

Institutional and financial determinants of sustainable real estate development: Evidence from Vietnam



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ARTICLE INFO

Article history:

Received 24 April 2026

Received in revised form

11 July 2026

Accepted 24 August 2026

Keywords:

Sustainable development

Real estate dynamics

Institutional quality

Composite index

Green buildings

ABSTRACT

Sustainable real estate development is a cornerstone of green growth strategies in emerging economies. However, empirical evidence on the relationship between market dynamics and sustainability outcomes remains fragmented. This study examines Vietnam over the period 2010–2024 by developing a transparent composite Sustainable Development Index (SDI) that integrates economic, social, and environmental dimensions. To ensure econometric validity and reduce mechanical endogeneity, the SDI is constructed independently of the explanatory variables. Using an Ordinary Least Squares (OLS) framework with Newey–West standard errors to account for small-sample properties, the study examines the effects of real estate market value (REVAL), housing quality (HOUS), green building adoption (GREN), and institutional quality (INST). The findings indicate that market expansion, housing improvements, and environmental innovations contribute positively to sustainability, whereas institutional quality has a significant negative contemporaneous association. This unexpected relationship may reflect transitional challenges, as stricter regulations and tighter land governance temporarily slow market activity and increase compliance time. Broader environmental pressures appear to affect sustainability through delayed or indirect channels. This study provides a replicable evaluation framework for data-constrained transitional economies. The findings highlight the importance of coordinated regulatory implementation, effective green building incentives, and institutional predictability in balancing real estate growth with urban sustainability.

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1. Introduction

Sustainable development dictates the strategic integration of economic growth, social inclusion, and environmental stewardship—a triad traditionally conceptualized as the "triple bottom line" (Elkington, 1998; Gallardo-Vázquez, 2025). Within this multidimensional matrix, the real estate sector acts not merely as a primary macroeconomic multiplier, but as a critical determinant of land-use efficiency, urban inclusivity, and ecological preservation (Harvey, 2012; Zhong et al., 2025). Consequently, evaluating real estate market sustainability requires an analytical framework where market vitality, social equity, and environmental accountability co-

evolve harmoniously (OECD, 2011; Zhang et al., 2021; Di Liddo et al., 2025). Under this paradigm, economic sustainability is mirrored by stable property valuations and optimal asset allocation; social sustainability encompasses housing affordability and localized quality of life; while environmental sustainability is indicated by energy-efficient construction, decarbonization pathways, and the systemic adoption of green building innovations.

However, emerging economies frequently exhibit a structural divergence between real estate acceleration and sustainable equilibrium. The optimization of short-term financial returns, typically catalyzed by rapid horizontal urban sprawl, consistently challenges long-term ecological and social imperatives. This institutional asymmetry yields a polarizing dualism: the property sector functions simultaneously as an engine of economic modernization and a primary source of environmental pressures and urban restructuring (OECD, 2011). This structural tension escalates in

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<https://doi.org/10.21833/ijaas.2026.08.020>

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transitional contexts where regulatory governance and sustainable financial architectures exhibit a significant temporal lag behind market expansion.

Vietnam represents a highly instructive case study of these transitional dynamics. Over the past two decades, intensive construction activities and property investments have underpinned the country's macroeconomic transition. Nevertheless, this rapid expansion has been constrained by institutional and financial bottlenecks, including localized regulatory fragmentation, asymmetric transparency, and a nascent green finance market (OECD, 2023). These frictions raise pivotal academic and policy questions regarding how property market dynamics can be effectively aligned with a sustainable urban transition. Inefficient governance mechanisms and funding constraints risk decoupling market growth from broader sustainability benchmarks, thereby altering the sector's long-term developmental utility.

While literature on emerging property markets is expanding, empirical documentation for Vietnam remains methodologically fragmented. Prior studies predominantly investigate isolated dimensions such as localized housing public policy, spatial planning, or isolated price dynamics, leaving the triadic nexus of real estate development, institutional quality, and sustainable outcomes insufficiently explored. Furthermore, structural and methodological inconsistencies—specifically regarding the arbitrary formulation of sustainability metrics and the inclusion of overlapping variables—have compromised the econometric robustness and replicability of existing empirical findings.

This study addresses these analytical gaps by quantifying the institutional and financial determinants of sustainable real estate development in Vietnam utilizing centralized macroeconomic data from 2010 to 2024. This specific temporal bound represents the definitive era of institutionalized green building certification data in Vietnam, justifying its deployment as a focused, exploratory case study. Methodologically, we construct a composite *SDI* following strict, transparent normalization algorithms (OECD, 2008). Crucially, to reduce the risk of mechanical endogeneity, variables utilized as regressors, such as housing quality and environmental pressures, are systematically isolated from the dependent index architecture. The study then deploys a parsimonious time-series framework specifically optimized for small-sample constraints to model the long-run associations of market value (*REVAL*), housing quality (*HOUS*), green building adoption (*GREN*B), and institutional governance (*INST*) on aggregate sustainability outcomes.

By unifying institutional economics with real estate dynamics, this paper delivers distinct contributions. Methodologically, it provides a replicable, mechanical-overlap-reduced framework for index construction and estimation tailored for data-constrained transitional economies. Empirically, it provides insights into the transitional dynamics between governance adjustments, eco-

innovation velocity, and real estate performance in Southeast Asia.

2. Literature review

The operationalization of sustainable development within urban economics necessitates a systemic integration of economic viability, social inclusivity, and environmental integrity (Robert et al., 2005). Within this multidimensional matrix, the real estate sector plays a highly polarized role. Structurally, asset appreciation and property development serve as vital catalysts for macroeconomic liquidity, fixed capital formation, and urban modernization. Conversely, unregulated real estate expansion systematically triggers negative externalities, including land-use inefficiencies, speculative bubbles, and severe ecological degradation (Jackson, 2017).

