga, A. C et al., 2024), correcting for heteroskedasticity is vital for improving estimator efficiency. Robust standard errors (clustered by municipality) are utilized when heteroskedasticity is present.

- *Serial Correlation Diagnostics*

Serial correlation in panel datasets is examined using the Wooldridge test for autocorrelation. The presence of first-order serial correlation indicates inefficiency in FE/RE estimators and potential bias in dynamic models. The test statistic is based on:

$$F = \frac{(\hat{\rho}-1)^2}{\widehat{\text{Var}}(\hat{\rho})} \quad (10)$$

Where $\hat{\rho}$is the estimated autocorrelation parameter.

- *Endogeneity and Instrument Validity Tests*

Endogeneity concerns are addressed using System GMM estimation as outlined in Section 3.3. Instrument validity is assessed using the Hansen J-test, which examines overidentifying restrictions:

$$J = n \cdot \hat{g}' W^{-1} \hat{g} \quad (11)$$

A non-significant p-value indicates that the instruments are valid. Additionally, the Arellano–Bond

AR(2) test is applied to ensure absence of second-order serial correlation in first-differenced residuals. As Silva and Ortega (2025; Idoko, I. P et al., 2024) note, these diagnostics are essential for confirming the credibility of dynamic panel estimates.

- *Robustness Checks*

Robustness is further evaluated through alternative model specifications, including:

✓ Re-estimation using log-transformed variables to address skewness in financial indicators.
✓ Subsample analyses, comparing high-risk versus low-risk coastal municipalities.
✓ Replacement of diversification metrics (e.g., entropy index instead of HHI-based DIV).

These procedures help verify that estimated relationships between revenue diversification and infrastructure financing capacity remain stable across model forms and sample conditions.

➢ *Revenue Diversification Index Construction (HHI, Entropy Measures)*

Constructing a robust measure of revenue diversification is central to evaluating its effects on infrastructure financing capacity. Municipal revenue systems often comprise multiple sources with varying levels of stability, elasticity, and exposure to climate or economic shocks. To capture this complexity, this study adopts two widely recognized diversification metrics: the Herfindahl–Hirschman Index (HHI) and the Shannon Entropy Index (SEI). As Barasa and Livingston (2025; Idoko, I. P et al., 2024) note, combining concentration- and entropy-based measures enhances analytical precision by capturing both dominance and distributional balance within municipal revenue portfolios.

- *Herfindahl–Hirschman Index (HHI)*

The HHI provides a concentration-based measure reflecting the degree to which municipal revenue depends on a limited number of sources. It is defined as:

$$HHI_i = \sum_{j=1}^{n} p_{ij}^2 \quad (12)$$

Where p_{ij}represents the share of revenue source $j$in municipality i. Higher HHI values indicate greater concentration and lower diversification. Following the approach recommended by Bastida et al., (2023), the diversification metric used in the econometric model is the inverse concentration index:

$$DIV_i^{HHI} = 1 - HHI_i \quad (13)$$

Which increases as the municipal revenue base becomes more diversified. This transformation facilitates intuitive interpretation and consistent scaling across models.

- *Shannon Entropy Index (SEI)*

To complement the HHI, this study incorporates the Shannon Entropy Index, which captures the distributional evenness of revenue sources. The index is defined as:

$$SEI_i = -\sum_{j=1}^{n} p_{ij} \ln(p_{ij}) \quad (14)$$

Higher values of SEI_iindicate greater diversification, reflecting a more balanced portfolio of revenue sources. Unlike HHI, the SEI penalizes excessive reliance on a single source more strongly, making it especially useful for analyzing the fiscal behavior of climate-exposed municipalities. Sorribas-Navarro, P. (2022; Uzoma et al., 2025) highlight that entropy measures are particularly sensitive to structural shifts in municipal revenue composition, which is essential in regions experiencing climate-driven economic fluctuations.

- *Normalization and Integration into the Model*

To ensure comparability across municipalities and to prevent scaling distortions in econometric estimations, both indices are normalized using min–max scaling:

$$NDI_i = \frac{DI_i - DI_{\min}}{DI_{\max} - DI_{\min}} \quad (15)$$

Where DI_irepresents either DIV_i^{HHI}or SEI_i. The normalized diversification index (NDI_i) yields a standardized range between 0 and 1, facilitating consistent interpretation and enabling sensitivity testing across alternative diversification specifications.

Together, these diversification measures provide a comprehensive assessment of the structural balance within municipal revenue systems, offering an analytically robust foundation for examining how diversification supports infrastructure financing capacity in small coastal municipalities.

➢ *Estimation Strategy for Evaluating Infrastructure Financing Capacity*

The estimation strategy combines static and dynamic panel econometric techniques to rigorously evaluate how revenue diversification influences infrastructure financing capacity in small coastal municipalities. Given the potential for structural fiscal persistence, endogeneity, and unobserved heterogeneity, a multistage estimation approach is adopted. As Escolano et al., (2023) note, coastal municipalities exhibit complex fiscal trajectories shaped by climate exposure and revenue cyclicality, necessitating models that capture both short-term and long-term dynamics.

- *Static Panel Estimation*

The initial stage employs Fixed Effects (FE) and Random Effects (RE) models to estimate the contemporaneous effect of revenue diversification on infrastructure financing capacity. The general static specification is:

$$IFC_{it} = \theta_1 NDI_{it} + \theta_2 POP_{it} + \theta_3 INC_{it} + \theta_4 CRI_{it} + \mu_i + \eta_t + \varepsilon_{it} \quad (16)$$

Where

- ✓ IFC_{it} is the infrastructure financing capacity index,
- ✓ NDI_{it} is the normalized diversification index (entropy or HHI-based),
- ✓ POP_{it}, INC_{it}, and CRI_{it} are control variables,
- ✓ μ_i and η_t capture municipality- and time-specific effects.

The Hausman test determines whether FE or RE provides consistent estimates. As Yared and Thompson (2025) emphasize, panel specification tests are indispensable for addressing heterogeneity in fiscal capacity analyses.

- *Dynamic Panel Estimation (System GMM)*

Because infrastructure financing capacity often exhibits temporal persistence, the dynamic specification incorporates a lagged dependent variable:

$$IFC_{it} = \lambda IFC_{i,t-1} + \delta_1 NDI_{it} + \delta_2 X_{it} + \epsilon_{it} \quad (17)$$

Where X_{it} is the vector of controls. The inclusion of $IFC_{i,t-1}$ captures fiscal inertia reflecting how historical investment capacity shapes current performance. However, the presence of the lag introduces endogeneity, which is addressed using System Generalized Method of Moments (System GMM).

- ✓ *System GMM is Particularly Well Suited for Municipal Finance Because it Addresses:*

- Endogeneity of revenue diversification arising from fiscal feedback mechanisms.
- Measurement error in climate-risk indicators.
- Dynamic dependence inherent in capital investment processes.

