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REAL ESTATE CHALLENGES UNDER CLIMATE CHANGE AND DEVELOPMENT CONSTRAINTS

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ABSTRACT

Climate change is reshaping the risk, return, and liquidity profile of real estate assets worldwide. Drawing on a structured narrative review, this article develops a Climate–Finance–Infrastructure (CFI) Interaction Framework to synthesize evidence on how physical climate risks and varying levels of economic development jointly affect real estate markets. The analysis focuses on three transmission channels—insurability, financing, and infrastructure—and compares their behavior across tropical versus temperate climates and developed versus developing economies. Existing evidence shows that rising exposure to heat, floods, and storms reduces insurance availability, raises premiums, and widens protection gaps; tightens credit conditions via higher lending margins, lower loan-to-value ratios, and shorter maturities; and places growing stress on protective and basic infrastructure systems. These pressures are systematically amplified in lower-income tropical settings, where weaker infrastructure, patchy maintenance, and limited public compensation mechanisms undermine resilience. In contrast, more mature markets can partly cushion impacts through adaptation investments, stricter building standards, and advanced risk-transfer instruments. The CFI framework highlights self-reinforcing feedbacks between these channels and identifies "climate-finance traps" in which climate exposure, infrastructure deficits, and risk-averse capital reinforce one another, particularly in tropical low- and middle-income economies. By mapping evidence into a four-quadrant typology (climate zone × development level) and illustrating it in several urban cases, the finding offers a diagnostic tool for investors, lenders, and policymakers to prioritize adaptation investments, redesign insurance and credit products, and align infrastructure and financial regulation with the realities of a warming climate.

Keywords: *Climate risk, Real estate markets, Insurance and Insurability*

TANTANGAN USAHA PROPERTI DITINJAU DARI PERUBAHAN IKLIM DAN TINGKAT PEMBANGUNAN

ABSTRAK

Perubahan iklim mengubah profil risiko, imbal hasil, dan likuiditas aset properti di seluruh dunia. Artikel ini meggunakan tinjauan naratif terstruktur untuk mengembangkan kerangka interaksi Iklim–Keuangan–Infrastruktur (Climate-Finance-Infrastructure/CFI) untuk mensintesis pengaruh perubahan iklim dan tingkat perkembangan ekonomi pada usaha pasar properti. Analisis dilakukan pada tiga faktor: asuransi, pembiayaan, dan infrastruktur, dan membandingkan pengaruhnya pada negara-negara beriklim tropis dan iklim sedang, serta kondisi dengan ekonomi maju dan ekonomi berkembang. Hasil analisis menunjukkan bahwa peningkatan risiko terhadap cuaca panas, banjir, dan badai mengurangi ketersediaan asuransi, menaikkan premi, dan mengurangi opsi perlindungan. Hal ini juga menyebabkan margin pinjaman yang lebih tinggi, rasio pinjaman terhadap nilai yang lebih rendah, dan jangka waktu pinjaman yang lebih pendek, dan mengakibatkan tekanan yang semakin besar pada sistem perlindungan dasar infrastruktur. Tekanan ini tampak jelas di lingkungan tropis berpendapatan rendah, akibat infrastruktur yang masih lemah, pemeliharaan yang tidak merata, dan mekanisme kompensasi publik yang terbatas. Pada kondisi pasar yang lebih matang, sebagian dampak yang terjadi dapat dihindari melalui investasi yang adaptif, standar bangunan yang lebih ketat, dan cara-cara mengatasi risiko yang lebih baik. Analisis kerangka kerja CFI ini menitikberatkan umpan balik yang saling memperkuat antara faktor-faktor tersebut dan mengidentifikasi "jebakan iklim–finansial" di mana paparan terhadap perubahan iklim, kondisi infrastruktur yang kurang baik, dan keengganan pemodal untuk mengambil risiko, saling memperkuat satu sama lain. Dengan menggunakan pemetaan ke dalam tipologi empat kuadran (zona iklim × tingkat perkembangan ekonomi) analisis ini menawarkan alat diagnostik bagi investor, pemberi *pinjaman, dan pembuat kebijakan untuk memprioritaskan investasi yang adaptif, merancang ulang produk asuransi dan kredit, serta menyelaraskan regulasi di bidang infrastruktur dan keuangan pada saat dihadapkan pada permasalahn akibat perubahan iklim.*