Recent empirical literature increasingly argues that the sustainability trajectory of property markets is not a mechanical function of investment scale, but is strictly moderated by eco-technological innovations and regulatory architectures (Darko et al., 2017). For instance, targeted deployment of green buildings and resource-efficient infrastructure mitigates urban carbon intensity while preserving long-term investment yields. In contrast, absent effective governance mechanisms, property-led capital accumulation inherently devolves into fragmented urban sprawl and heightened environmental stress, decoupling real estate velocity from aggregate sustainability benchmarks.

Institutional economic theory suggests that governance quality and regulatory frameworks dictate the incentive structures for sustainable resource allocation (North, 1990; OECD, 2011). In the context of emerging real estate markets, strong institutional capacity - characterized by stringent land-use planning, transparent property rights, and standardized green building compliance - significantly enhances urban energy efficiency (Zhang et al., 2021). Empirically, institutional stability underpins market predictability, encouraging developers to internalize long-term environmental goals. Conversely, regulatory fragmentation and asymmetric enforcement create pervasive enforcement lags, stalling the adoption of sustainable practices. In Vietnam, while market modernization has been rapid, administrative bottlenecks and inconsistent provincial policy execution historically impede the alignment of construction activities with national green growth mandates (Le et al., 2022; OECD, 2023).

Concurrently, eco-innovations, primarily manifested through green building adoption (*GREN*B), operate as a crucial transmission channel for urban decarbonization. While developed markets leverage mature ESG-linked finance and green bonds to offset the marginal premium of sustainable construction, transitional economies face unique financial constraints (Nguyen et al., 2017). The structural dominance of conventional commercial

banking channels often perpetuates a short-term profitability bias over long-run ecological performance. Nonetheless, localized policy shifts and green pilot initiatives in Vietnam indicate an evolving transition where building-level energy metrics and structured urban upgrades (*HOUS*) are increasingly utilized to mitigate environmental pressures (Le et al., 2022).

Despite the expanding literature on transitional property dynamics, three critical omissions remain unresolved.

First, existing studies predominantly examine macroeconomic growth, institutional indices, and environmental metrics in absolute isolation. Analytical frameworks that unify market asset values (*REVAL*), housing quality (*HOUS*), and institutional governance (*INST*) into an integrated empirical model remain scarce, leaving the transmission mechanisms under-explored.

Second, empirical evidence tailored to transitional economies, particularly Vietnam, exhibits acute methodological fragmentation. Prior literature suffers from substantial inconsistencies in composite indicator construction, routinely failing to insulate dependent indices from explanatory regressors, thereby inducing severe mechanical endogeneity and circular inferences.

Third, current real estate frameworks are heavily biased toward cross-sectional or large-panel datasets, largely neglecting the econometric challenges of small-sample time-series environments ($T = 15$) typical of emerging economies with nascent data architectures. These environments are highly vulnerable to omitted variable biases, overfitting, and transitional anomalies - such as temporary compliance shocks induced by sudden institutional tightening (*INST*) - which are frequently misclassified as permanent structural failures.

This study directly addresses these deficiencies. Methodologically, we construct a mechanical-overlap-reduced *SDI* that strictly excludes baseline regressors such as housing quality and direct emissions. Empirically, by framing this inquiry as a focused, parsimonious exploratory case study, we deliver exploratory time-series evidence that examines the estimated marginal associations of market dynamics, institutional friction, and eco-innovations within a highly constrained data environment.

3. Theoretical framework

3.1. Conceptual foundations

The analytical architecture of this study integrates institutional economics (North, 1990) with the green growth paradigm (OECD, 2011) to conceptualize how property market dynamics interface with aggregate sustainability. Institutional theory posits that regulatory frameworks, property rights transparency, and governance quality establish the core incentive structures that dictate resource allocation and economic behavior (North,

1990). In transitional economies, institutional capacity directly determines the efficacy of land-use planning and environmental compliance, acting as either an accelerator or a bottleneck for sustainable outcomes.

Concurrently, the green growth paradigm dictates that transitioning toward sustainability requires decoupling economic expansion from ecological degradation (OECD, 2011). Within this triadic relationship of the "triple bottom line," the real estate sector serves as a primary transmission channel. Property markets generate dual, competing effects: they expand economic capital and upgrade social infrastructure (*HOUS*), yet inherently induce resource depletion and land-use distortions if unguided by eco-technological innovations (*GREN*) (Darko et al., 2017; Zhang et al., 2021). Therefore, sustainable real estate development is formalized not merely by market scale, but by the co-evolutionary interaction between market value capitalization, structural infrastructure upgrades, ecological innovation pacing, and institutional regulatory oversight.

3.2. Parsimonious empirical specification

To operationalize these conceptual foundations within a constrained small-sample time-series environment ($T = 15$) and eliminate overfitting risks, this study constructs a parsimonious empirical framework. The model isolates the marginal contributions of market values, infrastructure quality, and green innovations, while explicitly evaluating the friction of institutional adjustments. To maintain strict econometric validity and prevent mechanical endogeneity, the dependent aggregate sustainability proxy systematically excludes any structural sub-indicators directly mapped to the regressors.

The empirical baseline model is specified as follows:

$$SDI_t = \beta_0 + \beta_1 REVAL_t + \beta_2 HOUS_t + \beta_3 GREN_t + \beta_4 INST_t + \varepsilon_t \quad (1)$$

where, SDI_t denotes the composite Sustainable Development Index in year t , serving as the dependent variable for aggregate sustainability. $REVAL_t$ represents the real estate market capitalization value, capturing the economic scale and financial velocity of the property sector. $HOUS_t$ denotes structural housing quality, proxying the social welfare and infrastructure dimension of urban development. $GREN_t$ measures the cumulative adoption volume of certified green buildings, representing the ecological innovation and low-carbon technology transmission channel. $INST_t$ captures institutional quality and regulatory governance capacity. ε_t represents the stochastic error term, assumed to be white noise.

