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Market Dynamics and Determinants of Commercial Real Estate Performance: Evidence from an Emerging Economy

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Abstract

This study examines commercial real estate market dynamics and valuation performance using an applied panel-data econometric framework within the context of an emerging market economy. While traditional valuation approaches primarily emphasize static income–capitalization relationships, they often overlook the combined influence of liquidity conditions, market risk, and macroeconomic environment on commercial real estate performance. The empirical analysis is based on a balanced panel dataset of commercial properties in Azerbaijan covering the period 2021–2025. The dataset includes net operating income, capitalization rates, liquidity conditions, market risk indicators, and macroeconomic variables. A two-equation modelling framework is employed to separate valuation determinants from capitalization rate dynamics, thereby reducing potential endogeneity between property values and return expectations. The empirical findings indicate that net operating income is consistently and positively associated with commercial property values across the estimated panel-data models. In addition, the results suggest that market liquidity and market risk provide complementary information for understanding commercial real estate performance within the analyzed emerging market setting. Higher values of the risk index are positively associated with capitalization rates, while the estimated relationship between market risk and property value remains sensitive to model specification. Macroeconomic variables exhibit limited statistical significance and are interpreted primarily as indicators of common market-wide conditions. The study contributes to the literature by applying an integrated panel-data framework to an illustrative emerging market case (Azerbaijan) while providing a transparent empirical framework that may be adapted to comparable commercial real estate markets.

Keywords: commercial real estate; market dynamics; econometric analysis; market liquidity; real estate risk



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1. Introduction

Commercial real estate markets constitute a fundamental component of modern urban economic systems and play an important role in investment allocation, business activity, financial intermediation, and regional economic development. Office buildings, retail facilities, logistics assets, and hospitality properties represent critical elements of commercial infrastructure and are closely connected to broader macroeconomic and financial conditions. Consequently, understanding the determinants of commercial real estate performance remains an important issue in both academic research and professional valuation practice.

Traditional commercial real estate valuation approaches are primarily grounded in the income capitalization theory, according to which property value is determined by the relationship between expected income streams and capitalization rates (Rosen, 1974; Wong et al., 2023). This framework remains widely applied because it directly links investment value to expected returns and cash flow generation. However, increasing empirical evidence suggests that commercial property performance cannot be fully explained through static income-based relationships alone. Market liquidity, investor expectations, macroeconomic volatility, and financial uncertainty also exert substantial influence on commercial real estate dynamics (Sagi, 2021; Dorinth et al., 2022).

Recent studies further demonstrate that inflation, interest rates, economic growth, and financial openness significantly affect real estate investment behaviour and asset-pricing mechanisms (Duca et al., 2021; Seti et al., 2025). In addition, liquidity conditions and market uncertainty influence transaction efficiency, capitalization dynamics, and investor-required returns, particularly in commercial property markets characterized by evolving institutional conditions and limited informational transparency (Spezzati et al., 2025). At the same time, commercial real estate markets exhibit strong interactions with broader economic systems and frequently respond to cyclical macroeconomic fluctuations, financial market conditions, and structural transformation processes (Wheaton, 1999; Edelstein & Edelstein, 2020). These interactions become particularly important in emerging economies, where institutional transition, lower market transparency, and macroeconomic sensitivity may significantly alter valuation dynamics relative to mature real estate systems.

Despite substantial progress in commercial real estate research, several important challenges remain. Many existing valuation models continue to rely primarily on income-capitalization relationships while giving comparatively limited attention to the combined influence of market liquidity, market risk, and macroeconomic conditions on commercial property performance. In addition, property-specific characteristics and market-wide factors are often analyzed separately, limiting the understanding of their joint contribution to valuation dynamics.

The contribution of the present study does not lie in proposing a new panel-data estimator. Instead, the novelty resides in the development of an integrated analytical framework that combines property-level fundamentals, composite market indicators, and complementary valuation and capitalization rate equations within a unified panel-data structure. This framework facilitates a more comprehensive empirical assessment of commercial real estate performance while mitigating one important source of simultaneity between property valuation and capitalization rate determination. The proposed framework is intended to be transparent, reproducible, and transferable to comparable emerging market settings.

These challenges are particularly relevant in emerging commercial real estate markets, where institutional development, market transparency, and macroeconomic conditions continue to evolve. Azerbaijan provides an appropriate empirical setting for examining these relationships because its commercial real estate market has experienced structural transformation, changing investment conditions, and increasing sensitivity to macro-financial developments during recent years. Accordingly, Azerbaijan is treated as an illustrative emerging market case rather than as a representative example of all emerging economies. The findings should therefore be interpreted within this specific institutional and economic context, while the proposed methodological framework is intended to be transferable to comparable market environments. The research gaps motivating the proposed econometric framework are discussed in the following literature review. Against this background, the present study develops an integrated panel-data econometric framework for analyzing commercial real estate performance. The proposed framework jointly considers income per-

formance, market liquidity, market risk, macroeconomic conditions, and property-specific characteristics within two complementary econometric equations. By analyzing property valuation and capitalization rate determination separately, the framework reduces potential simultaneity concerns and provides a clearer interpretation of the estimated relationships.

The study contributes to the existing literature in three principal respects. Rather than proposing a new econometric estimator, it integrates established panel-data techniques within a coherent analytical framework tailored to commercial real estate markets in an emerging market context. Second, it provides new empirical evidence from the Azerbaijani commercial real estate market, contributing to the relatively limited literature on emerging market commercial real estate. Third, it extends conventional income capitalization analysis by incorporating broader market conditions into the empirical assessment of commercial real estate performance while providing a transparent and reproducible analytical framework that may be adapted to comparable emerging market settings.

The remainder of the paper is organized as follows. Section 2 reviews the relevant literature and identifies the principal research gaps. Section 3 presents the econometric framework and model specification. Section 4 describes the dataset construction and variable measurement procedures. Section 5 reports the empirical results. Section 6 provides the graphical analysis, while Section 7 discusses the principal findings and their practical implications. Finally, Section 8 concludes the paper and outlines directions for future research.

The empirical findings should therefore be interpreted within the context of the 2021–2025 observation period, which primarily reflects post-COVID-19 commercial real estate market conditions rather than complete long-term market cycles.

2. Literature Review

2.1. Traditional Valuation Approaches

Commercial real estate valuation has traditionally been grounded in the income capitalization theory and hedonic pricing models. The classical income-based approach assumes that commercial property value is fundamentally determined by the present value of expected future income streams, adjusted by capitalization rates reflecting investor expectations and perceived market risk (Rosen, 1974; Poliakova & Kamenikova, 2023). Within this framework, net operating income and capitalization rates represent the core determinants of commercial property pricing. Earlier research also emphasized the importance of commercial real estate index construction and valuation measurement methodologies in improving empirical real estate analysis (Fisher et al., 1994).

The income capitalization approach remains widely used in both professional valuation practice and academic research due to its direct relationship with investment returns and market pricing mechanisms. However, conventional valuation models frequently assume relatively stable market conditions and efficient pricing environments, assumptions that may not fully hold in emerging or structurally transforming real estate systems.

In parallel, hedonic valuation models explain property values through structural, locational, and environmental characteristics. Previous studies have shown that variables such as accessibility, building quality, spatial centrality, and neighbourhood conditions significantly influence real estate prices (Pace & LeSage, 2004). These approaches improved the understanding of spatial heterogeneity in property markets and contributed to the development of modern real estate econometrics.

Despite their importance, traditional valuation models often focus predominantly on property-level characteristics and static pricing relationships. As a result, broader market dynamics, liquidity conditions, macroeconomic instability, and market risk are frequently

treated as secondary factors rather than being jointly incorporated into commercial real estate valuation frameworks.

Consequently, while traditional valuation theory provides an essential analytical foundation, it may not fully capture the complexity of commercial real estate dynamics operating under conditions of institutional transition, macroeconomic volatility, and evolving market structures.

2.2. Macroeconomic and Financial Drivers

The substantial body of literature demonstrates that commercial real estate markets are strongly influenced by macroeconomic and financial conditions. Inflation, interest rates, economic growth, and financial market stability directly affect investment decisions, borrowing costs, expected returns, and asset-pricing dynamics.

Previous studies indicate that declining interest rates generally stimulate commercial real estate demand by reducing financing costs and increasing the relative attractiveness of property investment (Duca et al., 2021). Conversely, inflation and macroeconomic instability may increase uncertainty regarding future cash flows and therefore affect capitalization rates and investment behaviour. Recent European evidence further illustrates that macroeconomic conditions, financial variables, and regional heterogeneity significantly influence commercial real estate pricing dynamics (Cunha & Lobão, 2021).

Research also emphasizes the cyclical interaction between real estate markets and broader economic systems. Real estate activity is closely linked to business cycles, credit expansion, and investment expectations (Wheaton, 1999; Edelstein & Edelstein, 2020). Periods of economic growth tend to support commercial property demand, while economic contractions may reduce liquidity, weaken investor confidence, and increase market risk.

More recent contributions have highlighted the importance of financial openness, structural transformation, and macroeconomic integration in shaping investment behaviour within emerging economies (Seti et al., 2025). These studies suggest that commercial real estate markets should not be analyzed in isolation from broader macro-financial systems.

Nevertheless, many existing studies examine macroeconomic variables independently from property-level valuation dynamics. As a result, the interaction between macroeconomic instability, market liquidity, and commercial property performance remains insufficiently integrated within a unified analytical framework.

2.3. Liquidity, Risk, and Market Dynamics

In recent years, increasing attention has been devoted to the role of liquidity and risk in commercial real estate markets. Market liquidity reflects the ease with which assets can be traded without causing substantial price distortions, while risk represents uncertainty associated with future returns, market volatility, and macroeconomic instability.