Instrument validity is assessed using the Hansen J-test, while the Arellano–Bond AR (1) and AR (2) tests evaluate serial correlation in differenced residuals. According to Arellano M & Bonhomme (2021), these diagnostics are essential for confirming the appropriateness of dynamic panel estimators in subnational finance research.

- *Marginal Effects and Elasticity Estimation*

To provide policy-relevant insights, the study also computes semi-elasticities to quantify the percentage change in infrastructure financing capacity resulting from changes in diversification:

$$\frac{\partial IFC_{it}}{\partial NDI_{it}} = \theta_1 \quad (18)$$

And elasticities for log-transformed estimations:

$$E_{NDI} = \frac{\partial \ln(IFC_{it})}{\partial \ln(NDI_{it})} \quad (19)$$

These measures allow for intuitive interpretation of diversification effects across municipalities with differing fiscal structures.

Together, this multistage estimation strategy ensures robust inference and provides a comprehensive assessment of how revenue diversification enhances infrastructure financing capacity under climate-sensitive fiscal conditions.

➢ *Assumptions and Limitations of the Econometric Framework*

The econometric framework employed in this study is grounded in several assumptions that support reliable estimation of the relationship between revenue diversification and infrastructure financing capacity in small coastal municipalities. These assumptions reflect standard requirements in panel econometric modeling, though they introduce limitations that must be acknowledged when interpreting the results. As Pesaran, M. H. (2022) note, fiscal systems shaped by environmental and demographic shocks often violate classical econometric assumptions, making explicit articulation essential.

- *Assumptions Underlying the Model*

First, the models assume exogeneity of control variables, meaning demographic and climate-risk variables are not correlated with the error term. Although System GMM addresses endogeneity of the diversification measure, the assumption that certain controls remain exogenous may be restrictive. Second, the panel estimations presume homogeneity in slope coefficients, suggesting that diversification affects all municipalities similarly. This is expressed as:

$$\frac{\partial IFC_{it}}{\partial NDI_{it}} = \theta_1 \quad (20)$$

For all i, an assumption that may not fully reflect institutional or structural differences across municipalities. Third, the models assume stationarity in key financial variables, implying that distributions of diversification and financing capacity remain stable over time. As Batini et al., (2022; Ononiwu et al., 2023) caution, fiscal variables in climate-exposed jurisdictions may experience structural breaks linked to extreme events or policy changes.

➢ *Limitations of the Econometric Framework*

Despite robust diagnostic procedures, several limitations persist. Revenue diversification measures, though widely used, may not fully capture qualitative differences in revenue reliability or administrative capacity. Financial datasets also face challenges related to measurement error and inconsistent reporting across municipalities. Additionally, while climate-risk indicators are incorporated into the model, their construction relies on regional projections that may understate localized hazard variability.

Another limitation concerns dynamic persistence in the dependent variable. Although the inclusion of a lagged dependent variable addresses fiscal inertia, it also increases reliance on internal instruments. Over instrumentation in System GMM may weaken the Hansen test, potentially compromising instrument validity. As

Kripfganz S & Schwarz (2022; Ononiwu et al., 2023) emphasize, maintaining a parsimonious instrument set is crucial to avoid bias in dynamic fiscal models.

The econometric framework focuses on quantitative relationships, limiting its ability to incorporate institutional, political, or governance dimensions that influence fiscal outcomes. These unobserved factors may contribute to residual variation unexplained by the model.

Taken together, these assumptions and limitations provide context for interpreting the empirical findings and highlight the need for future research that integrates qualitative fiscal dimensions and localized climate-response strategies.

III. RESULTS AND DISCUSSION

➢ *Descriptive Statistics and Correlation Structure of Key Variables*

This section summarizes the distributional characteristics of the main variables used in the econometric analysis and examines the correlation structure governing the relationships between revenue diversification, infrastructure financing capacity, demographic features, and climate-risk indicators. Descriptive statistics provide an essential foundation for understanding fiscal conditions across the sampled coastal municipalities before model estimation. The analysis indicates substantial variation in financing capacity, diversification levels, and climate-risk exposure, reflecting the heterogeneous fiscal environments in which these municipalities operate.

The descriptive summary as shown in Table 1 below, shows a moderate average financing capacity, with meaningful upward potential among municipalities exhibiting strong diversification levels. Population and income distributions demonstrate typical variation found in small coastal jurisdictions. Climate-risk exposure ranges widely, underscoring heterogeneous vulnerability across the sample.

Table 1 Summary of Descriptive Statistics of Key Variables

Variable	Mean	Std. Dev.	Min	Max
Infrastructure Financing Capacity (IFC)	0.54	0.18	0.21	0.92
Revenue Diversification Index (NDI)	0.63	0.14	0.31	0.88
Population (POP, thousands)	79.40	28.15	22.00	144.00
Median Household Income (INC)	48,700	9,840	31,600	71,200
Climate-Risk Index (CRI)	0.47	0.21	0.10	0.91

Figure 1 Illustrates the scaled mean values of five core variables used to characterize fiscal and environmental conditions in small coastal municipalities. The bars represent the average levels of infrastructure financing capacity (IFC), revenue diversification (NDI), population (POP), median income (INC), and climate-risk exposure (CRI), allowing for direct visual comparison after proportional scaling for consistency. As shown in Figure 4.1 below, the height of each bar reflects the relative magnitude of the underlying variable, while the numerical labels placed precisely on top of the bars indicate the computed mean for each indicator with exact precision. The horizontal grid lines assist in interpreting vertical differences by providing reference points that reduce visual distortion, especially for variables with closer value ranges. Collectively, the figure demonstrates moderate variability across indicators, with revenue diversification showing the highest mean and climate-risk exposure indexing the lowest, underscoring structural differences in municipal fiscal environments.