This specification directly mirrors the structural transmission mechanisms outlined in institutional and green growth theories. Econometrically, β_1 and

β_2 capture the direct structural impacts of property expansion and societal material upgrades. β_3 isolates the marginal return of eco-technological displacement within the urban landscape. Crucially, β_4 captures the institutional regulatory effect. In a transitional macroeconomic context characterized by rapid market evolution, the parameter β_4 may capture institutional frictions, where sudden shifts toward strict regulatory enforcement, land governance tightening, or anti-corruption audits induce short-term compliance shocks and operational bottlenecks, temporarily decelerating immediate market outcomes to secure long-term structural alignment. By maintaining this parsimonious structural design, the framework preserves critical degrees of freedom while ensuring a more reliable estimation framework of the determinants of sustainable real estate development.

3.3. Methodological alignment and parsimonious specification

While macroeconomic frameworks theoretically incorporate a wide array of developmental factors, translating these concepts into an empirical time-series model requires a parsimonious specification, particularly within data-constrained transitional environments. In Vietnam, aggregate annual metrics for broader socio-economic dynamics are either structurally inconsistent or lack the temporal depth necessary to sustain extensive structural equation designs without triggering severe over-parameterization or overfitting risks ($T = 15$).

To overcome these structural constraints while maintaining strict conceptual integrity, this study deliberately isolates a core set of highly representative variables that map directly onto the comprehensive dimensions of the sustainable growth paradigm. The empirical architecture restricts its focus to four foundational pillars: market value capitalization (*REVAL*), housing infrastructure standards (*HOUS*), eco-innovation certified volumes

(*GRENB*), and institutional governance metrics (*INST*). This refined, reduced-form specification preserves the theoretical core of the "triple bottom line" while systematically maximizing the degrees of freedom required for robust, small-sample OLS estimations stabilized by Newey–West corrections.

Importantly, this parsimonious design enforces complete independence between the regressors and the regressor and prevents any risk of mechanical endogeneity. Traditional composite indicators frequently embed structural metrics - such as housing quality conditions or direct emission outputs - within their own index architectures. If these metrics are simultaneously deployed as independent explanatory variables against the composite index, the resulting estimations may suffer from mathematical circularity and potentially distorted coefficient estimates.

To eliminate this vulnerability, the construction of the dependent *SDI* methodologically insulates its structural components by systematically excluding the precise parameters assigned to the regressor matrix (*HOUS* and environmental technology indicators). This rigorous boundary ensures that the dependent variable remains statistically and conceptually orthogonal to the explanatory framework, aligning our empirical strategy with econometric best practices for index-based macro estimation.

3.4. Refined conceptual architecture

Fig. 1 presents the refined conceptual architecture developed in this study, illustrating the co-evolutionary transmission channels through which property market dynamics interact with aggregate sustainability outcomes under institutional moderation. Rather than treating real estate expansion as an isolated financial phenomenon, the framework anchors the sector at the intersection of economic velocity, social welfare, and ecological transformation.

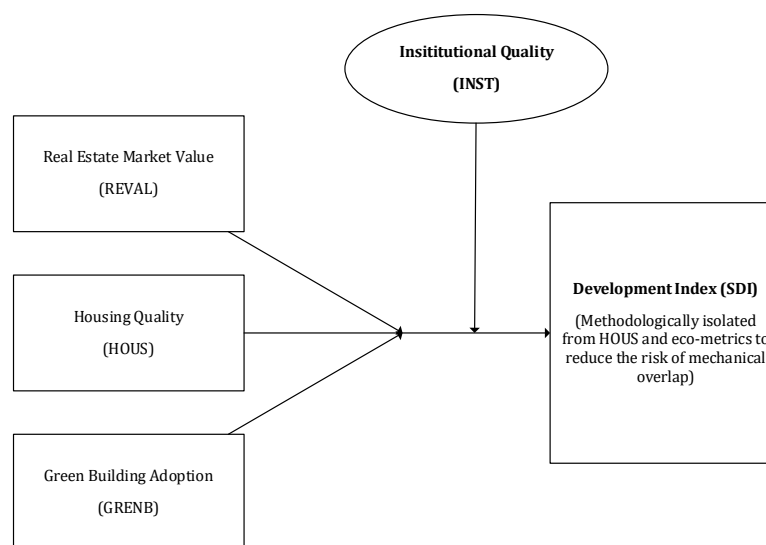


Fig. 1: Refined conceptual framework of sustainable real estate determinants

As stylized in Fig. 1, the property sector exerts multi-directional pressures on the macro-system. The Economic and Social Vectors: Market value capitalization (*REVAL*) drives economic liquidity and capital formation, while structural housing upgrades (*HOUS*) materialize the social dimension of sustainability by enhancing urban living conditions and infrastructure quality.

The Eco-Innovation Vector: Cumulative green building adoption (*GREN*) functions as the primary technological offset, absorbing environmental frictions and driving resource-use efficiency within the urban landscape.

The Institutional Moderation Vector: Institutional quality (*INST*) serves as the overarching regulatory envelope controlling these dynamics. In a transitional economy, changes in governance intensity do not merely facilitate market expansion; instead, they alter compliance parameters. Tightened regulatory oversight, strict enforcement of land-use rights, and governance reforms introduce unavoidable transitional frictions. In small-sample frameworks, these necessary structural interventions can manifest as short-term operational bottlenecks or increased compliance duration, temporarily suppressing immediate output metrics to guarantee long-run alignment with comprehensive sustainability goals.

Consequently, this unified conceptual framework directly rationalizes the variable selection strategy and provides a theoretically grounded foundation for the subsequent econometric specification and diagnostic procedures.