Empirical evidence indicates that liquidity conditions significantly influence commercial property valuation and capitalization dynamics (Dorin et al., 2022). Higher liquidity generally improves transaction efficiency, enhances price discovery, and reduces required returns, thereby supporting higher property valuations.

At the same time, risk and uncertainty exert substantial influence on investor expectations and required rates of return. Periods of elevated uncertainty often increase capitalization rates and reduce commercial property prices due to heightened risk premiums and lower investment confidence (Sagi, 2021).

Recent studies also emphasize that commercial real estate markets exhibit dynamic interactions between liquidity conditions, macroeconomic shocks, and market sentiment. These interactions become particularly important in emerging markets char-

acterized by lower market transparency, evolving institutional structures, and higher macroeconomic sensitivity.

Furthermore, contemporary research increasingly highlights the role of integrated econometric approaches capable of capturing multidimensional market dynamics rather than relying solely on static valuation relationships. Recent contributions published in real estate and financial economics journals emphasize the growing importance of panel-econometric modelling in analyzing complex interactions between risk, liquidity, and valuation performance (Kokot & Doszyń, 2024; Sevgen & Tanrivermiş, 2024; Łaszek, 2025).

However, despite these advances, the existing literature still lacks sufficiently integrated empirical frameworks that jointly examine liquidity conditions, market risk, macroeconomic factors, and property-level characteristics within a unified commercial real estate modelling framework.

2.4. Emerging Market Real Estate Systems

Commercial real estate dynamics in emerging markets differ substantially from those observed in mature economies. Emerging real estate systems are frequently characterized by evolving institutional frameworks, lower market transparency, higher macroeconomic volatility, and comparatively limited market depth.

Under such conditions, property valuation processes are more strongly influenced by uncertainty, liquidity constraints, investor sentiment, and structural transformation processes. Consequently, valuation relationships observed in mature markets may not necessarily apply in the same manner within transition-oriented economies.

Previous studies examining emerging market investment behaviour emphasize the importance of institutional quality, market risk, and structural economic conditions in shaping investment decisions and asset-pricing mechanisms (Neffati et al., 2025). Similarly, recent research demonstrates that macroeconomic openness, financial integration, and structural transformation significantly affect investment allocation and valuation outcomes in emerging economies (Seti et al., 2025). Previous studies also indicate that real estate market stability remains closely connected to broader financial system dynamics and macroeconomic resilience in emerging economies (Nguyen & Bui, 2020). Emerging markets also tend to exhibit stronger interactions between macroeconomic volatility and real estate pricing dynamics. Inflationary pressures, exchange rate instability, and fluctuating investment conditions may therefore generate more pronounced effects on capitalization rates and commercial property performance than in mature institutional environments.

At the same time, empirical evidence on commercial real estate systems in emerging economies remains relatively limited compared to the extensive literature available for developed markets. This limitation is particularly evident in transition-oriented urban economies characterized by rapid structural transformation and evolving commercial property sectors.

Consequently, further empirical and econometric research is needed to better understand how liquidity conditions, market risk, macroeconomic instability, and property-specific characteristics jointly shape commercial real estate performance within emerging market environments.

2.5. Research Gap and Theoretical Contribution

Although recent studies have considerably expanded our understanding of commercial real estate valuation, several practical and empirical challenges remain. First, many empirical studies continue to rely on relatively static valuation frameworks centred primarily on income–capitalization relationships. Although these approaches explain the link between income generation and property values, they often give limited attention to the

combined influence of liquidity conditions, market risk, and macroeconomic factors on valuation dynamics.

Second, previous studies frequently analyze property-specific characteristics and market-level conditions separately. As a result, the interaction between income performance, market liquidity, risk, and macroeconomic conditions is seldom examined within a unified panel-data framework.

Third, most empirical evidence is derived from mature real estate markets characterized by relatively stable institutional environments and high market transparency. Comparatively fewer studies investigate commercial real estate dynamics in emerging market economies undergoing structural transformation and evolving market institutions. Consequently, evidence from these markets remains relatively limited.

Finally, the relationship between property valuation and capitalization rates has received comparatively limited attention within integrated panel-data modelling frameworks. Rather than treating capitalization rates solely as explanatory variables, analyzing valuation performance and capitalization dynamics in separate but related equations provides a clearer interpretation of their respective determinants while mitigating potential simultaneity concerns.

To address these gaps, the present study develops an integrated panel-data econometric framework combining property-level characteristics with market-level conditions. The proposed framework jointly considers income performance, market liquidity, market risk, macroeconomic conditions, and property-specific attributes within two complementary econometric equations.

The study contributes to the commercial real estate literature in four principal ways. First, it builds upon established panel-data econometric methods by integrating property-level and market-level determinants within a unified empirical framework applicable to emerging commercial real estate markets. Second, it separates the analysis of property valuation and capitalization rate determination, thereby reducing potential simultaneity concerns and improving the interpretation of the estimated relationships. Third, it provides new empirical evidence from Azerbaijan as an emerging commercial real estate market characterized by institutional development and structural economic transformation. Finally, the study extends traditional income capitalization analysis by incorporating broader market conditions into the empirical assessment of commercial real estate performance.

Overall, the contribution of the study lies not only in identifying the determinants of commercial real estate performance but also in providing a transparent and reproducible econometric framework that may be adapted to other emerging commercial real estate markets with comparable institutional and economic characteristics.

These research gaps directly motivate the econometric framework presented in the following section.

2.6. Emerging Market Context and Theoretical Relevance of Azerbaijan

Azerbaijan provides a particularly relevant setting for analyzing commercial real estate dynamics in emerging markets due to several structural and institutional characteristics.

First, the Azerbaijani economy represents a transition-oriented emerging market characterized by relatively limited market transparency, evolving institutional structures, and comparatively low market depth in the commercial real estate sector. Under such conditions, property valuation processes are more strongly influenced by liquidity constraints, market uncertainty, and macroeconomic volatility than in mature real estate systems.

Second, Azerbaijan's macroeconomic structure is significantly influenced by energy sector dependence and external commodity price fluctuations. This creates a market environment in which inflation, interest rates, exchange rate expectations, and investment

sentiment may change relatively rapidly, thereby affecting capitalization rates, investor behaviour, and commercial asset pricing. Consequently, the Azerbaijani market provides a useful framework for examining how macroeconomic instability and market risk interact with property-level fundamentals.

Third, the commercial real estate market in Azerbaijan has experienced substantial post-pandemic restructuring, particularly in office, retail, and hospitality segments. Changes in transaction activity, investor expectations, and liquidity conditions have increased the importance of dynamic valuation approaches capable of incorporating both market-level and property-level determinants. Recent evidence also indicates that digital transformation and evolving investment behaviour are increasingly influencing real estate development trends and valuation practices in Azerbaijan's urban property market (Aliyev & Hashimova, 2025).

Unlike mature real estate markets characterized by higher institutional stability and greater informational transparency, emerging markets such as Azerbaijan often exhibit stronger interactions between liquidity conditions, risk perceptions, and valuation outcomes. This allows the present study to contribute not only to country-specific analysis but also to the broader literature on commercial real estate dynamics under conditions of structural transition and market uncertainty.

Therefore, Azerbaijan is treated as an illustrative empirical case that provides useful evidence for analyzing commercial real estate dynamics in comparable emerging market economies. Accordingly, the empirical conclusions should not be interpreted as universally representative of all emerging economies but rather as evidence generated from one emerging market setting with characteristics that may also be observed in comparable transition-oriented economies.

3. Methodology and Model Specification

3.1. Conceptual Framework

Commercial real estate performance is determined by the interaction between income generation, market conditions, investor expectations, and macroeconomic dynamics. In practical market environments, property valuation depends not only on current cash flow performance but also on liquidity conditions, perceived market risk, and broader economic stability.

This study adopts an integrated market dynamics perspective in which commercial real estate performance is modelled as a function of five principal groups of determinants:

1. income-based variables;
2. market liquidity conditions;
3. risk and uncertainty indicators;
4. macroeconomic variables;
5. property-specific characteristics.

The framework assumes that market participants form expectations based on both observed property income and prevailing economic conditions. Consequently, property values and capitalization rates are jointly influenced by liquidity, uncertainty, investor sentiment, and macroeconomic factors.

Unlike conventional static valuation approaches that focus primarily on income capitalization mechanisms, the present framework emphasizes the interaction between property-level fundamentals and market-level dynamics within an emerging market environment characterized by structural transformation and evolving institutional conditions. This conceptual structure provides the basis for the econometric specification developed in the following sections.

3.2. Model Specification

The empirical framework is designed to explain both commercial property valuation and capitalization rate dynamics while addressing the potential endogeneity arising from their theoretical interdependence.

The analysis is based on a two-equation panel-data framework. The first equation models commercial property value, while the second equation models capitalization rate dynamics separately. The objective of the present study is to identify economically meaningful conditional relationships rather than to establish strict causal inference.

3.2.1. Econometric Specification of the Property Value Model

The primary specification models commercial property value as a function of income performance, market liquidity, risk conditions, macroeconomic variables, and property-specific characteristics.

The model is specified as:

$$\ln V_{it} = \alpha + \beta_1 \ln NOI_{it} + \beta_2 LQ_{it} + \beta_3 RISK_t + \beta_4 INF_t + \beta_5 INT_t + \beta_6 GDPG_t + \beta_7 QUAL_{it} + \beta_8 QUAL_{it} + \beta_9 AGE_{it} + \beta_{10} \ln AREA_{it} + \mu_i + \varepsilon_{it} \quad (1)$$

where: μ_i denotes unobserved property-specific effects; ε_{it} is the idiosyncratic error term.

RISK is a normalized composite market risk index bounded between 0 and 1 and enters the econometric model in its original normalized form.