Kata kunci: *Risiko iklim, Pasar properti, Asuransi dan Kelayakan Asuransi*

1. INTRODUCTION

Climate change poses a fundamental threat to the stability and valuation of global real estate markets by altering the risk, return, and liquidity profiles of property assets. Yet markets do not face these physical threats on a level playing field. Their adaptive capacity is critically mediated by economic development and institutional strength, which shape the ability to bear risks through insurance, finance risks through credit, and mitigate risks through infrastructure.

While a substantial literature has examined climate impacts on insurance, credit, and infrastructure in isolation, this siloed approach fails to capture the feedback mechanisms and interconnected transmission channels through which risks propagate. This gap is particularly pronounced across different climatic and developmental contexts, leading to a fragmented understanding of systemic vulnerability in real estate markets.

Against this background, the central research question of this article is: How do insurance markets, credit systems, and infrastructure quality interact to amplify or mitigate climate risks in real estate markets across different climate zones and development levels? The article is a structured narrative review that develops a conceptual framework and a diagnostic tool rather than an empirical econometric study. It combines a structured literature search across Scopus, Web of Science, and EconLit with comparative indicators and focused case illustrations from Southern India, Bali, and urban China.

This article makes three main contributions. First, it develops the Climate–Finance–Infrastructure (CFI) Interaction Framework, which integrates the channels of insurability, financing, and infrastructure to model their feedback loops and identify self-reinforcing climate–finance traps. Second, it synthesizes fragmented evidence into a systematic four-quadrant typology (climate zone × development level), providing a comparative diagnostic tool to assess market-specific vulnerabilities. Third, it proposes the Resilience Capacity Index (RCI) as a practical device for stakeholders and derives concrete implications for investors, lenders, and policymakers to prioritize adaptation and redesign financial products. The focus is on physical climate risks for real estate; transition risks and purely macroeconomic impacts remain outside the scope.

2. CLIMATE RISK AND DEVELOPMENT CHALLENGES IN REAL ESTATE

2.1 Climate risk transmission channels

Physical climate risks affect real estate through several intertwined mechanisms. A growing body of research shows that increasing heat stress, flood exposure, and storm damage can erode property cash flows by raising operating costs, triggering additional capital expenditures for adaptation, and increasing required discount rates through higher risk premia (Ling et al., 2024; Bienert, 2014). Conventional valuation and risk models have often treated these hazards as stationary, even though there is mounting evidence that their statistical properties are changing under climate change, introducing deep uncertainty that standard approaches struggle to capture (IPCC, 2022; ClimateX, 2025).

The existing evidence base also exhibits clear geographic and climatic biases. Studies on advanced, temperate markets predominantly focus on riverine and coastal flooding, wildfire, and incremental sea-level rise, while research on tropical regions places greater emphasis on cyclones, storm surges, and coastal erosion. This dichotomy often obscures converging risk profiles—such as rising flood and heat extremes in both temperate and tropical cities—and tends to underplay the role of institutional capacity and development level in shaping how physical risks translate into financial outcomes (Ling et al., 2024; Savills, 2025a). These gaps motivate the need for an integrated framework that jointly considers climatic and developmental dimensions rather than treating hazards in isolation.

2.2 Insurance channel

The first transmission channel operates through insurance markets. Insurability depends on the ability to quantify risk, price coverage, access reinsurance, and operate within regulatory constraints. As physical climate risks intensify, insurance markets increasingly rely on granular risk-based pricing, higher deductibles, narrower coverage, and stricter underwriting in high-exposure zones. While this can improve risk signalling, it frequently widens insurance protection gaps, particularly in low- and middle-income countries where baseline insurance penetration is low and informal housing is prevalent (European Central Bank, 2025; Golnaraghi, 2023).