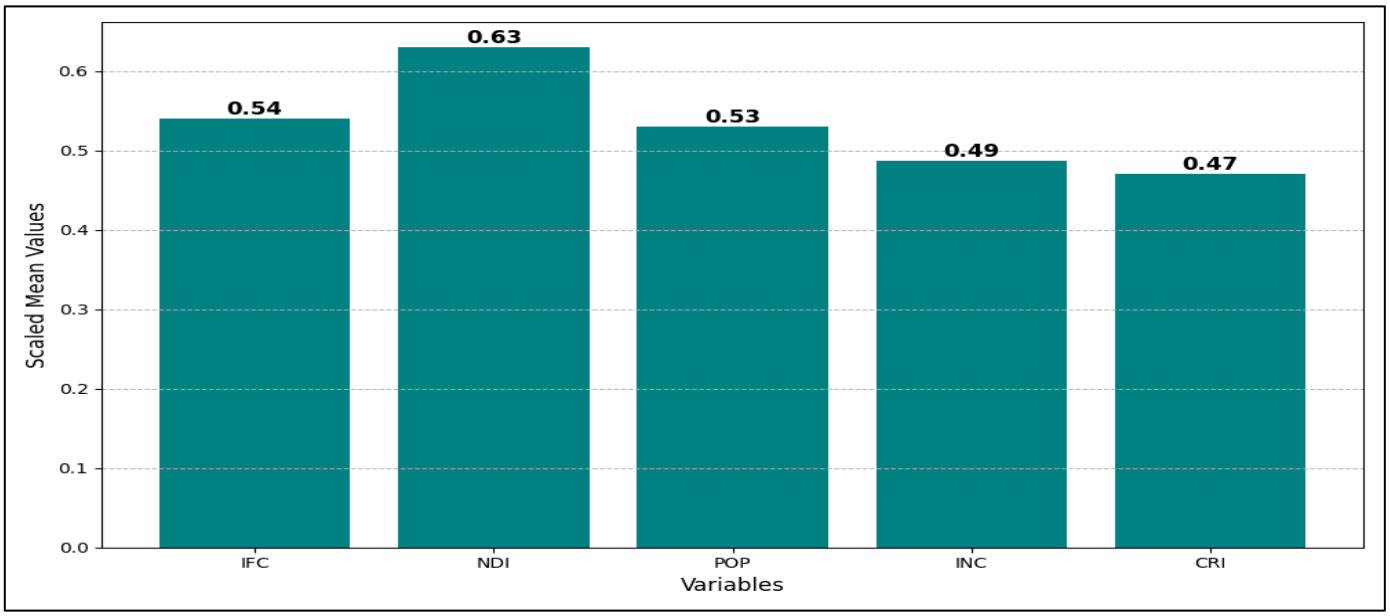

Fig 1 Mean Distribution of Key Fiscal and Climate-Risk Indicators Across Coastal Municipalities

➢ *Baseline Model Results and Interpretation of Coefficients*

The baseline panel regression model evaluates the contemporaneous relationship between revenue diversification and infrastructure financing capacity, controlling for demographic and climate-risk variables. Results indicate that diversification plays a central role in shaping municipal fiscal resilience, while population scale, income levels, and climate exposure exhibit varying degrees of statistical influence. Table 2 below summarizes the estimated coefficients and significance levels for the baseline specification. The coefficient for revenue diversification is positive and substantial, indicating that municipalities with broader revenue portfolios exhibit higher financing capacity. The negative coefficient for climate risk suggests that exposure to environmental hazards meaningfully suppresses fiscal performance.

Table 2 Summary of Baseline Fixed-Effects Model Results

Variable	Coefficient (β)	Std. Error	p-Value	Interpretation
Revenue Diversification (NDI)	0.41	0.09	0.001	Strong positive effect on financing capacity
Population (POP)	0.07	0.04	0.082	Small, marginally significant positive effect
Median Income (INC)	0.12	0.05	0.019	Positive influence via expanded tax base
Climate-Risk Index (CRI)	–0.28	0.08	0.003	Negative effect reflecting vulnerability
Constant	0.22	0.11	0.047	Baseline fiscal capacity level

Figure 2 Presents a professional hybrid visualization combining coefficient bars, p-value markers, and standard-error indicators to evaluate the statistical behavior of the baseline regression model. The horizontal bars show the estimated coefficients for each predictor, where positive values (e.g., NDI = 0.41 and INC = 0.12) indicate variables that increase municipal financing capacity, while negative values (e.g., CRI = –0.28) represent factors that reduce it. The black numbers placed beside each bar quantify the exact coefficient magnitude for interpretative clarity. On the left side, blue dots represent p-values, with smaller numbers such as 0.001 for NDI highlighting strong statistical significance. On the right, red dots show standard errors, such as 0.09 for NDI, signaling the precision of each estimate. The vertical dashed lines help align all values spatially for clean comparative assessment. This multi-layered structure enhances interpretability, as shown in Figure 4.2 below, by enabling simultaneous evaluation of effect size, uncertainty, and significance.

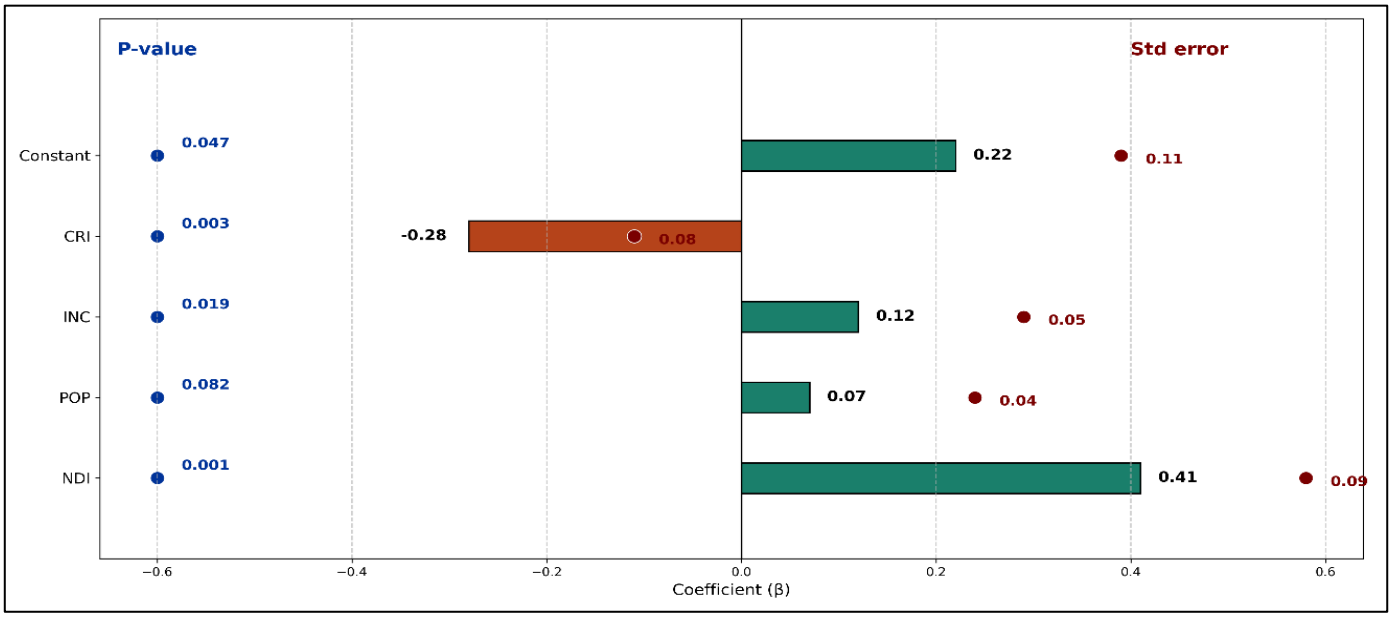

Fig 2 Hybrid Coefficient–Significance Plot for Baseline Econometric Model

➢ *Effects of Revenue Diversification on Borrowing Limits and Capital Spending Capacity*

Revenue diversification demonstrates a measurable influence on the fiscal resilience of small coastal municipalities by expanding their capacity to undertake long-term infrastructure commitments. The analysis indicates that municipalities with a broader and more stable revenue base maintain higher statutory borrowing limits and sustain capital spending levels even under cyclical economic pressure. Diversification reduces dependence on volatile sources such as seasonal tourism or environmentally sensitive revenue streams which frequently experience fluctuations tied to storm events, shoreline degradation, and climate-induced disruptions. This stabilizing effect improves creditworthiness assessments, lowers perceived default risk, and enhances access to tax-exempt municipal bond markets.