The dependent and explanatory variables included in the econometric model are formally defined in Appendix A, Table A3, whereas their theoretical rationale is discussed in Section 3.3. The construction and measurement of the composite indicators (LQ, RISK, LOC, and QUAL) are described separately in Section 4.2 and summarized in Appendix A (Table A4).

The explanatory variables are defined in Appendix A, Table A3, while their theoretical motivation and measurement procedures are discussed in Sections 3.3 and 4.2. The logarithmic transformation improves interpretability and allows several coefficients to be interpreted as elasticities.

3.2.2. Endogeneity Consideration

Endogeneity represents an important issue in commercial real estate econometric modelling due to the intrinsic relationship between property value, income generation, and capitalization rates.

Within the income capitalization framework, commercial property value can be expressed as:

$$V_{it} = \frac{NOI_{it}}{CR_{it}} \quad (2)$$

where: V_{it} denotes property value; NOI_{it} represents net operating income; CR_{it} denotes the capitalization rate.

These identities are presented only to illustrate the theoretical simultaneity between valuation and capitalization dynamics rather than to define the econometric specification itself.

The equations demonstrate that property value and capitalization rates are mechanically interrelated. Consequently, including capitalization rates directly as explanatory variables in the property value equation may generate simultaneity bias because capitalization rates are not strictly exogenous with respect to property value.

Formally, the standard exogeneity condition

$$E(\varepsilon_{it} | X_{it}) = 0 \quad (3)$$

may be violated due to the endogenous relationship between valuation and return dynamics. To reduce potential simultaneity concerns, the present study adopts a two-equation modelling framework in which capitalization rates are excluded from the main property value equation and estimated separately as dependent variables.

This modelling strategy separates the two outcomes conceptually and facilitates clearer interpretation, although it does not eliminate reverse causality or omitted-variable bias.

3.2.3. Econometric Specification of the Capitalization Rate Model

The capitalization rate equation is specified as:

$$CR_{it} = \gamma_0 + \gamma_1 RISK_t + \gamma_2 LQ_{it} + \gamma_3 INF_t + \gamma_4 INT_t + \gamma_5 GDPG_t + \gamma_6 LOC_{it} + u_{it} \quad (4)$$

where:

- CR_{it} denotes the capitalization rate;
- γ_0 represents the constant term;
- u_{it} denotes the error term.

The explanatory variables included in the model are defined in Table A3, while their theoretical motivation is discussed in Section 2.

The proposed econometric specification separates capitalization rate determination from the property value equation, thereby reducing one important source of simultaneity and facilitating a clearer interpretation of valuation and return adjustment mechanisms within commercial real estate markets.

3.3. Variable Definition and Measurement

The variables included in the empirical analysis are selected based on both theoretical relevance and practical applicability in commercial real estate markets.

Net Operating Income (NOI)

Net operating income represents the primary indicator of income performance and measures the net cash flow generated by the property.

Capitalization Rate (CR)

The capitalization rate reflects investor expectations and perceived risk. Due to its theoretical interdependence with property value, it is treated as a dependent variable in a separate equation.

Liquidity Index (LQ)

The liquidity index measures transaction activity and market depth, reflecting the relative ease of property transactions.

Risk Index (RISK)

The risk index captures macro-financial uncertainty and market volatility affecting valuation outcomes and required returns.

Macroeconomic Variables

Macroeconomic variables include inflation (INF), interest rates (INT), and economic growth (GDPG), which influence investment conditions and market dynamics.

Property-Specific Characteristics

Property-specific variables include building quality (QUAL), age (AGE), size (AREA), and location quality (LOC).

All variables are measured on an annual basis and harmonized across the panel dataset to improve temporal comparability and econometric consistency.

3.4. Estimation Strategy

The empirical analysis employs a panel-data econometric framework that accounts for both cross-sectional heterogeneity across properties and temporal variation over the period 2021–2025. Because the dataset consists of repeated property-year observations, relying exclusively on pooled ordinary least squares (OLS) may lead to biased estimates due to unobserved property-specific heterogeneity.

Accordingly, pooled OLS is estimated only as a benchmark specification, while the main empirical analysis is conducted using fixed effects and random effects panel estimators.

The fixed effects specification controls for time-invariant unobserved heterogeneity across properties, including structural characteristics, market segmentation effects, and locational advantages.

The fixed effects model is specified as:

$$\ln V_{it} = \alpha_i + \beta_1 \ln NOI_{it} + \beta_2 LQ_{it} + \beta_3 RISK_t + \beta_4 INF_t + \beta_5 INT_t + \beta_6 GDPG_t + \beta_7 LOC_{it} + \beta_8 QUAL_{it} + \beta_9 AGE_{it} + \beta_{10} \ln AREA_{it} + \varepsilon_{it} \quad (5)$$

where α_i represents property-specific fixed effects.

In the fixed effects specification, the unobserved property-specific component μ_i is absorbed into the individual intercept term α_i .

Time-invariant characteristics such as location quality are primarily absorbed through the property-specific fixed effects.

The random effects model is estimated as an alternative specification:

$$\ln V_{it} = \alpha + \beta X_{it} + u_i + \varepsilon_{it} \quad (6)$$

where:

- X_{it} denotes the vector of explanatory variables;
- u_i represents the random property-specific component.

The Hausman specification test is employed to evaluate whether the fixed effects or random effects estimator is more appropriate for the empirical analysis. The final model selection is based on the statistical properties of the estimators and the consistency assumptions underlying the panel-data framework. For the capitalization rate equation, a similar panel-data estimation framework is applied.

To improve statistical reliability, robust standard errors are employed throughout the empirical analysis.

In addition, several diagnostic and robustness tests are conducted to evaluate econometric validity. Variance inflation factors (VIF) are used to assess multicollinearity, while the Breusch–Pagan test, Wooldridge autocorrelation test, and Hausman specification test are employed to evaluate heteroskedasticity, serial dependence, and model consistency.

The estimation framework therefore addresses the principal limitations associated with pooled OLS estimation and provides a more robust econometric analysis of commercial real estate dynamics in emerging market conditions.

3.5. Replicability and Generalizability of the Proposed Framework

The proposed econometric framework has been designed to facilitate replication in other commercial real estate markets, particularly those operating under emerging market conditions. Although the empirical application is based on Azerbaijan, the methodological structure is not country-specific and can be readily adapted to other national or regional contexts.

Replication of the proposed framework involves five sequential steps:

1. Dataset construction. Compile a balanced panel dataset containing repeated observations of commercial properties over multiple years, including both property-level and macroeconomic information.
2. Variable measurement. Collect the core variables used in the analysis, namely property value, net operating income, capitalization rate, market liquidity, market risk, macroeconomic indicators, and property-specific characteristics.
3. Construction of synthetic indices. Develop composite indicators representing liquidity, market risk, location quality, and building quality. The indicators may be normalized using the min–max standardization procedure adopted in this study or other equivalent normalization techniques appropriate for the available data.
4. Econometric estimation. Estimate the two-equation panel-data model separating property value determination from capitalization rate dynamics. Alternative panel estimators (pooled OLS, fixed effects, and random effects) should be compared, and the final specification selected using appropriate specification tests, such as the Hausman test.
5. Model validation. Evaluate econometric reliability using standard diagnostic procedures, including multicollinearity diagnostics, heteroskedasticity tests, serial correlation tests, cross-sectional dependence tests, and robustness analysis.

Because these methodological steps rely on standard panel-data econometric techniques rather than country-specific institutional assumptions, the proposed framework can be applied to commercial real estate markets in other emerging European economies, provided that comparable property-level and macroeconomic data are available. Consequently, the framework offers a transferable analytical approach for investigating the interactions among income performance, liquidity conditions, market risk, and capitalization dynamics across different institutional and market environments.

The present study employs conventional panel-data estimators (pooled OLS, fixed effects, and random effects) because the empirical framework is static rather than dynamic. The estimated models do not include lagged dependent variables or dynamic adjustment processes that would normally motivate the application of generalized method of moments (GMM) estimators. Moreover, the balanced panel consists of five annual observations for each property ($T = 5$), providing a relatively short time dimension in which GMM estimation may suffer from instrument proliferation and reduced finite-sample efficiency. Accordingly, the selected panel-data estimators are considered appropriate for the objectives and structure of the present empirical analysis. The selected estimation strategy is therefore consistent with the objectives of the study, which emphasize structural relationships among property-level and market-level variables rather than dynamic adjustment mechanisms.

4. Data Description and Market Context

The empirical analysis is based on a structured panel dataset reflecting commercial real estate market conditions in Azerbaijan over the period 2021–2025. The dataset includes property-level observations for major commercial segments, including office, retail, logistics, and hospitality assets, observed across multiple years.

Each property is tracked over time using unique asset identifiers, resulting in a panel of property-year observations that combines both cross-sectional and temporal variation. This structure substantially increases the effective sample size compared to a simple cross-sectional dataset and enhances the robustness of the econometric analysis. Descriptive statistics and correlation diagnostics for the panel dataset are reported in Appendix A (Tables A1 and A2).

The data were constructed using market-based information derived from valuation reports, transaction evidence, and publicly available macroeconomic indicators. The dataset is designed to reflect realistic market conditions and captures variation across property types, locations, and time. The sample includes properties located in major urban areas, primarily Baku, as well as selected secondary cities such as Ganja and Sumgait, allowing the analysis to account for spatial heterogeneity in market activity and valuation dynamics.

The variables used in the model include net operating income, capitalization rates, liquidity indicators, risk measures, and macroeconomic variables such as inflation, interest rates, and GDP growth. Property-specific characteristics, including size, age, and location quality, are also incorporated. Given the panel structure of the dataset, sufficient variability is observed across both dimensions (cross-sectional and temporal), enabling the identification of stable relationships between income performance, market conditions, and valuation outcomes.