A key limitation in the protection-gap literature is that many studies rely on aggregate comparisons of insured and economic losses without disentangling the roles of affordability, availability, regulatory design, and risk awareness. Case evidence of insurance withdrawal or sharp repricing in high-risk zones illustrates how correlated losses and reinsurance constraints can generate abrupt changes in coverage, with limited empirical insight into the longer-term feedbacks that shape resilience or vulnerability (Ling et al., 2024; Climate Foresight, 2025).

2.3 Credit and capital-market channel

The second transmission channel runs through credit markets and capital allocation. Climate risk can affect real estate finance through higher lending margins, lower loan-to-value ratios, shorter maturities, stricter collateral requirements, and tighter covenants in high-risk locations (Ling et al., 2024). Where physical risks are credibly integrated into risk models, expected losses and collateral haircuts increasingly reflect exposure to floods, heat, and storms, particularly for long-lived assets such as real estate (European Central Bank, 2025; UNEP FI, 2025).

Empirical findings, however, are not uniform. While some studies document clear climate-related spread premia and quantity restrictions, others find weak or delayed price signals, attributing this to information frictions, regulatory constraints, relationship banking, or expectations of public disaster support. These responses can be procyclical: anticipated valuation declines trigger credit tightening, which further depresses investment and prices, especially under non-stationary risk (Ling et al., 2024; ECB, 2025). Such dynamics are likely to be more severe in developing economies where banking systems are highly collateral-based and access to long-term capital is limited.

2.4 Infrastructure channel

The third transmission channel hinges on infrastructure quality. Protective systems such as flood defences and drainage, together with reliable basic services, play a central role in moderating realised losses and recovery times. Well-maintained infrastructure can stabilise occupancy, rental income, and financing conditions, while underinvestment and fragmented governance can transform moderate hazards into systemic shocks (Hallegatte & Rentschler, 2019; Ling et al., 2024).

Empirical evidence shows that jurisdictions combining capital investment with robust operations and maintenance experience lower loss ratios and faster recovery. Nevertheless, infrastructure resilience is often proxied by coarse indices that fail to capture local service reliability, and few studies quantify how infrastructure performance feeds back into insurance pricing or credit availability. This limits the ability to treat infrastructure not merely as a background condition but as an integral component of financial risk transmission (Savills, 2025a; European Central Bank, 2025).

2.5 Limitations of existing approaches

Despite substantial progress, current approaches to climate-related financial risk in real estate remain fragmented. Insurance analyses focus on protection gaps, credit studies on pricing and collateral, and infrastructure research on physical performance, with limited integration across these domains. Backward-looking hazard statistics remain common, heterogeneous definitions hamper cross-country comparison, and asset-level exposure data are scarce in many regions. As a result, the feedback loops connecting insurance, finance, and infrastructure are still only partially understood and rarely analysed within a unified framework (Ling et al., 2024; NGFS, 2025; Climate Foresight, 2025).

2.6 The Climate–Finance–Infrastructure (CFI) interaction framework

Building on the reviewed literature, this section develops the Climate–Finance–Infrastructure (CFI) Interaction Framework as the paper’s central conceptual contribution. Physical climate hazards affect real-estate outcomes through three interacting channels—insurability, financing conditions, and infrastructure quality—embedded within broader climatic and developmental contexts. These channels interact through mutually reinforcing feedbacks: rising hazard intensity can increase insurance premiums or trigger coverage withdrawal; lenders respond by tightening credit terms; constrained access to finance limits investment in protective infrastructure; and infrastructure deficits amplify realised losses, further undermining insurability and credit availability (Hallegatte & Rentschler, 2019; European Central Bank, 2025).