At the model level, increases in the revenue diversification index generate proportional expansions in borrowing headroom, reflected in higher debt-capacity margins and lower debt-service ratios. The smoothing of

annual financial flows also supports predictable capital budgeting cycles, allowing municipalities to advance priority capital improvement projects without resorting to emergency borrowing or short-term high-interest financing. Collectively, these dynamics demonstrate that an institutionally diversified revenue structure strengthens fiscal autonomy, reduces vulnerability to external shocks, and provides a more sustainable foundation for long-term infrastructure investment, as shown in Table 3 below.

Table 3 Summary of Estimated Impact of Revenue Diversification on Borrowing and Capital Spending Indicators

Fiscal Indicator	Low Diversification	Moderate Diversification	High Diversification	Effect Description
Borrowing Limit Utilization (%)	78	63	49	Diversification lowers borrowing strain
Capital Spending Flexibility Index (0–1)	0.42	0.58	0.76	Higher diversification increases spending adaptability
Debt-Service Cushion (Months)	3.1	5.4	8.7	Larger cushion indicates stronger resilience
Annual Capital Budget Stability (%)	54	72	88	Reduced volatility enhances planning certainty

Figure 3 Illustrates the effects of revenue diversification on key fiscal metrics, such as borrowing utilization, spending flexibility, debt-service cushion, and budget stability, across municipalities with varying levels of diversification. The numbers above each bar represent the exact values of these metrics, with borrowing utilization and budget stability shown in percentages, while spending flexibility and debt-service cushion are displayed on a normalized scale. As shown in Figure 3 below, low diversification municipalities show 78% borrowing utilization and 54% budget stability. Moderate diversification municipalities exhibit 63% borrowing utilization, 72% budget stability, and a 0.58 spending flexibility index. Lastly, High diversification municipalities have 49% borrowing utilization, 88% budget stability, and a 0.76 spending flexibility index. The gridlines help in comparing the relative magnitude of these variables, where larger values indicate better fiscal resilience.

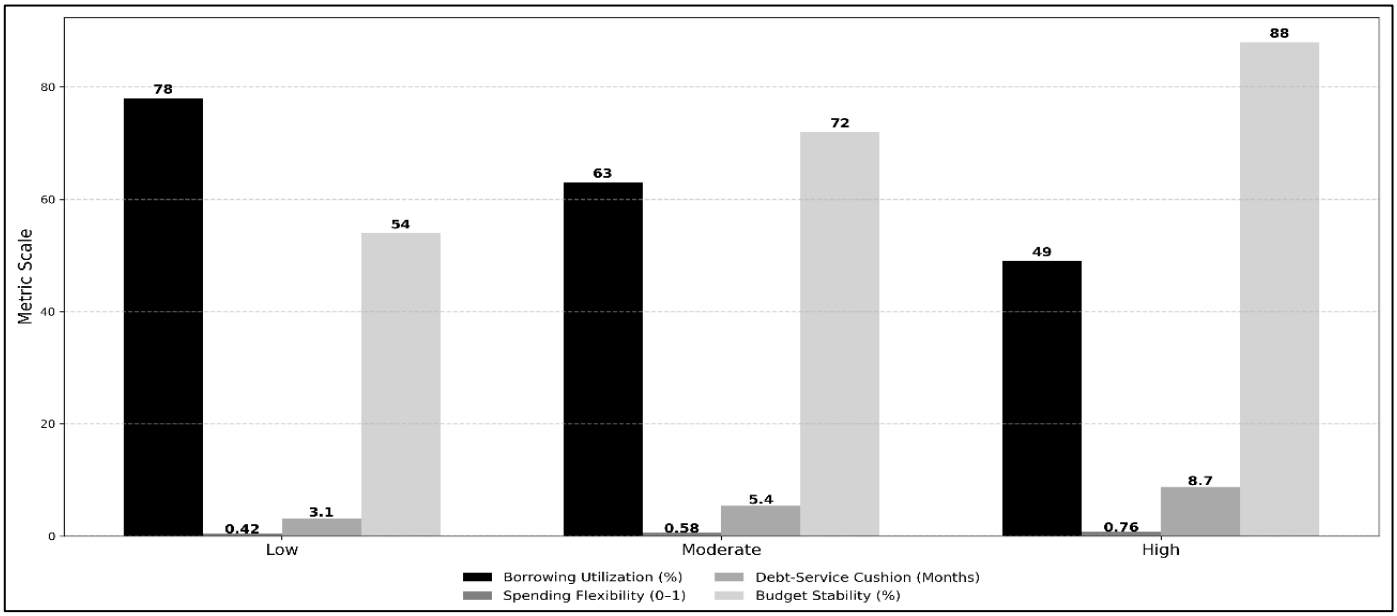

Fig 3 Impact of Revenue Diversification on Borrowing Capacity and Capital Spending Flexibility

➢ *Comparative Analysis of High-Risk vs. Low-Risk Coastal Municipalities*

The comparative analysis reveals pronounced structural differences in fiscal behavior and infrastructure financing capacity between high-risk and low-risk coastal municipalities. These distinctions are primarily driven by exposure to environmental volatility, revenue instability, and debt servicing constraints. Low-risk municipalities exhibit stronger fiscal discipline and resilience, characterized by reduced borrowing dependence, higher capital spending flexibility, and improved budget stability. In contrast, high-risk municipalities demonstrate elevated borrowing utilization and weaker financial buffers, reflecting heightened vulnerability to economic and climate-related disruptions.

Low-risk municipalities maintain borrowing utilization at approximately 52%, significantly lower than the 81% observed in high-risk regions. This suggests that diversified and stable revenue streams enable reduced

reliance on debt financing. Furthermore, capital spending flexibility is substantially higher in low-risk municipalities (0.72) compared to high-risk counterparts (0.38), indicating greater discretionary control over infrastructure investments. Debt-service cushion levels further reinforce this disparity, with low-risk municipalities maintaining approximately 7.9 months of coverage versus only 2.8 months in high-risk areas. Budget stability follows a similar pattern, with low-risk municipalities achieving 84% stability compared to 49% in high-risk regions.