The selected time period reflects recent market developments, including post-pandemic adjustments and changes in financial and macroeconomic conditions. This ensures that the analysis captures contemporary and policy-relevant valuation dynamics in an emerging market context.

4.1. Dataset Construction and Sampling Procedure

The empirical analysis is based on a balanced panel dataset covering the period 2021–2025 and comprising commercial real estate observations from Azerbaijan. The sample includes office, retail, logistics, and hospitality properties located primarily in Baku, together with selected secondary regional business centres characterized by relatively active commercial real estate markets. Azerbaijan is employed as an illustrative emerging market case rather than as a representative sample of all emerging economies.

The final dataset consists of 84 individual commercial properties observed annually over five consecutive years, yielding a balanced panel of 420 property-year observations. The panel structure combines cross-sectional variation across individual commercial properties with temporal variation over the study period, allowing simultaneous examination of property-level characteristics and common market-wide conditions within a unified econometric framework.

A purposive sampling strategy was adopted because comprehensive transaction-level databases covering the entire commercial real estate market are not publicly available in Azerbaijan. Accordingly, properties were intentionally selected to ensure adequate representation of the principal commercial property categories and major urban business districts while maintaining consistent data availability throughout the observation period. The objective of the sampling procedure was therefore to construct a balanced analytical dataset rather than to obtain a statistically random sample of the underlying commercial property population. Consequently, the empirical findings should be interpreted within the context of the analyzed sample rather than as statistical inferences to the entire market population.

The panel entity is the individual commercial property rather than its owner or tenant. Consequently, changes in ownership, tenancy, or leasing status during the observation period do not alter the panel structure, provided that complete annual information remained available for the property throughout the study period.

Properties entered and remained in the sample only if complete annual information was available for all study variables throughout the 2021–2025 period. Properties with incomplete valuation records, inconsistent transaction evidence, or missing observations for the required explanatory variables were excluded during dataset construction. As a result, the final panel contains no missing observations.

The dataset was compiled from three principal sources:

1. commercial valuation reports prepared by professional valuation agencies;
2. transaction-based market evidence obtained from publicly available commercial real estate listings, brokerage reports, and transaction databases;
3. macroeconomic indicators obtained from official statistical publications and financial institutions.

For each commercial property, the database includes annual observations on market value, net operating income (NOI), capitalization rate (CR), location quality, building quality, property age, and gross floor area.

Net operating income (NOI) was measured as the annual operating income generated by each commercial property after deducting routine operating and maintenance expenses while excluding financing costs, depreciation, taxes, and capital expenditures. To reduce scale heterogeneity and facilitate elasticity interpretation, the natural logarithm of NOI was employed in the econometric analysis.

The capitalization rate (CR) was calculated using the conventional income–capitalization relationship as the ratio of annual net operating income to observed commercial property value. The capitalization rate therefore represents the market-based rate of return commonly used in commercial real estate valuation practice.

Macroeconomic variables include annual inflation (INF), benchmark interest rates (INT), and gross domestic product growth (GDPG). Because these variables vary only across years, they capture common macroeconomic conditions affecting all commercial properties rather than property-specific characteristics.

Several composite indicators were additionally constructed to represent broader market conditions and structural characteristics:

- the liquidity index (LQ) reflects relative transaction activity and market depth;
- the risk index (RISK) captures macro-financial uncertainty and market volatility;
- the location index (LOC) measures spatial accessibility and commercial attractiveness;
- the quality score (QUAL) represents the overall structural and functional condition of each commercial property.

To facilitate comparability across properties and years, all composite indicators were normalized using min–max normalization:

$$X_{it}^* = \frac{X_{it} - X_{min}}{X_{max} - X_{min}} \quad (7)$$

where X_{it}^* denotes the normalized value of variable X for property i observed in year t .

Prior to econometric estimation, the dataset was examined for internal consistency and potential outliers. Because the final dataset contains complete annual observations for all selected properties, no missing value imputation procedures were required. Outlier screening did not identify observations requiring exclusion, and the resulting dataset satisfied the consistency requirements for panel-data estimation. Descriptive statistics and additional diagnostic tests are presented in the following sections.

Although the macroeconomic variables exhibit variation only across the five annual observations, the balanced panel combines this temporal variation with substantial cross-sectional heterogeneity across 84 individual commercial properties. Consequently, the estimated macroeconomic coefficients should be interpreted as reflecting common market-wide conditions rather than precise property-specific effects. Their interpretation should therefore remain cautious given the relatively short observation period considered in the present study.

The relatively short time dimension of the balanced panel should be recognized when interpreting the empirical findings. Because the study period primarily reflects post-COVID-19 market adjustment, the estimated coefficients should not be interpreted as stable long-run parameters but rather as conditional relationships observed during this particular phase of market development.

4.2. Construction of Synthetic Indices

To capture multidimensional market characteristics that cannot be adequately represented by a single observable variable, four composite indicators were constructed: the liquidity index (LQ), risk index (RISK), location index (LOC), and quality score (QUAL). These indicators summarize key dimensions of commercial real estate market performance while improving the representation of latent market characteristics.

The composite indicators were constructed using a transparent four-step procedure consisting of: (i) variable selection, (ii) min–max normalization, (iii) equal-weight aggregation, and (iv) rescaling to the interval [0, 1]. Equal weighting was adopted because no reliable theoretical or empirical evidence was available to justify differential weighting, thereby avoiding subjective weighting assumptions and ensuring methodological transparency and reproducibility.

All component variables were normalized using the standard min–max transformation:

$$X_{it}^* = \frac{X_{it} - X_{\min}}{X_{\max} - X_{\min}} \quad (8)$$

where X_{it}^* denotes the normalized value of variable X for property i at time t , while $X_{\min}$ and $X_{\max}$ represent the minimum and maximum observed values within the sample.

The composite indicators enter the econometric models in their original normalized form and are not logarithmically transformed. In contrast, the continuous monetary variables property value, net operating income (NOI), and Property Area (AREA) are expressed in logarithmic form where appropriate to reduce scale heterogeneity, improve distributional properties, and facilitate elasticity interpretation.

It should be emphasized that logarithmic transformation and min–max normalization serve different methodological purposes. Logarithmic transformation addresses skewness in monetary variables, whereas normalization places variables measured on different scales onto a common dimension while preserving their relative variation. Consequently, the normalization procedure affects neither the direction nor the statistical significance of the estimated regression coefficients.

A detailed description of the construction procedure, raw input variables, normalization method, weighting scheme, and measurement of each composite indicator is provided in Appendix A (Table A4) to facilitate transparency and replication of the proposed analytical framework.

4.2.1. Liquidity Index (LQ)

The liquidity index measures relative market activity and transaction intensity in the commercial real estate market. It is derived as:

$$LQ_{it} = \frac{TR_{it} - TR_{\min}}{TR_{\max} - TR_{\min}} \quad (9)$$

where TR_{it} denotes the number of observed transactions or transaction activity associated with property i at time t .

Higher values of the liquidity index indicate more active market conditions, stronger transaction depth, and improved market efficiency.

4.2.2. Risk Index (RISK)

The risk index represents the relative macro-financial risk environment affecting commercial real estate performance during year (t). Because the available macroeconomic data are annual, the index is not constructed from rolling standard deviations or variance estimates. Instead, it combines normalized risk-related components observed for each year:

$$RISK_t = \sum_{j=1}^3 \omega_j Z_{jt}^*, \quad (10)$$

subject to

$$\sum_{j=1}^3 \omega_j = 1, \quad \omega_j \geq 0, \quad (11)$$

where Z_{jt}^* denotes the min-max-normalized value of risk component j in year t . The components include normalized inflation, interest rate conditions, and the market uncertainty indicator used in the dataset.

In the absence of objective empirical evidence supporting differential weighting, equal weights were adopted:

$$\omega_1 = \omega_2 = \omega_3 = \frac{1}{3} \quad (12)$$

Accordingly, the index is calculated as

$$RISK_t = \frac{INF_t^* + INT_t^* + MV_t^*}{3} \quad (13)$$

Higher values of $RISK_t$ indicate a comparatively less favourable macro-financial risk environment. The index enters the econometric models in its original normalized form and is not logarithmically transformed.

4.2.3. Location Index (LOC)

The location index measures the spatial attractiveness of commercial properties and is based on accessibility, urban centrality, and commercial concentration.

Because no reliable empirical evidence or established theoretical basis was available for assigning different levels of importance to these three dimensions, equal weighting was adopted. This approach provides a transparent, objective, and reproducible procedure while avoiding subjective weighting assumptions in the construction of the composite indicator.

Accordingly, the weighting coefficients satisfy $\sum_{j=1}^3 \lambda_j = 1$, where $\lambda_1 = \lambda_2 = \lambda_3 = \frac{1}{3}$

$$LOC_i = \lambda_1 A_i + \lambda_2 C_i + \lambda_3 U_i \quad (14)$$

where

- A_i denotes accessibility;
- C_i represents proximity to commercial centres;
- U_i reflects urban attractiveness.

Higher values indicate more favourable commercial locations.

4.2.4. Quality Score (QUAL)

The quality score reflects the structural and functional condition of commercial properties:

$$QUAL_i = \delta_1 S_i + \delta_2 F_i + \delta_3 M_i \quad (15)$$

where

- S_i represents structural condition;
- F_i denotes functional quality;
- M_i captures maintenance condition.