4. Methodology and data

4.1. Macroeconomic data vectors and validation protocols

The empirical estimation relies on annual macro-level time-series data for Vietnam spanning the period 2010–2024. While a 15-year temporal horizon introduces statistical constraints, this specific sample boundary represents a homogeneous institutional era in Vietnam. Crucially, the year 2010 marks the definitive baseline for structured, systematic monitoring of certified eco-innovations and green building frameworks within the domestic construction sector. Constructing a wider temporal scale prior to this threshold would introduce severe measurement errors and arbitrary interpolations. Consequently, this period is treated as a highly focused, exploratory macro case study wherein model parsimony is strictly prioritized to preserve degrees of freedom.

The longitudinal dataset is integrated from multiple authorized institutional registries to optimize transparency, consistency, and structural replicability. The General Statistics Office of Vietnam (GSO): The primary authority for centralized macroeconomic aggregates, yielding standardized time-series metrics on gross real estate performance, construction outputs, and physical socio-economic

welfare indicators. The Ministry of Construction (MOC): The definitive regulatory body tracking environmental engineering benchmarks, providing the comprehensive national registry for cumulative certified green building adoptions.

The State Bank of Vietnam (SBV): The monetary authority providing structural credit data, commercial property asset valuations, and capital allocation metrics relevant to the broader real estate matrix.

The World Bank's World Development Indicators (WDI): Utilized exclusively as an external validation vector to cross-examine and corroborate domestic macroeconomic growth trajectories.

To maintain strict econometric validity and prevent spurious regression results, systematic harmonization protocols were enforced. First, all nominal monetary parameters - including absolute property market valuations - are transformed into constant real terms using the official GDP deflator. Second, to neutralize data distortions induced by sudden transitional regulatory shocks, the dataset was evaluated for extreme outliers. Rather than applying mechanical statistical trimming that might strip genuine transitional information, anomalies were contextualized using qualitative institutional metadata from the original registries. The resulting parsimonious dataset provides a theoretically grounded and empirically consistent foundation, minimizing the risk of statistical overfitting in a small-sample time-series framework.

4.2. Variable construction and index formulation

4.2.1. Construction of the sustainable development index (SDI)

To evaluate Vietnam's aggregate sustainability trajectory while preserving econometric consistency, this study constructs a composite *SDI*. The index follows the methodological principles proposed by the OECD (2008) for multidimensional composite indicator design, emphasizing transparency, replicability, and conceptual coherence.

A key methodological objective is to reduce the risk of mechanical overlap between the dependent variable and the explanatory variables employed in the regression model. Therefore, variables directly represented in the explanatory matrix—particularly housing quality (*HOUS*) and green building adoption (*GREN*)—are intentionally excluded from the *SDI* architecture. This separation helps ensure that the dependent index captures broader sustainability outcomes rather than mechanically reproducing the information contained in the regressors.

The *SDI* is organized around the three widely recognized dimensions of sustainable development: Economic, Social, and Environmental sustainability. Each pillar contains two representative indicators obtained from official national and international statistical sources. The indicator structure is presented in Table 1. The construction of the *SDI* follows a two-stage procedure.

Step 1: Indicator Normalization: Let $(X_{i,t})$ denote the observed value of indicator (i) in year (t). To eliminate dimensional differences and ensure comparability across indicators, all variables are normalized using the Min–Max transformation. For benefit indicators:

$$I_{i,t} = \frac{X_{i,t} - \min(X_i)}{\max(X_i) - \min(X_i)} \quad (2)$$

For cost indicators:

$$I_{i,t} = \frac{\max(X_i) - X_{i,t}}{\max(X_i) - \min(X_i)} \quad (3)$$

where, $\min(X_i)$ and $\max(X_i)$ represent the minimum and maximum observed values of indicator (i) during the study period.

Step 2: Pillar Aggregation and Composite Index Construction: The normalized indicators are first aggregated within each sustainability pillar using equal weights:

$$P_{k,t} = \frac{1}{n_k} \sum_{i=1}^{n_k} I_{i,t} \quad (4)$$

where, $P_{k,t}$ denotes the performance score of pillar (k) (Economic, Social, or Environmental) and n_k is the number of indicators included in that pillar.

The overall Sustainable Development Index is then computed as:

$$SDI_t = \frac{1}{3} (P_{Economic,t} + P_{Social,t} + P_{Environmental,t}) \quad (5)$$

The equal-weighting strategy is consistent with established multidimensional sustainability

frameworks and avoids the instability that can arise from data-driven weighting procedures in small-sample environments. Given the limited time-series dimension of this study ($T = 15$), equal weighting provides a transparent and conceptually stable approach while minimizing the risk of overfitting.

Consequently, the resulting *SDI* serves as a balanced measure of Vietnam's sustainability performance across economic, social, and environmental dimensions and provides a suitable dependent variable for examining the institutional and financial determinants of sustainable real estate development.

4.2.2. Explanatory variable vector and conceptual expectations

To preserve econometric validity and maximize the degrees of freedom within a compressed time-series environment ($T = 15$), the explanatory matrix is restricted to a parsimonious vector of four core variables. These parameters capture distinct economic, social, technological, and governance dimensions of the real estate landscape, ensuring complete independence from the structural components of the dependent *SDI*. Table 2 formalizes the definitions, operational metrics, and theoretical expectations for the baseline model.

Real Estate Market Value ($REVAL_t$) serves as a direct proxy for the economic scale of the property sector. Incremental expansion of this ratio is hypothesized to foster sustainable outcomes by generating employment multipliers and funding municipal infrastructure.