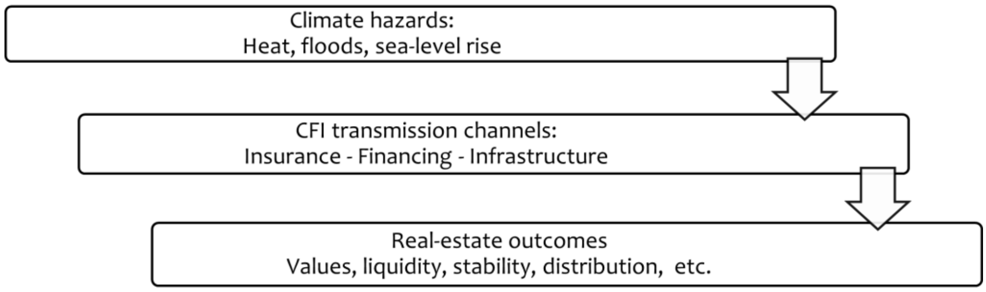

Figure 1: Climate–Finance–Infrastructure (CFI) Interaction Framework

Table 1 summarises the three CFI dimensions, indicative indicators, and typical data sources. In operational terms, the framework can be summarised through a conceptual Resilience Capacity Index (RCI) that combines indicative measures of insurance penetration and affordability, risk-sensitive financing conditions, and infrastructure coverage and reliability. In this article, the RCI is used as a diagnostic lens rather than a fully estimated index, with the purpose of clarifying how climate zone and development level shape resilience capacity across markets.

Table 1: Dimensions of CFI

Dimension	Key Indicators	Measurement Metrics	Data Sources
Insurability	• Insurance penetration • Protection gap • Premium affordability • Coverage completeness	• % of GDP • Insured vs. economic losses • Premium-to-income ratios • Deductible levels & exclusions	• National regulators • Reinsurance reports • World Bank datasets
Financing	• Risk-adjusted lending terms • Credit availability • Collateral valuation • Loan performance	• LTV ratios • Interest rate premiums • Debt service coverage • Default rates by hazard zone	• Central bank reports • Loan-level data • Credit registries
Infrastructure	• Protective capacity • Maintenance quality • System reliability • Adaptive governance	• Drainage capacity indices • O&M expenditure ratios • Downtime metrics • Institutional scores	• Municipal reports • Infrastructure audits • World Governance Indicators

The framework's theoretical contribution lies in formalising climate–finance–infrastructure interactions as a coherent system that explains why similarly exposed markets can experience divergent trajectories. By integrating insurance, finance, and infrastructure into a single analytical lens and embedding this lens within a two-dimensional climate–development typology, the CFI framework identifies conditions under which markets move toward adaptive responses or become locked into self-reinforcing climate–finance traps (Ling et al., 2024; Hallegatte & Rentschler, 2019).

3. METHODS

This article adopts a structured narrative review to synthesise how physical climate risks affect real estate markets through three interacting transmission channels: insurance (insurability), finance (credit conditions and capital allocation), and infrastructure (protective and service systems). Rather than estimating pooled effect sizes through a formal meta-analysis, the objective is to transparently compare mechanisms and contextual differences across climate zones (tropical versus temperate) and levels of economic development (high-income versus developing and emerging economies) using the Climate–Finance–Infrastructure (CFI) Interaction Framework.

The literature search combined peer-reviewed academic research with selected institutional and policy reports. Academic studies were identified through Scopus, Web of Science, and EconLit, covering the period 2000–2024. Search strings combined climate-hazard and physical-risk terms (e.g. climate change, physical risk, flood, heat, storm, sea-level rise) with real estate and financial market terms (real estate, housing, mortgage, property values, insurance, credit, infrastructure). In addition, targeted searches were conducted for reports issued by central banks, international financial institutions, and supervisory bodies that explicitly address physical climate risk, real estate exposure, insurance markets, or financial stability.

The screening process followed three steps. First, titles and abstracts were reviewed to remove clearly irrelevant records. Second, full texts were assessed against predefined inclusion criteria. Publications were retained if they (i) focused on physical climate risks rather than transition risks alone; (ii) established a direct link to real estate, housing markets, or closely related infrastructure; and (iii) analysed at least one of the three CFI dimensions—insurability, financing conditions, or infrastructure quality. Studies that discussed abstract climate-risk pricing without a real-estate application, or that reported aggregate macroeconomic damage estimates without market-level outcomes, were excluded. For institutional reports, preference was given to sources with transparent methodologies or clearly documented data sources.