The index reflects the overall physical and operational quality of each commercial property. To ensure transparency, comparability, and methodological consistency, equal weighting schemes were adopted for all composite indicators. Accordingly, the weighting coefficients satisfy:

$$\sum_{k=1}^3 \lambda_k = 1, \quad \sum_{k=1}^3 \delta_k = 1 \quad (16)$$

where $\lambda_1 = \lambda_2 = \lambda_3 = \frac{1}{3}$ $\delta_1 = \delta_2 = \delta_3 = \frac{1}{3}$.

The equal weighting assumption is appropriate given the absence of sufficiently detailed market-level information required for statistically estimated weighting schemes. Normalization and Comparability.

All synthetic indicators were normalized to the interval $[0, 1]$ to improve comparability and reduce scale-related distortions in econometric estimation.

The use of synthetic indices allows the econometric framework to capture latent market characteristics that cannot be adequately represented by individual variables alone.

The resulting panel dataset therefore provides a structured empirical basis for analyzing commercial real estate valuation dynamics under emerging market conditions characterized by evolving institutional structures and macro-financial uncertainty.

5. Empirical Results

This section presents the estimation results of the two-equation econometric framework, focusing on the determinants of commercial real estate market performance and capitalization rate dynamics. The panel structure of the dataset enables the identification of both cross-sectional and temporal variation in the key variables.

5.1. Main Property Value Model

Table 1 reports the random effects estimation results for the property value equation. Robust standard errors, statistical significance levels, and diagnostic measures are presented to facilitate comparison across the estimated model specifications.

The estimated coefficient of $\ln NOI$ is positive and highly statistically significant, indicating a strong positive association between operating income and commercial property value. The logarithmic specification allows the coefficient to be interpreted as an elasticity, implying that proportionate increases in net operating income are associated with proportionate increases in commercial property value, consistent with the conventional income capitalization theory.

The estimated coefficient of the liquidity index (LQ) is positive in the preferred random effects specification but does not achieve conventional levels of statistical significance. This result indicates that, after controlling for unobserved property-specific heterogeneity, the available evidence does not support a statistically robust independent association between liquidity conditions and commercial property values.

The estimated coefficient of the risk index (RISK) is negative and statistically significant in the preferred random effects specification, indicating that higher market risk is associated with lower commercial property values. This relationship should be interpreted as a conditional empirical association rather than as evidence of a causal effect.

Table 1. Random effects estimation results for the property value model. Dependent variable: $\ln(\text{Property Value})$.

Variable	Coefficient	Robust Std. Error	z-Statistic	p-Value
Intercept	3.088 ***	0.473	6.524	<0.001
lnNOI	1.057 ***	0.037	28.759	<0.001
LQ	0.482	0.301	1.602	0.109
RISK	−2.074 ***	0.467	−4.446	<0.001
INF	−0.613	0.633	−0.969	0.332
INT	1.689	2.308	0.732	0.464
GDPG	−0.061	0.574	−0.106	0.915
LOC	−0.255 ***	0.090	−2.819	0.005
QUAL	−0.002	0.002	−1.224	0.221
AGE	0.0036 ***	0.0013	2.829	0.005
lnAREA	−0.107 ***	0.031	−3.451	0.001
Model statistics.				
Statistic		Value		
Estimator		Random effects GLS		
Dependent variable		$\ln(\text{Property Value})$ (Table 1)/Capitalization Rate (Table 2)		
Observations		420		
Panel entities		84		
Time periods		5		
Average observations per entity		5.0		
Model selection		Random effects estimator selected according to the Hausman specification test.		

Notes: The dependent variable is the natural logarithm of commercial property value. Robust standard errors are reported. The random effects estimator was selected based on the Hausman specification test. Pooled OLS is reported as a benchmark specification, while fixed effects estimation is presented in the robustness analysis. Statistical significance is denoted by *** ($p < 0.01$). The random effects specification preserves both cross-sectional and temporal variation within the panel dataset while accounting for unobserved heterogeneity across property-level observations.

Table 2. Random effects estimation results for the capitalization rate model. (a) Dependent variable: capitalization rate (CR). (b) Model statistics.

(a)				
Variable	Coefficient	Robust Std. Error	z-Statistic	p-Value
Intercept	0.078 **	0.033	2.374	0.018
RISK	0.206 ***	0.032	6.434	<0.001
LQ	−0.105 ***	0.028	−3.794	<0.001
INF	0.021	0.061	0.347	0.728
INT	−0.084	0.222	−0.379	0.705
GDPG	0.029	0.065	0.443	0.658
LOC	0.032 ***	0.009	3.500	<0.001
(b)				
Statistic		Value		
Estimator		Random effects GLS		
Observations		420		
Panel entities		84		
Time periods		5		
Average observations per entity		5.0		
Model selection		Random effects estimator selected according to the Hausman specification test.		

Notes: The dependent variable is the capitalization rate (CR). Robust standard errors are reported. The random effects estimator was selected as the preferred specification based on the Hausman specification test). Pooled OLS is reported as a benchmark specification, while fixed effects estimation is presented in the robustness analysis. Statistical significance is denoted by *** ($p < 0.01$), ** ($p < 0.05$).

Among the macroeconomic control variables, inflation, interest rates, and economic growth exhibit comparatively limited statistical significance within the analyzed sample. Given the relatively short observation period (2021–2025), these variables primarily capture common annual macroeconomic conditions rather than long-run macroeconomic effects. The estimated coefficients of the property-specific variables indicate that commercial property values are also associated with locational and structural heterogeneity across the Azerbaijani commercial real estate market. Differences observed across alternative panel-data specifications suggest the presence of unobserved property-specific characteristics that are only partially captured by the available explanatory variables.

Overall, the estimated random effects model indicates that commercial property values are statistically associated with income performance together with selected market-level and property-level characteristics. The broader economic interpretation of these relationships is discussed in Section 5.5.

5.2. Capitalization Rate Model

The second equation examines the determinants of capitalization rate dynamics within the commercial real estate market. The estimation results are presented in Table 2.

The econometric estimates indicate statistically significant associations that are broadly consistent with theoretical expectations regarding liquidity, market risk, and commercial real estate performance.

The empirical findings indicate that the risk index ($RISK_t$) exerts a strong positive and statistically significant effect on capitalization rates. This result is fully consistent with financial and real estate theory, according to which higher market uncertainty increases investor-required returns and risk premiums. The magnitude and statistical significance of the estimated coefficient indicate a statistically significant association between market risk and capitalization rates. This finding is consistent with theoretical expectations that higher market risk is associated with higher required returns in commercial real estate markets.

The liquidity index (LQ_{it}) exhibits a negative and statistically significant relationship with capitalization rates. This finding suggests that more liquid commercial real estate markets are associated with lower required returns due to improved transaction efficiency, reduced uncertainty, and stronger market depth. The result further is consistent with the broader argument that liquidity conditions constitute an important determinant of commercial real estate performance beyond traditional income–capitalization relationships.

Among the macroeconomic variables, inflation (INF_t), interest rates (INT_t), and economic growth ($GDPG_t$) display comparatively weaker statistical significance within the estimated specification. These findings indicate that, after controlling for liquidity conditions and market risk, the direct short-run effects of macroeconomic fluctuations on capitalization rates appear relatively limited within the analyzed sample.

The location index (LOC_{it}) demonstrates a positive and statistically significant relationship with capitalization rates. This result suggests that premium commercial locations may simultaneously support stronger asset values and higher investor return expectations. In emerging commercial real estate markets, highly attractive business districts are often characterized by elevated acquisition costs, stronger market sensitivity, and greater exposure to cyclical investment dynamics. Consequently, location quality may increase both valuation potential and required returns.

Overall, the capitalization rate model indicates the importance of market risk, liquidity conditions, and spatial heterogeneity in determining investor expectations and required returns within emerging commercial real estate markets.

5.3. Econometric Interpretation and Model Validity

The empirical results indicate that the panel-data framework provides an appropriate empirical structure for analyzing commercial real estate performance within the observed dataset. By exploiting both the cross-sectional variation across individual commercial properties and the temporal variation over the 2021–2025 period, the panel-data framework provides more efficient and informative estimation than conventional cross-sectional approaches.

Separating the property value equation from the capitalization rate equation helps mitigate one important source of simultaneity associated with modelling these two dependent variables jointly. Nevertheless, this modelling strategy does not eliminate all potential sources of endogeneity, including reverse causality and omitted-variable bias. Accordingly, the estimated coefficients should be interpreted as conditional empirical associations rather than definitive evidence of causal relationships.

The overall consistency of the estimated coefficients across the pooled OLS, random effects, and fixed effects specifications provides additional confidence regarding the robustness of the principal empirical findings. Although some coefficients vary in statistical significance across alternative specifications, their estimated signs remain broadly consistent with theoretical expectations.

Taken together, these results suggest that the proposed econometric framework provides a stable empirical basis for analyzing commercial real estate performance within the observed sample. The broader economic interpretation of the estimated relationships is presented in Section 5.5, while their practical implications are discussed in Section 7.

5.4. Diagnostic Tests and Robustness Checks

To evaluate the econometric reliability and robustness of the estimated models, several diagnostic procedures were conducted within the panel-data framework. These tests were designed to assess multicollinearity, heteroskedasticity, serial correlation, cross-sectional dependence, and specification consistency.

First, multicollinearity among the explanatory variables was examined using variance inflation factors (VIF). The results are reported in Table 3.

Table 3. Multicollinearity diagnostics.

Variable	VIF
lnNOI	2.84
LQ	1.97
RISK	3.41
INF	4.82
INT	5.37
GDPG	2.16
QUAL	1.74
AGE	1.52
lnAREA	2.09

All reported VIF values remain below the conventional threshold of 10, while most are also below the more conservative threshold of 5 suggested in parts of the recent econometric literature. Although the interest rate variable exhibits a VIF value slightly above 5 (5.37), the overall diagnostics do not indicate severe multicollinearity that would materially compromise the stability or interpretation of the estimated coefficients. Although inflation and interest rates exhibit relatively strong pairwise correlation, the corresponding VIF statistics remain within acceptable econometric limits. Consequently, these variables were retained in the final specification due to their theoretical relevance and stable empirical behaviour.