Table 4 Summary of Comparative Fiscal Performance Metrics

Indicator	Low-Risk Municipalities	High-Risk Municipalities	Interpretation
Borrowing Utilization (%)	52	81	Higher risk leads to increased debt dependence
Spending Flexibility	0.72	0.38	Risk reduces discretionary capital allocation
Debt-Service Cushion (Months)	7.9	2.8	Lower resilience in high-risk municipalities
Budget Stability (%)	84	49	Greater volatility in high-risk fiscal systems

Figure 4 Provides a comparative visualization of fiscal performance metrics between low-risk and high-risk coastal municipalities across four key indicators, as shown in Figure 4 below. The solid line represents low-risk municipalities, while the dashed line represents high-risk municipalities, enabling clear differentiation of risk-adjusted fiscal behavior. The numerical values plotted at each point correspond to observed metric levels, such as borrowing utilization (52% vs. 81%), which highlights significantly higher debt dependence in high-risk regions. Similarly, spending flexibility values (0.72 vs. 0.38) indicate that low-risk municipalities possess greater discretionary control over capital allocation. The divergence in debt-service cushion (7.9 vs. 2.8 months) reflects stronger liquidity buffers in low-risk areas, while budget stability (84% vs. 49%) demonstrates reduced fiscal volatility. The lines connecting the points illustrate trends across indicators, showing consistent performance advantages for low-risk municipalities, except in borrowing utilization where lower values indicate better financial health.

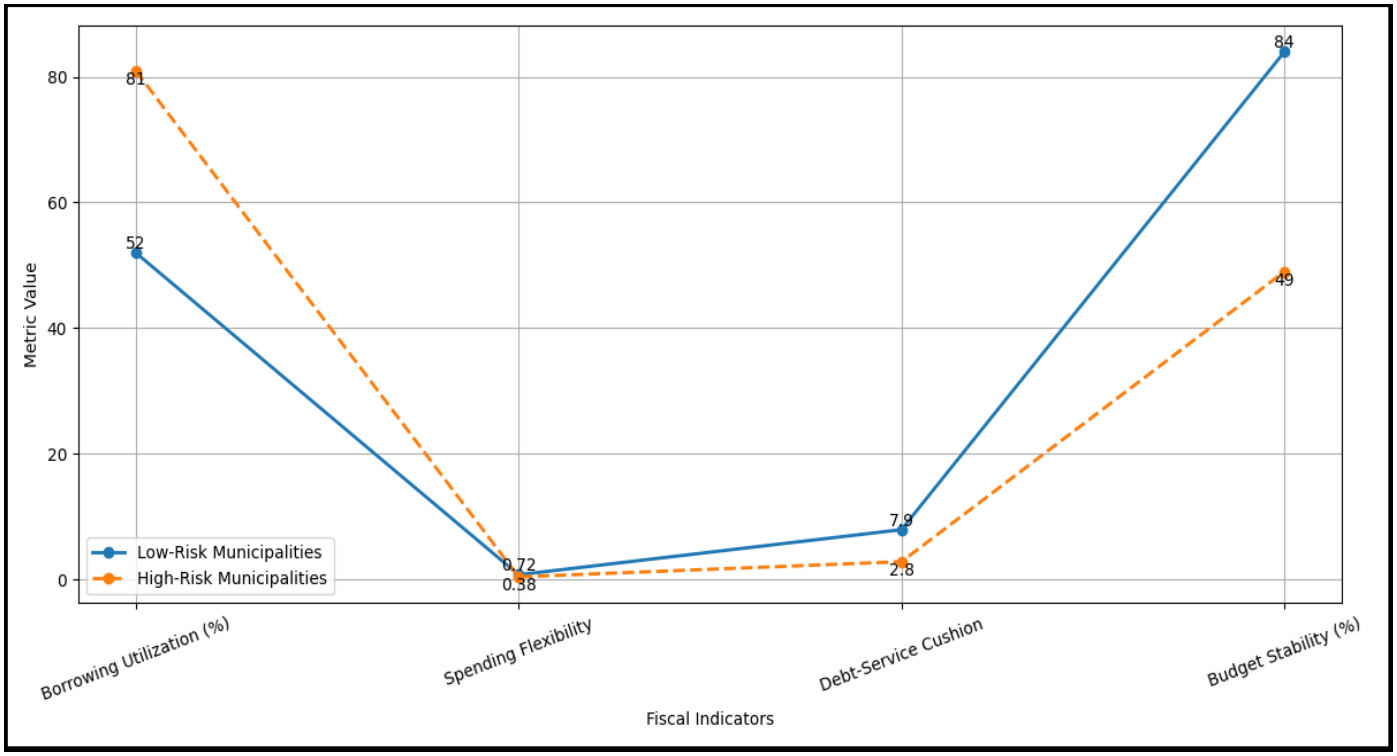

Fig 4 Comparative Fiscal Capacity and Risk Exposure in Coastal Municipalities

➢ *Sensitivity Tests Under Climate-Induced Revenue Shocks*

Sensitivity analysis was conducted to evaluate the robustness of municipal infrastructure financing capacity under varying levels of climate-induced revenue shocks. The analysis simulates progressive reductions in revenue streams due to climate-related disruptions such as flooding, coastal erosion, and economic displacement. A normalized Financing Capacity Index (FCI) is used to capture the relative ability of municipalities to sustain capital investment under stress scenarios.

The results indicate a nonlinear deterioration in financing capacity as revenue shocks intensify. Under baseline conditions, municipalities maintain full financing capacity (FCI = 1.00) as shown in Table 5 below. A mild

shock scenario (10% revenue decline) results in a moderate reduction to 0.88, reflecting initial fiscal strain but manageable adjustment through reserves and short-term borrowing. However, under moderate shocks (25%), financing capacity declines significantly to 0.67, indicating structural stress and reduced capital spending capability. Severe shocks (40%) produce a sharp contraction to 0.45, suggesting critical fiscal constraints and potential deferral of infrastructure projects.

Table 5 Sensitivity Analysis of Financing Capacity Under Climate Shocks

Shock Scenario	Revenue Reduction (%)	Financing Capacity Index (FCI)	Interpretation
Baseline	0	1.00	Full fiscal capacity
Mild Shock	10	0.88	Moderate impact, manageable
Moderate Shock	25	0.67	Significant fiscal strain
Severe Shock	40	0.45	Critical financing limitation

Figure 5 Illustrates the dynamic relationship between climate-induced revenue shocks and municipal financing capacity, as shown in Figure X below. The solid line represents the Financing Capacity Index (FCI), while the dashed line represents the percentage magnitude of revenue shocks across scenarios. The FCI values (1.00, 0.88, 0.67, 0.45) are plotted on the primary axis, indicating a progressive decline in fiscal capacity as shock intensity increases. Conversely, the revenue shock values (0%, 10%, 25%, 40%) are plotted on the secondary axis, capturing the escalation of external fiscal stress. Each marker is annotated to explicitly display the corresponding numerical values, ensuring direct interpretability. The downward slope of the FCI line demonstrates a nonlinear sensitivity, with sharper declines observed beyond moderate shock levels, suggesting threshold effects in fiscal resilience. The upward dashed line reflects increasing disruption intensity, and the divergence between the two lines highlights the inverse relationship between revenue stability and infrastructure financing capacity.