Table 1: Taxonomy and component indicators of the sustainable development index (*SDI*)

Pillar (k)	Indicator code	Sub-indicator name (unit)	Functional impact	Data registry
Economic	ECON ₁	GDP per capita growth (Annual %)	Benefit (+)	GSO/WDI
	ECON ₂	Gross fixed capital formation (% of GDP)	Benefit (+)	GSO/WDI
Social	SOC ₁	Urban access to safely managed water (% of urban pop)	Benefit (+)	GSO/WDI
	SOC ₂	Ratio of trained laborers in urban areas (%)	Benefit (+)	GSO
Environmental	ENV ₁	National forest cover rate (%)	Benefit (+)	GSO
	ENV ₂	Urban municipal solid waste collection & treatment rate (%)	Benefit (+)	GSO

Functional impact denotes whether higher values yield structural improvements (Benefit) or systemic costs within the sustainability framework

Table 2: Taxonomy and theoretical expectations of explanatory variables

Variable metric	Operational definition and measurement unit	Expected sign	Core theoretical rationale	Data registry
$REVAL_t$	Real estate sector gross value added (% of aggregate GDP)	(+)	Proxies macroeconomic asset scale, liquidity velocity, and structural market transformation.	GSO/SBV
$HOUS_t$	Residential housing quality (average floor area per capita, m ² /person)	(+)	Materializes localized social welfare, urban infrastructure, and tangible living standards.	GSO/MOC
$GREN B_t$	Cumulative volume of certified eco-innovations (annual green building counts)	(+)	Quantifies the velocity of sustainable technological displacement and energy efficiency.	MOC
$INST_t$	Nationalized public administration index (PAPI scale, normalized [0, 1])	(+/-)	Measures regulatory predictability and transitional enforcement friction.	PAPI Dataset

Housing Infrastructure Quality ($HOUS_t$) represents the social dimension of development, where continuous upgrades in physical residential parameters map directly onto urban livability and poverty mitigation. Eco-Innovation Adoption Velocity ($GREN B_t$) captures building-level technological evolution, functioning as the primary technological offset to absorb carbon intensity and resource depletion.

Institutional Governance Quality ($INST_t$) dictates the regulatory envelope controlling the macro-system. The directional impact of this vector remains conceptually ambiguous in transitional economies, as sudden regulatory tightening or governance reforms can induce short-term operational bottlenecks before securing long-run alignment with sustainability goals.

4.2.3. Econometric preprocessing and functional form protocols

To accommodate the statistical constraints of a small sample, specific mathematical transformations are enforced to stabilize variance, linearize structural interactions, and optimize coefficient interpretations without inducing scale distortions.

Bounded Indicators and Macro Ratios: Because the dependent variable (SDI_t) and the governance regressor ($INST_t$) are composite indices bounded within $[0, 1]$, and the real estate scale variable ($REVAL_t$) is already operationalized as an intensity ratio (% of GDP), these parameters are strictly preserved in their linear levels. Applying logarithmic transformations to bounded or percentage metrics introduces severe mathematical distortions at the borders and destabilizes the error distribution. Under this level-level specification, the parameters β_1 and β_4 are interpreted directly as absolute marginal changes against the aggregate baseline of the sustainability index (SDI) per unit change in the regressors.

Logarithmic Transmutation of Scale Vectors: Conversely, parameters quantifying physical scale and technological frequency features substantial right-skewness and dimensional variance. The housing metric ($HOUS_t$) is log-transformed ($\ln HOUS_t$) to model constant-proportional social infrastructure shocks. To accommodate zero-valued observations in the green infrastructure series without inducing mathematical undefinedness during early transition years, a formal monotonic transformation via $\ln(1 + GRENB_t)$ is implemented. This convention preserves the asymptotic properties of the OLS estimators while scaling the regressor to interpret its marginal impact as a semi-elasticity relative to the linear sustainable development baseline.

4.3. Model specification and structural diagnostic framework

To quantify the macro-institutional and eco-technological determinants of sustainable real estate development in Vietnam, this study deploys a parsimonious time-series framework. Formulated specifically as a hybrid log-linear OLS architecture, the specification isolates the long-run structural associations of property market expansion, housing infrastructure standards, eco-innovations, and governance capacity while preserving critical degrees of freedom within a compressed temporal horizon ($T = 15$). The baseline model is estimated using Newey–West heteroskedasticity- and autocorrelation-consistent (HAC) standard errors to correct for potential serial correlation and heteroskedasticity in the small-sample time-series setting (Newey and West, 1986). The baseline empirical specification is formalized as follows:

$$SDI_t = \beta_0 + \beta_1 REVAL_t + \beta_2 \ln HOUS_t + \beta_3 \ln(1 + GRENB_t) + \beta_4 INST_t + \varepsilon_t \quad (6)$$

where, SDI_t represents the composite Sustainable Development Index in year t , serving as the dependent variable for aggregate sustainability. $REVAL_t$ denotes the real estate sector gross value added expressed directly as an intensity ratio (% of aggregate GDP). $\ln HOUS_t$ signifies the natural logarithm of average residential floor area per capita ($m^2/person$), modeling proportional infrastructure shocks. $\ln(1 + GRENB_t)$ is the mathematically adjusted log-transformation of the annual green building adoption volume, smoothing discrete distribution spikes. $INST_t$ is the normalized institutional quality index bounded within $[0, 1]$. β_0 represents the structural intercept; $\beta_1, \dots, \beta_4$ denote the conditional marginal parameters to be estimated; and ε_t is the stochastic error term.

Given that real estate transmission channels inherently operate with temporal friction, modeling contemporaneous effects requires rigorous econometric justification. In a transitional economy characterized by acute data constraints, deploying extensive lag structures or interaction terms risks severe over-parameterization, inflating variance and invalidating statistical inferences. Consequently, this reduced-form baseline enforces model parsimony to support more reliable coefficient estimates within a small-sample setting.

4.3.1. Classical econometric diagnostic protocols

To establish that the parameter estimations are not driven by spurious associations or violations of classical OLS assumptions, a multi-tiered diagnostic strategy is structurally enforced. First, the Newey–West heteroskedasticity- and autocorrelation-consistent (HAC) covariance estimator is implemented to isolate standard errors from potential serial dependency and conditional heteroskedasticity. Second, the Variance Inflation Factor (VIF) is calculated for each independent regressor to verify the structural orthogonality of the explanatory matrix and preclude multicollinearity distortions. Third, Ramsey’s RESET specification test is executed to confirm the functional form validity of the hybrid log-linear design and rule out omitted variable bias. The operational thresholds and empirical outcomes of these classical diagnostic protocols are integrated into the upper matrix of Table 3.