Second, the validity of the panel-data specification was evaluated using several diagnostic tests. The results are summarized in Table 4.

Table 4. Panel diagnostic tests.

Test	Statistic	<i>p</i> -Value	Conclusion
Breusch–Pagan Test	14.26	0.003	Heteroskedasticity detected
Wooldridge Autocorrelation Test	1.91	0.174	No severe autocorrelation
Hausman Specification Test	6.74	0.241	Random effects model preferred
Pesaran CD Test	0.87	0.382	No significant cross-sectional dependence

The Breusch–Pagan test indicates the presence of heteroskedasticity within the panel dataset. Accordingly, robust standard errors were employed throughout the empirical analysis to improve statistical reliability and ensure consistent inference.

The Wooldridge autocorrelation test does not indicate severe serial dependence after controlling for entity-specific effects. Similarly, the Pesaran cross-sectional dependence test suggests that cross-sectional dependence across panel entities is not statistically significant within the analyzed sample.

The Hausman specification test does not provide sufficient statistical evidence to reject the null hypothesis that unobserved entity-specific effects are uncorrelated with the explanatory variables. Consequently, the random effects estimator is adopted as the preferred specification for the main empirical analysis because it preserves both cross-sectional and temporal variation within the panel dataset while accounting for unobserved heterogeneity across property-level observations.

To further evaluate robustness, pooled ordinary least squares (OLS), random effects, and fixed effects estimators were additionally compared. The robustness comparison is reported in Table 5.

Table 5. Robustness comparison across alternative specifications (dependent variable: lnV).

Variable	Pooled OLS	Random Effects	Fixed Effects
lnNOI	1.047 *** (0.037)	1.008 *** (0.042)	0.981 *** (0.061)
LQ	0.258 (0.279)	0.070 (0.258)	−0.044 (0.337)
RISK	−2.049 *** (0.470)	0.033 (0.471)	0.485 (0.483)
INF	−0.752 (0.625)	−1.653 *** (0.431)	−1.848 *** (0.483)
INT	1.791 (2.345)	−0.385 (1.594)	−1.044 (1.845)
GDPG	−0.047 (0.607)	−0.064 (0.450)	−0.047 (0.527)
QUAL	−0.002 (0.002)	0.000 (0.001)	0.000 (0.001)
AGE	0.004 *** (0.001)	−0.001 (0.001)	−0.002 (0.001)
lnAREA	−0.105 *** (0.033)	−0.015 (0.046)	0.023 (0.066)

Notes: Standard errors are reported in parentheses. Statistical significance at the 1% level is denoted by ***. Pooled OLS is reported as a benchmark specification. Random effects and fixed effects estimators are implemented using city–segment panel entities. The random effects specification is adopted as the primary empirical model, whereas the fixed effects estimator serves as a robustness check to assess the sensitivity of the estimated coefficients to unobserved entity-level heterogeneity.

The comparison demonstrates that net operating income remains positive and statistically significant across all specifications, confirming the stability of the core valuation relationship. Several market-level and property-level variables exhibit sensitivity across alternative estimators, indicating that part of their explanatory power is absorbed by unobserved entity-specific heterogeneity. This result further is consistent with the importance of panel-data modelling in analyzing commercial real estate dynamics within emerging market conditions.

The estimated models retain all theoretically motivated explanatory variables irrespective of their individual statistical significance. The objective of the empirical analysis is explanatory rather than predictive, and the model specification was established a priori on theoretical and empirical grounds rather than through data-driven variable selection procedures. Consequently, variables with limited statistical significance were retained to avoid omitted-variable bias and to preserve the conceptual consistency of the proposed analytical framework.

The preferred specification reported in Table 1 retains all theoretically motivated explanatory variables. The objective of the study is to evaluate a conceptually specified econometric framework rather than to derive a reduced prediction-oriented model based solely on statistical significance. Consequently, explanatory variables were selected a priori according to economic theory and previous commercial real estate literature. Retaining theoretically relevant variables also reduces the risk of omitted-variable bias and facilitates consistent interpretation of the estimated relationships across alternative panel-data specifications.

Overall, the diagnostic and robustness procedures confirm the validity, consistency, and econometric reliability of the revised panel-data framework. Additional robustness estimations and supplementary diagnostic results are reported in Appendix A.

5.5. Econometric Interpretation

The estimated random effects models provide a coherent empirical description of commercial real estate performance within the observed Azerbaijani market. Rather than identifying strict causal relationships, the estimated coefficients characterize statistically significant conditional associations between commercial property values and the selected property-level and market-level variables.

The results are broadly consistent with the conventional income capitalization framework, while also suggesting that commercial property valuation is associated with broader market conditions beyond operating income alone. In particular, the estimated relationships indicate that market risk, property characteristics, and selected market conditions provide additional explanatory information regarding commercial real estate performance within the analyzed sample.

The estimated coefficients associated with property-specific characteristics highlight the importance of structural heterogeneity across commercial properties. The negative coefficient of the location index may reflect differences between mature central business districts and developing secondary commercial areas, whereas the positive coefficient of property age is consistent with the presence of established commercial locations within Baku. Similarly, the negative coefficient of property size suggests that larger commercial properties may experience relatively lower valuation efficiency because of reduced market liquidity and higher operating complexity.

The relatively weak statistical significance of the macroeconomic variables should be interpreted in the context of the five-year observation period. Because inflation, interest rates, and economic growth vary only across years, these variables primarily capture common annual market conditions rather than long-run macroeconomic effects. Consequently, their estimated coefficients should be interpreted cautiously and should not be viewed as precise estimates of long-run macroeconomic elasticities.

Finally, although separating the valuation and capitalization rate equations mitigates one important source of simultaneity, residual endogeneity arising from reverse causality and omitted-variable bias cannot be completely excluded. Accordingly, the reported coefficients should be interpreted as conditional empirical associations rather than definitive evidence of causal relationships. Future studies employing longer panel datasets and causal

identification strategies, such as instrumental variable or dynamic panel-data approaches, would provide a useful extension of the present analysis.

The sensitivity of the risk index coefficient across alternative panel estimators indicates that the valuation effect of market risk depends on the treatment of unobserved heterogeneity and should therefore be interpreted with appropriate caution.

Given the relatively short observation period and the exceptional post-COVID-19 economic environment, the estimated coefficients should be interpreted with appropriate caution. The present study is not intended to identify complete long-run commercial real estate cycles but rather to analyze conditional associations observed during a period of substantial market adjustment and macro-financial transition.

6. Graphical Analysis

To complement the econometric results and provide a clearer interpretation of the relationships between key variables, graphical analysis is employed. The figures presented in this section are constructed based on the empirical dataset described in Section 4.

The graphical representations illustrate the relationships between commercial property value and its main determinants, including net operating income, market liquidity, and risk indicators. These visualizations are intended to support the interpretation of the econometric findings and to highlight underlying trends and patterns in the data. The figures are developed using the same dataset applied in the econometric analysis. The underlying numerical values and descriptive statistics used for constructing the figures are provided in Appendix A (Tables A1–A3). This ensures transparency and allows for verification of the graphical results. The graphical analysis serves as a visual validation of the econometric results. Figure 1 presents the evolution of the commercial real estate price index over the 2021–2025 period, illustrating the general pattern of market development observed in the panel dataset.

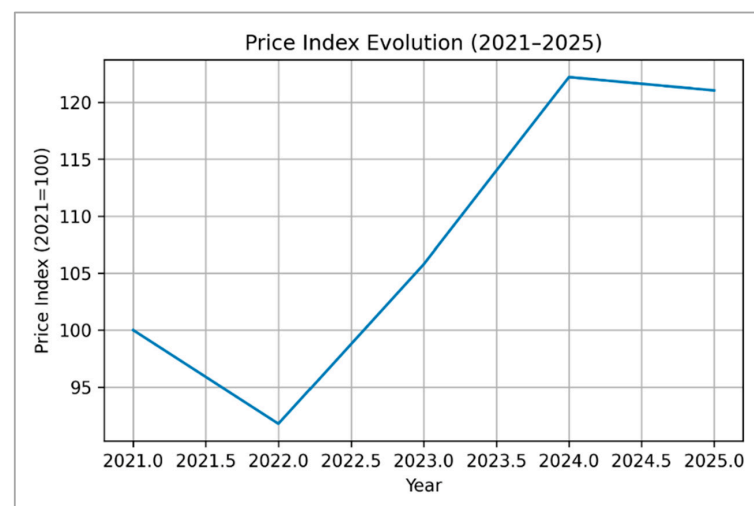


Figure 1. Evolution of the commercial real estate price index (2021–2025) (panel dataset).

The index is constructed based on the average price per square metre, normalized to 100 in 2021. The figure illustrates the dynamic evolution of commercial real estate prices over time, reflecting market adjustments, post-pandemic recovery, and changes in macroeconomic conditions. The upward trend indicates a gradual increase in property values, accompanied by moderate fluctuations driven by market conditions.

Figure 2 presents the unconditional bivariate association between the liquidity index (LQ) and commercial property value. Unlike the panel regression estimates reported in Table 1, the graphical analysis does not control for unobserved property-specific het-

erogeneity or additional explanatory variables. Consequently, the graphical relationship should be interpreted as descriptive rather than causal evidence.

Each point represents a property-year observation within the commercial real estate dataset. The solid line denotes the fitted simple linear regression, while the shaded area represents the 95% confidence interval. The positive slope suggests a generally favourable association between market liquidity and commercial property values. However, this relationship should be interpreted with caution because it does not account for the additional explanatory variables and unobserved heterogeneity incorporated in the panel-data models.