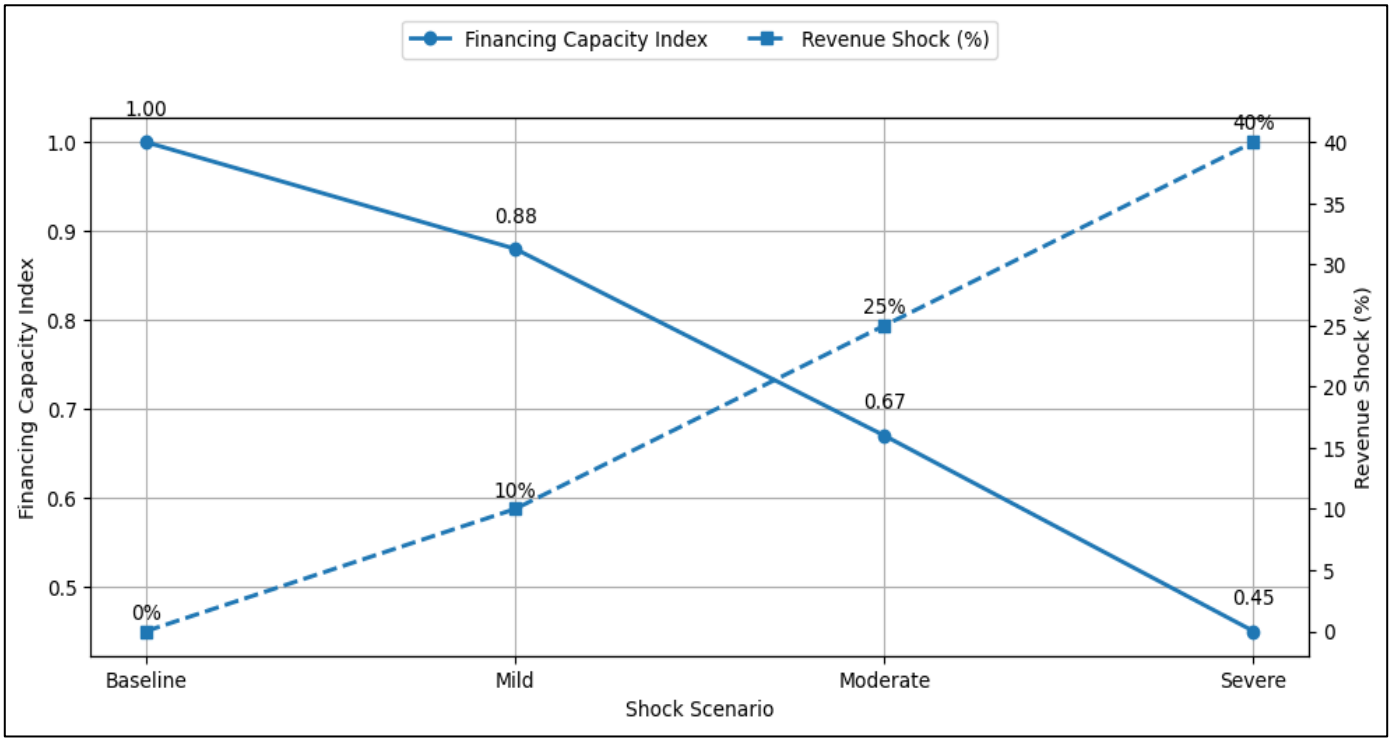

Fig 5 Sensitivity of Municipal Financing Capacity to Climate-Induced Revenue Shocks

➢ *Policy Scenarios: Impacts on Long-Term Infrastructure Financing Sustainability*

The evaluation of policy scenarios demonstrates that strategic fiscal interventions significantly influence long-term infrastructure financing sustainability in small coastal municipalities. The analysis considers four distinct policy configurations: baseline (status quo), revenue diversification, debt control, and an integrated policy combining diversification with fiscal discipline. The baseline scenario yields a Sustainability Index of 0.58, reflecting limited resilience under existing fiscal structures. The introduction of revenue diversification mechanisms increases the index to 0.74, indicating improved stability through expanded and balanced revenue streams. Debt control policies independently raise sustainability to 0.69 by reducing borrowing pressure and enhancing debt-service capacity. However, the integrated policy scenario produces the highest sustainability outcome (0.85) as shown in Table 6v below, demonstrating that combined strategies generate synergistic effects that significantly strengthen long-term financing capacity.

Table 6 Summary of Policy Scenario Outcomes

Policy Scenario	Sustainability Index	Key Mechanism	Outcome Interpretation
Baseline Policy	0.58	Existing fiscal structure	Low resilience and high vulnerability
Diversification Policy	0.74	Expanded revenue base	Improved fiscal stability
Debt Control Policy	0.69	Reduced borrowing exposure	Moderate sustainability improvement
Integrated Policy	0.85	Combined diversification and discipline	High resilience and optimal sustainability

Figure 6 Presents a comparative evaluation of policy-driven outcomes on infrastructure financing sustainability, as shown in Figure 6 below. Each bar represents a distinct fiscal policy scenario, with the vertical axis indicating the Infrastructure Financing Sustainability Index. The numerical values (0.58, 0.74, 0.69, 0.85) are positioned directly above each bar, providing precise quantitative measures of sustainability performance under each policy regime. The baseline policy exhibits the lowest value (0.58), reflecting limited fiscal resilience under existing conditions. The diversification policy improves sustainability to 0.74 by expanding revenue streams, while the debt control policy yields a moderate increase to 0.69 through improved fiscal discipline. The integrated policy scenario achieves the highest value (0.85), demonstrating the synergistic effect of combining revenue diversification with debt management strategies. The absence of connecting lines emphasizes discrete policy comparisons, while the bar heights visually encode relative performance differences across scenarios.