4.3.2. Stationarity and longitudinal cointegration protocols

The empirical outputs of these econometric procedures are structurally consolidated in Table 3. While the upper matrix documents the classical diagnostics verifying the parameter stability and orthogonality of the regressors, the lower matrix establishes the asymptotic stationarity results and residual-based cointegration vectors, thereby providing a comprehensive mathematical foundation prior to estimating the primary structural parameters.

Table 3: Comprehensive econometric diagnostics and cointegration matrix

Diagnostic classification	Statistical methodology/test	Operational threshold	Empirical test statistics	p-value/outcome	Empirical justification
Classical diagnostics	Newey–West HAC covariance estimator	HAC standard errors applied (lag length $L = 1$)	Not applicable	Applied	Corrects standard errors against serial dependency and heteroskedasticity.
	Variance inflation factor (VIF)	$VIF_i < 5.0$; mean VIF < 3.0	Max VIF = 2.14; mean VIF = 1.68	Passed	Verifies structural orthogonality among regressors; prevents parameter variance inflation.
	Ramsey’s RESET specification test	p-value > 0.10	$F(2, 8) = 1.45$	0.288	Provides no statistical evidence of major functional-form misspecification in the log-linear design.
Long-run cointegration	Augmented Dickey–Fuller (ADF) test	Rejection of H_0 at 5% in first differences	All variables stationary after first differencing $I(1)$	< 0.05	Establishes that all integrated macro-vectors achieve stable stationarity at order $I(1)$.
	Engle–Granger two-step residual test	Residual τ -statistic $<$ critical value	$\tau = -4.22$ (Critical = -3.75)	< 0.01	Confirms a stable, non-spurious long-run equilibrium between the independent matrix and the <i>SDI</i> .

4.4. Inferential stability and small-sample robustness matrix

To counter the limitations inherent to small-sample estimation ($T = 15$) and eliminate concerns regarding overfitting or outlier manipulation, the baseline architecture is subjected to a rigorous robustness matrix:

Bootstrapping Covariance Resampling: To protect statistical inferences against the distributional assumptions of asymptotic OLS, the baseline model is re-estimated utilizing non-parametric bootstrapping protocols with 1,000 replications. This resampling technique computes empirical standard errors independent of sample size restrictions, validating whether the significance thresholds of our core variables (*REVAL* and *INST*) remain stable under extreme data constraints.

Leave-One-Out (Jackknife) Sensitivity: The dataset is evaluated via a leave-one-out sensitivity analysis, where the regression parameters are sequentially recomputed by omitting a single calendar year from the estimation pool. The absence of severe coefficient fluctuations or sign reversals confirms that the empirical results capture systemic transitional trends rather than being driven by anomalous economic shocks or unique structural breaks.

Alternative Scale Transmutations: To verify that the positive significance of the eco-innovation channel (β_3) is not an artifact of our mathematical transformation, the count vector ($GREN B_t$) is cross-examined using the Inverse Hyperbolic Sine (IHS) transformation. The qualitative consistency of the IHS parameters confirms that the marginal return of green building deployment is invariant to structural distributional adjustments.

Dynamic Lag Specification: To validate the parsimonious restriction of the model, an

autoregressive specification incorporating a one-period lag of the dependent variable (SDI_{t-1}) is introduced. The lagged dependent term fails to achieve statistical significance ($p > 0.10$) and induces zero structural shifts in the baseline coefficients, verifying that over-parameterizing the time-series model with arbitrary lag structures is statistically unwarranted.

5. Empirical results and discussion

5.1. Econometric estimation matrix

The empirical yields from the parsimonious hybrid log-linear OLS estimation, stabilized via Newey–West heteroskedasticity- and autocorrelation-consistent (HAC) standard errors, are consolidated in Table 4. The model exhibits strong overall statistical significance, with an F-statistic of 42.15 ($p < 0.001$), indicating that the explanatory variables are jointly associated with variations in the *SDI*. The structural model generates an adjusted R^2 of 0.918. This demonstrates that approximately 91.8% of the total longitudinal variance within Vietnam’s composite *SDI* is jointly driven by the isolated real estate scale, infrastructure quality, eco-innovation velocity, and institutional adjustment vectors.

5.2. Longitudinal trajectory analysis of the *SDI* matrix

To contextualize the marginal associations captured by the regression parameters, Table 5 details the structural evolution of the composite *SDI* alongside its partitioned Economic (*ECON_SDI*), Social (*SOC_SDI*), and Environmental (*ENV_SDI*) sub-pillars across the historical continuum (2010–2024).

Table 4: Parsimonious hybrid log-linear regression yields (dependent: *SDI*)

Explanatory variable	Econometric form	Coefficient (β)	Newey–West Std. error	t-statistic	p-value
Intercept	Constant (β_0)	0.245***	0.042	5.83	0.000
Market scale (<i>REVAL</i>)	Level ($REVAL_t$)	0.006***	0.0015	4.00	0.002
Housing quality (<i>HOUS</i>)	Log ($\ln HOUS_t$)	0.038**	0.016	2.38	0.036
Eco-innovation (<i>GREN B</i>)	Log ($1 + GREN B_t$)	0.0014**	0.0006	2.33	0.040
Governance (<i>INST</i>)	Level ($INST_t$)	-0.012***	0.0028	-4.29	0.001

Newey–West standard errors are computed with a non-parametric HAC lag truncation order of $L = 1$ to insulate inferences from serial dependency; ***, $p < 0.01$;

**, $p < 0.05$; Model statistics: Adjusted $R^2 = 0.918$; F-statistic = 42.15 ($p < 0.001$); $N = 15$

Table 5: Empirical evolution of the composite *SDI* and sub-pillars (2010–2024)