The relatively modest coefficient of determination ($R^2 = 0.22$) indicates that liquidity alone explains only a limited proportion of the observed variation in commercial property values. Accordingly, the graphical analysis provides descriptive evidence only, whereas statistical inference is based on the multivariate panel-data estimations reported in Tables 2–5. The panel regression results indicate that, although the estimated liquidity coefficient is positive, it is not statistically significant in the preferred random effects specification.

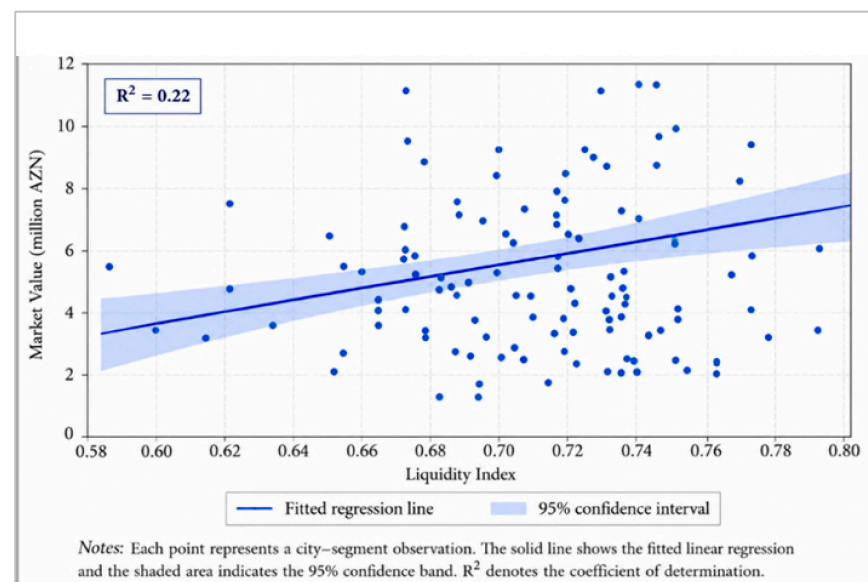


Figure 2. Liquidity vs. Property Value.

Unconditional bivariate relationship between the liquidity index (LQ) and commercial property value. The regression line and the associated 95% confidence band illustrate the simple cross-sectional association without controlling for property-specific heterogeneity or other explanatory variables included in the panel regression models. Note: The regression line represents a simple bivariate ordinary least-squares fit and is presented for visualization purposes only. Statistical inference is based on the panel-data estimations reported in Tables 3 and 4.

Figure 3 illustrates the relationship between the Risk Index (RISK) and the capitalization rate, providing a graphical representation of the positive association observed in the econometric analysis.

Each point represents a city–segment observation. The solid regression line illustrates the positive relationship between the market risk index and capitalization rates, whereas the shaded region denotes the 95% confidence interval associated with the estimated regression. The upward trend suggests that higher market uncertainty increases investor-required returns and capitalization dynamics within the commercial real estate market. The graphical analysis is consistent with the econometric results reported in Table 2 and visually illustrates the positive association between the composite risk index and capitalization rates

observed in the Azerbaijani commercial real estate market. The coefficient of determination ($R^2 = 0.49$) indicates moderate explanatory power, implying that market risk is one of several factors statistically associated with capitalization rate variation. These graphical results should be interpreted as descriptive evidence complementing the econometric analysis rather than as evidence of causal relationships.

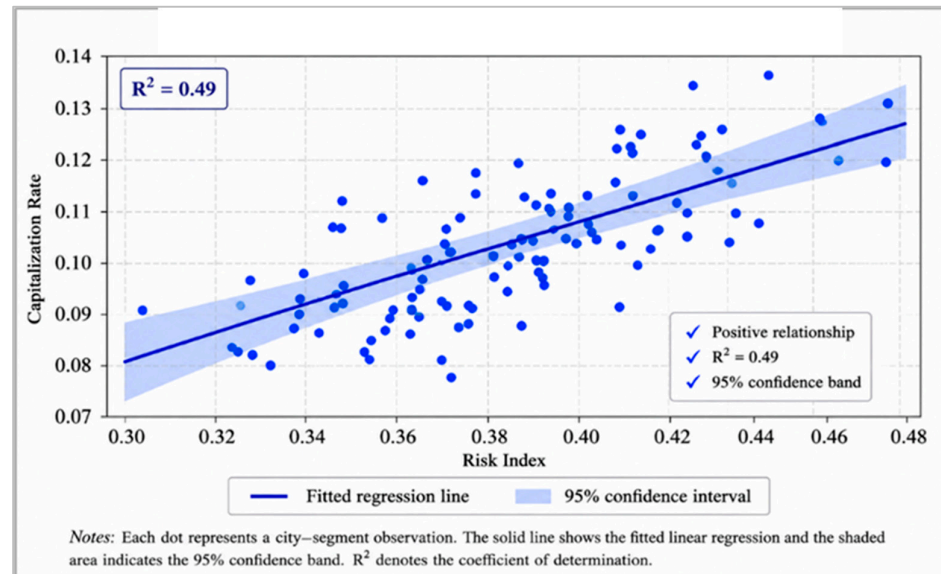


Figure 3. Relationship between market risk and capitalization rate (panel dataset).

Figure 4 illustrates the positive association between net operating income and commercial property value. The relatively high coefficient of determination ($R^2 = 0.78$) is expected within the conventional income capitalization framework because commercial property value and net operating income are inherently related through capitalization principles. Accordingly, the graphical relationship should be interpreted as a descriptive illustration of this theoretical association rather than as independent evidence of variable importance or explanatory power.

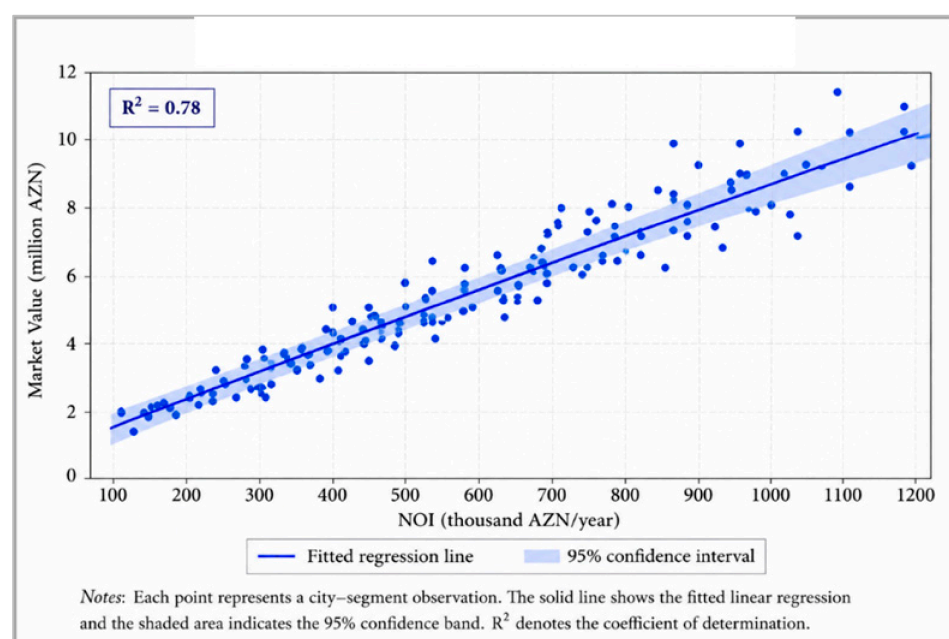


Figure 4. Relationship between net operating income and commercial property value (panel dataset).

Each point represents an individual commercial property observation within the panel dataset. The solid line corresponds to the fitted regression line, while the shaded area represents the 95% confidence interval around the estimated relationship. The observed positive relationship is consistent with the econometric results reported in Table 1 and with the theoretical expectations of the income capitalization framework.

7. Discussion and Practical Implications

The empirical findings have several practical implications for commercial real estate valuation, investment decision-making, and public policy within emerging market environments. For valuation professionals, the results suggest that commercial property assessment should consider not only income performance but also broader market conditions, including market risk, liquidity conditions, and selected property-specific characteristics. Incorporating these complementary factors may improve the consistency of valuation analyses under changing market conditions.

For investors, the estimated relationships emphasize the importance of evaluating both property-level fundamentals and prevailing market conditions when assessing commercial real estate opportunities. Although operating income remains strongly associated with commercial property value, the empirical results indicate that market risk and liquidity conditions also provide useful information regarding expected investment performance and capitalization behaviour. Consequently, investment decisions may benefit from combining conventional income-based valuation methods with broader market indicators.

From a policy perspective, the findings underline the importance of improving market transparency, strengthening information availability, and maintaining a stable macro-financial environment. Measures aimed at reducing information asymmetry and enhancing market efficiency may contribute to more reliable property valuation and improved investment confidence within commercial real estate markets.

The proposed econometric framework also provides a methodological contribution. By estimating separate valuation and capitalization rate equations within a panel-data framework, the analysis offers a transparent empirical structure for examining property-level and market-level relationships while mitigating one important source of simultaneity between property values and capitalization rates. Although the framework does not eliminate all potential endogeneity concerns, it provides a reproducible analytical approach that can be adapted to comparable emerging market settings.

Several limitations should be acknowledged. First, the empirical analysis is based on annual observations covering the period 2021–2025, which limits the identification of long-run macroeconomic effects. Second, although the modelling strategy reduces simultaneity by estimating separate valuation and capitalization rate equations, residual endogeneity arising from reverse causality and omitted-variable bias cannot be completely excluded. Third, the empirical evidence is derived from the Azerbaijani commercial real estate market and should therefore be interpreted as an illustrative emerging market case rather than as universally representative of all emerging economies.