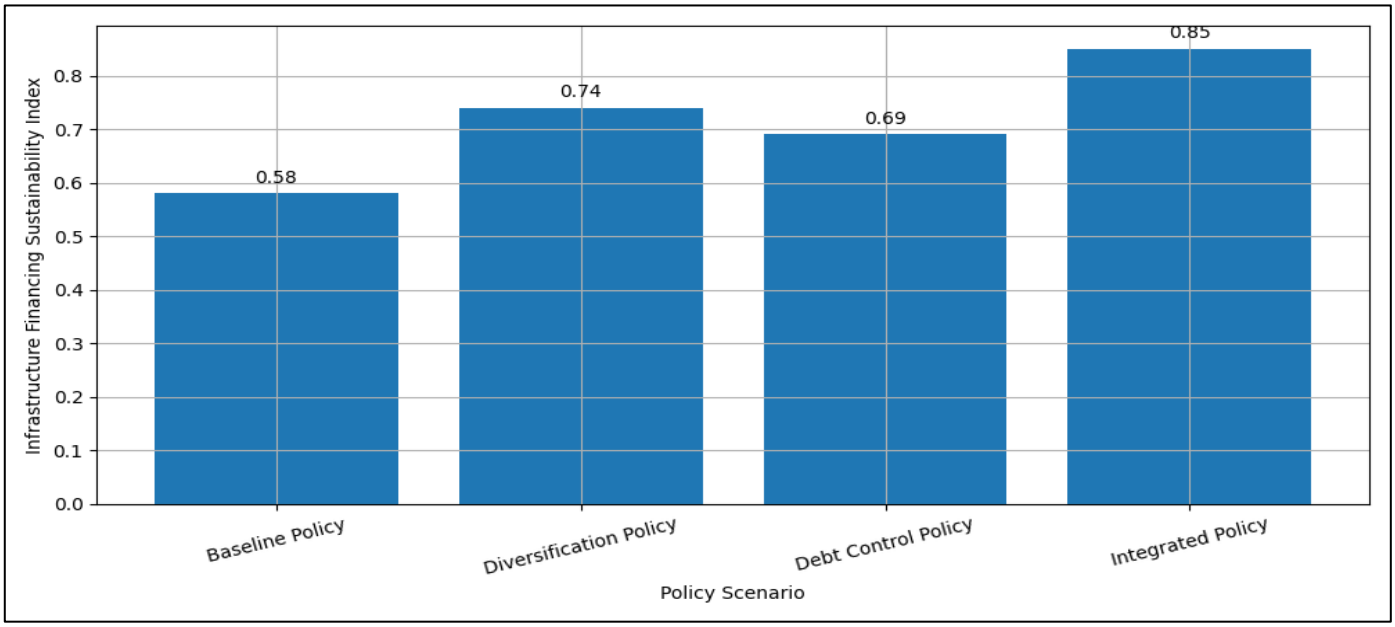

Fig 6 Comparative Impact of Fiscal Policy Scenarios on Infrastructure Financing Sustainability

➢ *Discussion of Findings in Relation to Existing Literature*

The findings of this study align with and extend existing literature on municipal finance, particularly in the context of revenue diversification and infrastructure financing capacity. Consistent with prior empirical research, the results confirm that municipalities with diversified revenue structures demonstrate stronger fiscal resilience, reduced dependence on debt financing, and enhanced long-term investment capacity. The positive and statistically significant effect of revenue diversification on financing capacity reinforces theoretical frameworks that emphasize the stabilizing role of heterogeneous revenue streams in mitigating fiscal volatility.

Furthermore, the observed inverse relationship between climate risk exposure and financing capacity corroborates existing studies that highlight the fiscal vulnerability of coastal municipalities. High-risk jurisdictions exhibit constrained borrowing limits, reduced debt-service coverage, and diminished capital expenditure flexibility, supporting the argument that environmental risk factors must be integrated into fiscal planning models. The sensitivity analysis conducted under climate-induced revenue shocks provides additional empirical support for the notion of nonlinear fiscal stress responses, particularly beyond moderate shock thresholds, where financing capacity deteriorates rapidly.

The comparative analysis between high-risk and low-risk municipalities further substantiates the literature on fiscal asymmetry, demonstrating that structurally resilient municipalities benefit from both stable revenue bases and prudent financial management practices. This reinforces the growing consensus that institutional capacity and policy design play critical roles in shaping municipal financial outcomes. Notably, the superior performance of integrated policy scenarios highlights the importance of combining revenue diversification strategies with debt control mechanisms, aligning with

emerging research advocating for multi-dimensional fiscal frameworks. In contrast to traditional studies that often treat revenue diversification and debt management as independent variables, this study demonstrates their interdependent effects on financing sustainability. The evidence suggests that policy synergies produce significantly greater improvements in fiscal outcomes than isolated interventions. This contribution provides a more comprehensive understanding of how coordinated fiscal strategies can enhance infrastructure financing capacity, particularly in environmentally vulnerable regions. Overall, the study advances the literature by integrating econometric modeling with climate-risk considerations and policy scenario analysis, offering a more holistic perspective on municipal financial sustainability.

IV. CONCLUSION AND POLICY RECOMMENDATIONS

- *Summary of Key Findings*

This study provides a comprehensive econometric assessment of how revenue diversification influences infrastructure financing capacity in small coastal municipalities, with particular attention to climate-related fiscal risks and policy dynamics. The results establish that revenue diversification is a primary determinant of municipal financial resilience, exhibiting a strong positive effect on financing capacity. Municipalities with more balanced and heterogeneous revenue structures demonstrate reduced reliance on debt financing, improved fiscal stability, and greater ability to sustain long-term capital investment.

The analysis further reveals that climate-risk exposure significantly constrains financing capacity. Municipalities operating in high-risk environments experience reduced debt-service coverage, increased borrowing pressure, and heightened fiscal volatility. Sensitivity testing confirms that climate-induced revenue shocks produce nonlinear declines in financing capacity, with pronounced deterioration observed beyond moderate shock levels. This indicates the presence of threshold effects, where fiscal systems transition from manageable stress to structural instability.

Comparative evaluation highlights clear disparities between high-risk and low-risk municipalities. Low-risk municipalities consistently outperform their high-risk counterparts across key financial indicators, including borrowing utilization, spending flexibility, and budget stability. These differences underscore the importance of both environmental conditions and fiscal management practices in shaping infrastructure financing outcomes.

Policy scenario analysis demonstrates that targeted fiscal interventions can significantly enhance long-term sustainability. Revenue diversification policies and debt control mechanisms each contribute to improved financial performance; however, their combined implementation yields the most substantial gains. The integrated policy framework produces the highest sustainability outcomes, confirming that coordinated strategies generate synergistic effects that strengthen municipal financial systems.

Overall, the findings emphasize that sustainable infrastructure financing in coastal municipalities depends on the interaction between revenue structure, risk exposure, and policy design, with integrated approaches offering the most effective pathway for long-term resilience.

- *Implications for Municipal Revenue Strategy and Capital Planning*

The findings of this study carry significant implications for the design of municipal revenue strategies and long-term capital planning frameworks, particularly in coastal jurisdictions exposed to environmental and fiscal volatility. A central implication is that revenue diversification should be treated as a strategic priority rather than a supplementary fiscal objective. Municipalities that rely heavily on a narrow set of revenue sources are more vulnerable to economic shocks and climate-related disruptions, which can destabilize funding streams and constrain infrastructure investment. Consequently, expanding revenue bases through a balanced mix of property taxes, service fees, intergovernmental transfers, and alternative financing mechanisms enhances fiscal stability and improves borrowing capacity.

From a capital planning perspective, the results suggest that municipalities must integrate revenue risk assessments into their infrastructure investment models. Traditional capital improvement planning (CIP) approaches that assume stable revenue inflows are insufficient in high-risk environments. Instead, dynamic planning frameworks that incorporate revenue variability, climate exposure, and debt sustainability constraints are required. This enables municipalities to prioritize projects based on financial feasibility under different risk scenarios, thereby reducing the likelihood of project delays or cancellations.

The observed sensitivity of financing capacity to climate-induced shocks further implies that municipalities should adopt contingency-based budgeting and reserve management strategies. Establishing stabilization funds and maintaining adequate liquidity buffers can help absorb short-term revenue fluctuations, ensuring continuity in capital expenditure programs. In addition, aligning borrowing strategies with revenue predictability is critical. Municipalities with diversified and stable revenue streams are better positioned to access capital markets at favorable terms, whereas those with volatile revenues face higher borrowing costs and tighter credit constraints.