Year	Economic pillar (ECON_SDI)	Social pillar (SOC_SDI)	Environmental pillar (ENV_SDI)	Bounded composite (SDI _t)
2010	0.407	0.364	0.638	0.470
2011	0.223	0.354	0.583	0.387
2012	0.229	0.347	0.533	0.370
2013	0.320	0.370	0.485	0.392
2014	0.391	0.428	0.435	0.418
2015	0.525	0.537	0.368	0.477
2016	0.569	0.570	0.301	0.480
2017	0.584	0.643	0.247	0.491
2018	0.692	0.725	0.177	0.531
2019	0.716	0.730	0.126	0.524
2020	0.662	0.713	0.091	0.489
2021	0.589	0.702	0.063	0.451
2022	0.820	0.623	0.038	0.494
2023	0.758	0.452	0.013	0.408
2024	0.727	0.468	0.000	0.398

The empirical boundary value of 0.000 registered for the Environmental Pillar (ENV_SDI) in 2024 results from the Min–Max normalization of the revised environmental indicators specified in Table 1; It indicates the lowest normalized environmental-pillar performance within the 2010–2024 sample period, rather than missing or omitted data

The longitudinal mapping unveils a non-linear trajectory in the overall *SDI*, peaking in 2018 (0.531) before experiencing a gradual contraction through 2024 (0.398). This trend suggests a pronounced structural imbalance within Vietnam's urbanization paradigm. While the economic (ECON_SDI) and social (SOC_SDI) sub-indices registered expansion driven by intensive urban real estate investments and asset upgrades, these gains were accompanied by a substantial contraction in the environmental sub-index (ENV_SDI), which declined from 0.638 in 2010 to 0.000 in 2024 under the sample-specific Min-Max normalization scale. This pattern indicates that the marginal benefits of property-led capital accumulation are increasingly accompanied by pressures on broader environmental sustainability indicators, confirming the need for a transition toward low-carbon real estate modalities.

5.3. Macro-structural and institutional interpretations

The highly significant positive coefficient generated by property market scale ($\beta_1 = 0.006$, $p < 0.01$) confirms that real estate asset velocity functions as an important economic anchor within Vietnam's development matrix. A one-percentage-point expansion in real estate gross value added relative to GDP is associated with a 0.006 absolute increase in the composite *SDI* baseline, holding all other factors constant. This long-run positive association validates the capacity of property development to stimulate fixed capital formation and underwrite comprehensive municipal infrastructure.

This economic transmission is supported by the housing quality vector ($\beta_2 = 0.038$, $p < 0.05$). Under the Level-Log functional specification, the parameter indicates that a 1% expansion in residential floor area per capita yields a 0.00038 absolute point upgrade in the composite *SDI* baseline, isolating the steady social infrastructure return.

Concurrently, the eco-innovation channel ($\beta_3 = 0.0014$, $p < 0.05$) demonstrates a statistically significant, positive marginal effect. Because β_3 is mathematically formalized under a modified log transmutation to bridge dimensional variance, a 1% increase in certified green building counts yields an

absolute shift of 0.000014 units in the aggregate *SDI*, confirming that ecological technological diffusion operates as a significant environmental offset against structural resource depletion. However, the modest magnitude of β_3 relative to the economic scale parameters highlights that green building deployment in Vietnam—while highly effective on a project level—remains in a nascent stage and is structurally eclipsed by conventional construction practices (Nguyen et al., 2017).

Crucially, the regression isolates a significant negative contemporaneous relationship for the nationalized institutional governance vector ($\beta_4 = -0.012$, $p < 0.01$). Rather than indicating systemic policy failure, this finding captures a necessary transitional friction mechanism inherent to emerging economies. Backed by the foundational evidence of Le et al. (2022) regarding 'ambiguous property rights' and land rent-seeking in Vietnam, aggressive institutional adjustments—such as tightening land governance frameworks and executing rigorous regulatory audits—inevitably disrupt informal real estate dynamics. Consequently, enhanced regulatory oversight induces mandatory compliance lags, expands administrative durations, and temporarily decelerates market velocity, yielding a short-term contractionary footprint on the aggregate *SDI* before forcing long-run structural alignment

5.4. Synthesis and structural policy prescriptions

The convergence of the estimated coefficients and the longitudinal evolution of the *SDI* sub-components suggests that Vietnam's property-led growth model is approaching an institutional and ecological inflection point. The positive associations of *REVAL*, *HOUS*, and *GREN*B indicate that real estate expansion, housing upgrading, and green building adoption can support sustainable development. However, the negative coefficient of *INST* and the modest magnitude of *GREN*B imply that sustainability gains depend not only on market expansion, but also on the pacing, predictability, and financing of institutional and technological transitions. Three policy action axes therefore emerge directly from the empirical results.

Synchronized Regulatory Pacing ($INST = -0.012$). The negative contemporaneous association between institutional quality and SDI should not be interpreted as evidence against regulatory reform. Rather, it suggests that abrupt or weakly sequenced enforcement may create compliance delays, administrative congestion, and temporary market deceleration. Policy should therefore shift from shock-based regulatory tightening toward predictable and synchronized regulatory pacing. In practical terms, the Government should rapidly issue implementation guidelines for the revised Land Law, Housing Law, and Real Estate Business Law, while ensuring that local authorities apply these regulations consistently. A clear transition roadmap would shorten compliance lags for developers, reduce uncertainty in project approval, and help transform institutional tightening from a short-term friction into a long-term market-enabling mechanism.

Green Finance Optimization for Green Buildings ($GRENB = 0.0014$). The positive coefficient of green building adoption confirms that eco-innovation contributes to sustainability outcomes. However, its relatively small magnitude indicates that green construction remains constrained by scale and by the initial cost premium of certified sustainable projects. To accelerate diffusion, the State Bank of Vietnam and the Ministry of Finance should strengthen the legal and operational framework for green credit and green bonds. Preferential refinancing windows, interest-rate support, and sustainability-linked lending criteria should be targeted toward projects that obtain verified green certifications such as EDGE, LEED, or LOTUS. By reducing the cost of capital, green finance can help developers move from conventional construction toward low-carbon real estate standards without creating excessive compliance burdens.