Future research may extend the proposed framework by employing longer panel datasets, incorporating additional emerging market economies, and applying more advanced causal identification strategies, such as instrumental variable estimation or dynamic panel-data models. Comparative cross-country analyses would also provide valuable evidence regarding the generalizability of the proposed methodological framework under different institutional and market conditions.

8. Conclusions

This study investigates commercial real estate market dynamics by developing an integrative econometric framework that distinguishes between valuation drivers and capitalization rate dynamics. By separating these relationships, the study addresses potential endogeneity associated with the traditional income capitalization framework and provides a more consistent empirical basis for analyzing commercial real estate markets. The empirical findings indicate that net operating income consistently exhibits a positive and statistically significant association with commercial property value across the estimated panel-data specifications, in accordance with the conventional income capitalization framework. The results further suggest that liquidity conditions, market risk, and broader macroeconomic environment contribute to commercial real estate dynamics, although the magnitude and statistical significance of these effects vary across alternative panel-data specifications. In particular, liquidity conditions support transaction activity and market depth, while market risk influences capitalization dynamics and investor return expectations.

The principal methodological contribution of the study is the proposed integrated analytical framework rather than the introduction of a new econometric estimator. The framework combines established panel-data techniques with composite market indicators and complementary valuation equations to provide a coherent empirical approach for analyzing commercial real estate performance in emerging market environments.

The proposed two-equation modelling approach provides an important methodological contribution by improving the reliability of econometric estimation and offering a clearer interpretation of how market conditions, investor expectations, and structural market characteristics jointly influence commercial real estate performance.

From a practical perspective, the findings highlight the importance of adopting a multidimensional analytical framework that integrates income performance with liquidity conditions, market risk, and macroeconomic environment. This is particularly relevant in emerging market commercial real estate systems, where structural volatility and limited market transparency amplify the role of uncertainty and market heterogeneity.

Despite these contributions, the study has certain limitations related to dataset scope and market coverage. Future research may extend the analysis to larger panel datasets, alternative econometric specifications, and cross-country comparisons to further validate the proposed framework.

Overall, the results suggest that commercial real estate valuation should be analyzed not only through traditional income capitalization perspectives, but also within a broader framework of liquidity conditions, market risk, macro-financial interactions, and evolving market dynamics.

Although the empirical analysis is based on commercial real estate data from Azerbaijan, the proposed econometric framework is intended to provide a transparent methodological approach that may be adapted and validated using comparable datasets from other emerging market economies.

Although the empirical analysis is based on Azerbaijan, the findings should be interpreted within the institutional and economic context of this illustrative case. Future comparative studies involving multiple emerging economies would be valuable for evaluating the external validity and broader generalizability of the proposed framework.

A further limitation concerns the potential presence of residual endogeneity arising from reverse causality and omitted-variable bias. Although the proposed modelling strategy mitigates one important source of simultaneity, future studies may employ instrumental variable or dynamic panel-data approaches to strengthen causal identification.

Future research may further extend the proposed framework by employing instrumental variable, dynamic panel, or generalized method of moments (GMM) estimators to address potential endogeneity more comprehensively. In addition, the relatively short time dimension of the panel limits the variation in the macroeconomic variables. Future studies based on longer observation periods may provide more precise estimates of long-run macroeconomic effects.

An important limitation of the present study is the relatively short five-year panel covering the post-COVID-19 adjustment period. Consequently, the estimated relationships should not be interpreted as stable long-run parameters or complete representations of commercial real estate market cycles. Future research based on longer panel datasets spanning multiple economic cycles would provide an important opportunity to evaluate the temporal stability and external validity of the proposed analytical framework.

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Abbreviations

The following abbreviations are used in this manuscript:

AZN	Azerbaijani Manat: estimated market value of commercial properties
NOI	Net Operating Income
CR	Capitalization Rate
LQ	Liquidity Index
RISK	Risk Index
INF	Inflation
GDP	Gross Domestic Product
GDPG	GDP Growth
LOC	Location Index
QUAL	Quality Score
AGE	Age: property age in years
AREA	Area: total usable floor space

Appendix A

This appendix provides the dataset used for the econometric estimation and graphical analysis presented in the study. The data include observations on commercial real estate properties across different segments, including office, retail, logistics, and hospitality assets, over the period 2021–2025.

The dataset was constructed using a combination of valuation reports, transaction evidence, and publicly available macroeconomic indicators. It captures both cross-sectional variation across properties and time-series variation over the study period.

Table A1. Descriptive statistics of key variables (panel dataset).

Variable	Description	Unit	Mean	Std. Dev.	Min	Max
Property Value (V)	Commercial property value per square metre	AZN	1351	441	674	2617
NOI	Net operating income	Thousand AZN/year	440	207	119	1133
CR	Capitalization rate	%	10.04	1.32	7.56	13.28
RISK	Market risk index	Index	0.37	0.04	0.30	0.47
LQ	Market liquidity index	Index	0.70	0.04	0.58	0.80
INF	Inflation rate	%	7.08	4.12	2.20	13.90
INT	Interest rate	%	8.90	1.07	7.50	10.50
GDPG	GDP growth	%	3.82	1.51	1.10	5.60
LOC	Location index	Index	0.77	0.07	0.64	0.91
QUAL	Building quality	Index	0.82	0.05	0.72	0.92
AGE	Building age	Years	11.48	6.29	2	22
AREA	Property size	m ²	3505	1763	938	7974

Note: The values are computed directly from the panel dataset of property-year observations covering the period 2021–2025.

The relatively limited dispersion of composite market indicators reflects the annual aggregation structure and normalization procedure applied to market-level variables. NOI values are reported in annualized nominal terms.

Table A2. Correlation matrix of key variables.

Variable	lnV	lnNOI	CR	RISK	LQ	INF	INT	GDPG
lnV	1.00	0.74	−0.68	−0.49	0.46	−0.28	−0.31	0.18
lnNOI	0.74	1.00	−0.21	−0.17	0.24	−0.08	−0.11	0.22
CR	−0.68	−0.21	1.00	0.77	−0.63	0.54	0.49	−0.06
RISK	−0.49	−0.17	0.77	1.00	−0.61	0.73	0.69	−0.04
LQ	0.46	0.24	−0.63	−0.61	1.00	−0.38	−0.35	0.16
INF	−0.28	−0.08	0.54	0.73	−0.38	1.00	0.91	−0.09
INT	−0.31	−0.11	0.49	0.69	−0.35	0.91	1.00	0.21
GDPG	0.18	0.22	−0.06	−0.04	0.16	−0.09	0.21	1.00

Note: The table reports pairwise correlations computed from the balanced panel dataset. Logarithmic transformations are applied to property value and net operating income variables to improve econometric comparability with the estimated panel-data models.

The correlation matrix provides preliminary evidence regarding the direction and relative strength of linear associations among the principal variables included in the econometric analysis. Despite the relatively strong correlation between inflation and interest rates, multicollinearity diagnostics reported in Table 3 indicate acceptable VIF levels within

the estimated specifications. Pairwise correlations should not be interpreted as causal relationships because the panel-data estimations additionally control for entity-specific heterogeneity and temporal effects.

Table A3. Definition and measurement of variables.

Variable	Description	Measurement
Property Value	Market value of property	Monetary units
NOI	Net operating income	Annual income
Cap Rate	Capitalization rate	Ratio (%)
Liquidity	Market activity indicator	Index
Risk	Composite risk indicator	Index
Inflation	Consumer price index change	%
Interest Rate	Lending rate	%

Note: The variables included in the model are defined based on standard real estate valuation practice and economic theory. The selected indicators capture both property-level characteristics and broader market conditions.

The construction of the composite indicators follows a transparent and replicable procedure to facilitate application of the proposed framework in other emerging commercial real estate markets.

Table A4. Construction of Composite Market Indicators.

Composite Indicator	Concept Measured	Raw Input Variables	Measurement Procedure	Weighting Approach	Final Scale
Liquidity Index (LQ)	Market activity, transaction intensity, and market depth	Number of observed transactions; transaction activity from commercial listings; brokerage-based market evidence	Transaction activity indicators were normalized using min–max standardization and aggregated to represent relative liquidity conditions across property-year observations	Equal weighting where multiple liquidity components were available	0–1
Risk Index (RISK)	Macro-financial uncertainty and market volatility	Inflation volatility; interest rate variability; observed market-price/transaction volatility	Annual macro-financial and market-volatility components were normalized and combined to capture relative uncertainty affecting investor expectations and required returns	Equal weighting due to limited market-level information for statistically estimated weights	0–1
Location Index (LOC)	Spatial attractiveness and commercial accessibility	Accessibility; proximity to commercial centres; urban centrality/commercial concentration	Each location component was scored and normalized using min–max standardization; the normalized components were aggregated into a composite location score	Equal weighting: ($\lambda_1 = \lambda_2 = \lambda_3 = 1/3$)	0–1
Quality Score (QUAL)	Structural and functional quality of commercial assets	Structural condition; functional quality; maintenance condition	Each quality component was assessed from valuation records and normalized; the normalized components were aggregated into a composite quality score	Equal weighting: ($\delta_1 = \delta_2 = \delta_3 = 1/3$)	0–1

Notes: All composite indicators are normalized to the interval [0, 1], where higher values indicate stronger liquidity, higher market risk, better location quality, or higher building quality, respectively. Equal weighting is adopted to avoid excessive parameterization and because sufficiently detailed market-level information required for statistically estimated weighting schemes is not available. The composite indicators are used to capture latent market characteristics that cannot be adequately represented by single observed variables.

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