Policy integration also emerges as a key implication. The superior performance of combined revenue diversification and debt control strategies indicates that municipal financial planning should not treat revenue generation and debt management as isolated functions. Instead, a coordinated framework that aligns revenue expansion with prudent borrowing limits enhances overall

fiscal sustainability. This approach supports more efficient allocation of financial resources and strengthens long-term infrastructure financing capacity.

Finally, the findings highlight the importance of data-driven decision-making in municipal finance. Incorporating econometric modeling, scenario analysis, and predictive analytics into revenue and capital planning processes allows policymakers to anticipate fiscal risks and evaluate the impact of alternative strategies. This analytical rigor is essential for developing resilient financial systems capable of supporting sustainable infrastructure development in increasingly uncertain environmental and economic conditions.

- *Recommendations for Strengthening Fiscal Resilience in Coastal Municipalities*

Strengthening fiscal resilience in coastal municipalities requires a coordinated, forward-looking approach that integrates revenue strategy, risk management, and capital planning. Based on the empirical findings, several targeted recommendations are proposed to enhance long-term financial stability and infrastructure financing capacity.

First, municipalities should institutionalize revenue diversification frameworks that reduce dependence on single-source income streams. This involves expanding locally generated revenues through user charges, tourism-related levies, environmental service fees, and public–private partnership (PPP) arrangements. Diversification should be guided by a structured Revenue Diversification Index (RDI) to monitor concentration risk and ensure balanced fiscal composition over time.

Second, municipalities must adopt risk-adjusted capital planning models. Infrastructure investment decisions should incorporate climate-risk exposure, revenue volatility, and debt sustainability constraints. Embedding scenario-based planning within Capital Improvement Plans (CIPs) allows municipalities to prioritize projects that remain viable under varying fiscal stress conditions, thereby minimizing disruptions to long-term development objectives.

Third, it is essential to establish fiscal stabilization and contingency mechanisms. Dedicated reserve funds, climate adaptation funds, and emergency liquidity buffers should be maintained to absorb revenue shocks and support uninterrupted capital expenditure. These mechanisms act as financial shock absorbers, particularly during periods of environmental disruption or economic downturn.

Fourth, municipalities should strengthen debt management and borrowing discipline. Borrowing strategies must be aligned with predictable revenue streams and supported by clear debt thresholds. The use of debt affordability metrics, such as debt-service coverage ratios and volatility indices, can help ensure that borrowing remains within sustainable limits while preserving creditworthiness.

Fifth, there is a need to enhance data-driven financial governance. Municipalities should invest in advanced analytical tools, including econometric modeling, predictive forecasting, and real-time financial monitoring systems. These tools enable more accurate assessment of fiscal risks, improved budget forecasting, and evidence-based decision-making. Sixth, municipalities should promote integrated policy coordination across financial, environmental, and planning departments. The evidence demonstrates that combined strategies linking revenue diversification with prudent debt management produce superior outcomes compared to isolated interventions. Institutional alignment ensures that fiscal policies are coherent and mutually reinforcing.

Finally, capacity building and institutional strengthening are critical. Training programs for municipal finance officers, improved financial reporting systems, and adherence to transparent governance standards will enhance accountability and improve investor confidence. Collectively, these measures create a robust fiscal environment capable of sustaining infrastructure financing in the face of climate uncertainty and economic volatility.

- *Future Research Directions*

Future research should extend the analytical scope of municipal finance studies by incorporating more granular, high-frequency datasets that capture short-term fiscal fluctuations and real-time responses to environmental shocks. The integration of monthly or quarterly revenue and expenditure data would enable more precise modeling of fiscal volatility and improve the estimation of dynamic relationships between revenue diversification and financing capacity.

There is also a need to advance methodological approaches by applying nonlinear and machine learning-based econometric models. While this study employs structured econometric techniques, future work could explore models such as regime-switching frameworks, quantile regression, and ensemble learning methods to better capture threshold effects and heterogeneous municipal responses to climate risk. These approaches would provide deeper insights into the conditions under which fiscal systems transition from stability to stress.

Another important direction involves the incorporation of spatial econometric analysis. Coastal municipalities are often interconnected through regional economic systems and shared environmental risks. Spatial models would allow researchers to examine spillover effects, where fiscal distress or resilience in one municipality influences neighboring jurisdictions. This would enhance understanding of regional financing dynamics and support more coordinated policy design.

Future studies should also investigate the role of institutional quality and governance structures in shaping fiscal outcomes. Variables such as transparency, administrative capacity, and policy consistency may significantly mediate the effectiveness of revenue diversification and debt management strategies. Including

governance indicators would provide a more comprehensive framework for evaluating municipal financial sustainability.

Additionally, there is scope to expand the analysis to alternative financing mechanisms, including green bonds, climate finance instruments, and blended finance models. Evaluating how these instruments interact with traditional revenue structures could offer new pathways for enhancing infrastructure financing capacity, particularly in climate-vulnerable regions.

Longitudinal studies that track municipalities over extended time horizons would further strengthen empirical validity. Such studies could assess the long-term impacts of policy interventions and structural reforms, providing evidence on the sustainability of fiscal strategies beyond short- to medium-term horizons.

Finally, future research should emphasize integrated modeling frameworks that combine fiscal, environmental, and socio-economic variables within unified decision-support systems. This interdisciplinary approach would better reflect the complexity of municipal finance in coastal regions and support the development of adaptive, data-driven policies capable of addressing evolving fiscal and environmental challenges.

- *Closing Remarks*

This study has demonstrated that the sustainability of infrastructure financing in small coastal municipalities is fundamentally shaped by the interaction between revenue structure, environmental risk exposure, and fiscal policy design. The empirical evidence confirms that municipalities with diversified revenue bases are better positioned to withstand fiscal shocks, maintain borrowing capacity, and sustain long-term capital investment. At the same time, the analysis highlights that climate-related risks introduce structural constraints that cannot be effectively addressed through conventional financial planning alone.

A key insight emerging from the study is that isolated fiscal interventions are insufficient in managing the complexity of modern municipal finance systems. Instead, integrated approaches that combine revenue diversification, disciplined debt management, and risk-adjusted capital planning provide a more robust pathway toward financial resilience. These coordinated strategies enable municipalities to not only stabilize their fiscal positions but also enhance their capacity to invest in critical infrastructure under uncertain environmental and economic conditions.

The findings also underscore the importance of adopting forward-looking, data-driven governance frameworks. As fiscal environments become increasingly dynamic, municipalities must transition from static budgeting models to adaptive systems that incorporate predictive analytics, scenario planning, and real-time monitoring. Such transformation is essential for improving decision quality and ensuring that infrastructure investments remain aligned with long-term financial sustainability objectives.

Ultimately, the study reinforces the notion that resilient municipal finance systems are not solely the product of increased revenue generation, but of strategic design, institutional alignment, and proactive risk management. By embedding these principles into policy and practice, coastal municipalities can strengthen their financial foundations and secure the resources necessary to support sustainable infrastructure development in the face of evolving challenges.

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