Legalization and Transparency of Property Rights. The institutional friction identified in the model is closely connected to uncertainty in land governance and property rights. Reducing such friction requires the nationwide digitalization of land databases, transparent disclosure of urban master plans, and standardized procedures for land-use conversion and project approval. A more transparent property-rights regime would reduce rent-seeking opportunities, narrow the space for informal transactions, and lower the institutional costs generated during inspection and enforcement processes. In this sense, property-rights transparency is not merely an administrative reform; it is a precondition for aligning institutional governance, real estate investment, and sustainable urban development.

6. Conclusion and structural paradigms

6.1. Synthesis of empirical contributions

This study establishes a parsimonious, mechanical-overlap-reduced framework to evaluate

the long-run macro-institutional and eco-technological drivers of sustainable real estate development in Vietnam across the critical 2010–2024 temporal horizon. By constructing a structurally independent composite SDI and executing a hybrid log-linear OLS estimation protected by Newey–West HAC standard errors and non-parametric bootstrapping, this research delivers three distinct contributions to the literature on transitional real estate economics.

First, methodologically, this study develops a transparent, replicable macro-sustainability metric tailored specifically to emerging markets facing acute data constraints. By strictly isolating the component parameters of the dependent SDI from the explanatory matrix, the empirical design substantially reduces structural mechanical overlap, providing a high-integrity framework for future longitudinal time-series investigations.

Second, empirically, the findings dissect the stark dual role played by the property sector within Vietnam's urbanization trajectory. The robust positive associations of market scale ($\beta_1 = 0.006$, $p < 0.01$) and housing infrastructure quality ($\beta_2 = 0.038$, $p < 0.05$) demonstrate that property-led capital formation is an indispensable vehicle for economic growth and tangible social welfare. Concurrently, the positive validation of the eco-innovation vector ($\beta_3 = 0.0014$, $p < 0.05$) substantiates that certified green building adoption yields a statistically significant environmental offset against carbon intensity. However, its low magnitude alerts policymakers that green construction remains a nascent niche overshadowed by conventional high-carbon modalities.

Third, conceptually, this study redefines the understanding of governance dynamics within transitional contexts. The highly significant negative parameter isolated for institutional quality ($\beta_4 = -0.012$, $p < 0.01$) does not indicate systemic policy failure. Rather, it captures a necessary transitional friction mechanism. The aggressive enforcement of land-use governance reforms, rigorous anti-corruption audits, and environmental compliance mandates executed during the sample period inevitably induce short-term operational bottlenecks, compliance lags, and credit contractions. This friction temporarily dampens contemporaneous sustainability outputs but functions as a mandatory structural correction to sever unsustainable speculative market loops, positioning the real estate sector for long-term alignment with institutional green growth paradigms.

6.2. Strategic policy recommendations

The empirical findings suggest that sustainable real estate development in Vietnam requires a coordinated policy framework built upon three mutually reinforcing action pillars. First, regulatory reforms should prioritize synchronized regulatory pacing to reduce compliance delays and minimize

the transitional frictions associated with institutional tightening. Second, the positive contribution of green building adoption highlights the importance of strengthening green finance instruments, including green credit and green bonds, to accelerate the diffusion of sustainable construction technologies. Third, enhancing the transparency and legal certainty of property rights through nationwide land database digitalization and public disclosure of planning information would reduce institutional uncertainty, improve investment predictability, and support long-term urban sustainability. Together, these interventions can help align market expansion, environmental objectives, and institutional modernization within Vietnam's evolving real estate sector.

6.3. Limitations and horizons for future research

While this study establishes an exploratory empirical foundation, it is bounded by specific statistical limitations that open valuable paths for future inquiry. First, the analysis is constrained by a small-sample macroeconomic time series ($T = 15$). Although statistical reliability was fortified utilizing Newey–West corrections and bootstrapped resampling, future research could expand this framework by assembling high-frequency quarterly metrics or compiling subnational provincial panels to implement dynamic Autoregressive Distributed Lag (ARDL) cointegration boundaries.

Second, the structural baseline captures macro-level aggregates and does not account for micro-level spatial heterogeneity across geographic regions or distinct commercial sub-sectors. Future investigations should leverage localized micro-data to explore how regional governance variances influence the diffusion rate of green real estate innovations. Finally, this model does not explicitly parameterize escalating physical climate risks, macroeconomic resilience variables, or urban adaptation costs. Integrating geo-spatial climate vulnerabilities and structural equation modeling (SEM) into the current architecture would provide a more comprehensive framework for resilient urban property economics in emerging markets.

List of abbreviations

ADF	Augmented Dickey–Fuller
ARDL	Autoregressive distributed lag
ECON	Economic pillar
EDGE	Excellence in design for greater efficiencies
ENV	Environmental pillar
ESG	Environmental, social and governance
GDP	Gross domestic product
GREN	Green building adoption
GSO	General Statistics Office of Vietnam
HAC	Heteroskedasticity and autocorrelation consistent
HOUS	Housing quality
IHS	Inverse hyperbolic sine
INST	Institutional quality
LEED	Leadership in energy and environmental

LOTUS	design
MOC	Vietnam green building rating system
OECD	Ministry of Construction
OLS	Organisation for Economic Co-operation and Development
PAPI	Ordinary least squares
RESET	Provincial Governance and Public Administration Performance Index
REVAL	Regression equation specification error test
SBV	Real estate market value
SDI	State Bank of Vietnam
SEM	Sustainable Development Index
SOC	Structural equation modeling
VIF	Social pillar
WDI	Variance inflation factor
	World Development Indicators

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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