For each selected publication, information was recorded on geographical focus, climate zone, development level, dominant hazard type, market segment, and key findings related to insurance, financing, and infrastructure. These elements were qualitatively coded to enable comparison across contexts and to identify recurring patterns, conflicting findings, and evidence gaps. In particular, each study was coded for (i) dominant hazard type, (ii) primary CFI transmission channel, (iii) country group defined by climate zone and income level, and (iv) the direction and relative strength of effects on real-estate outcomes.

The synthesis proceeds in three steps. First, evidence is summarised separately for each CFI dimension across country groups. Second, interactions between insurance, finance, and infrastructure are analysed to identify self-reinforcing climate–finance traps. Third, these patterns are organised into a comparative four-quadrant typology and used to motivate the Resilience Capacity Index and the subsequent discussion of adaptation pathways and policy implications.

Hypotheses

H1 (Insurability). The insurance protection gap relative to climate exposure is largest in lower-income markets where high hazard intensity coincides with limited insurance penetration and fiscal capacity, while higher-income markets are more likely to maintain narrower gaps through broader risk pools and public–private backstops (European Central Bank, 2025).

H2 (Premiums and underwriting). Increases in climate-related losses lead to higher insurance premiums and stricter underwriting in high-risk zones, particularly in tropical regions, but these effects are moderated by regulatory design, solidarity mechanisms, and access to reinsurance and capital-market risk transfer (Golnaraghi, 2023; IAIS, 2025).

H3 (Financing). Lenders respond to elevated climate risk by tightening lending terms—higher margins, lower loan-to-value ratios, shorter maturities, and stricter covenants—especially where physical risk is integrated into credit assessment and where financial systems rely heavily on collateral (Ling et al., 2024; UNEP FI, 2025).

H4 (Infrastructure). Higher-quality and well-maintained infrastructure reduces expected losses and service disruptions, improving insurability and easing financing constraints, with particularly strong effects in high-exposure and lower-income settings (Hallegatte & Rentschler, 2019; IPCC, 2022).

H5 (Adaptation payoff). Adaptation investments can stabilise cash flows and protect asset values, but the realised payoff depends on whether resilience improvements are recognised by insurance and credit markets and supported by governance systems that sustain operations and maintenance over time (Hallegatte & Rentschler, 2019; UNEP FI, 2025).

Although structured, this methodology has limitations. The review is restricted to English-language sources and to a selected set of databases and institutions, which may under-represent local studies and non-English evidence. The synthesis is qualitative and does not estimate pooled effect sizes or formal meta-analytic statistics. Moreover, the underlying evidence remains unevenly distributed across regions and sectors, with stronger coverage for high-income temperate markets than for many tropical developing economies. These limitations, and their implications for the strength of the conclusions, are revisited in the section on robustness and research needs.

4. RESULTS AND DISCUSSION

4.1 Empirical evidence and comparative analysis

The reviewed evidence indicates that physical climate risks affect real estate through three tightly linked channels—insurance, credit/finance, and infrastructure—whose interactions can amplify or dampen vulnerability depending on development level, governance capacity, and investment space (Hallegatte & Rentschler, 2019; Ling et al., 2024). Rather than operating independently, shocks in one domain often spill over into the others, shaping market outcomes such as asset values, liquidity, and access to finance.

Table 2: Selected empirical evidence on climate risk, real estate and CFI channels

Study (author, year)	Region/country & context	Hazard type	Primary CFI channel(s)	Key finding for real estate	Quadrant/RCI implication
Bernstein, Gustafson & Lewis (2019)	Coastal US, high income	Sea-level rise	Financing	Homes exposed to sea-level rise sell for approximately 7% less than unexposed, comparable properties; discount driven by sophisticated buyers.	Low RCI, emerging climate-finance trap (Quadrant 1/2)
Baldauf, Garlappi & Yannelis (2020)	United States, high income	Flooding	Information & Beliefs	Disclosure of flood risk leads to a price discount in exposed properties, but only if buyers believe the scientific consensus on climate change.	Information asymmetry drives RCI; belief-dependent valuation.
Murfin & Spiegel (2020)	United States, high income	Flooding, storms	Insurance	Mortgage credit supply decreases in areas with high climate risk, but only after major disasters make the risk salient to lenders.	"Wake-up call" effect; high climate risk, low RCI post-disaster.
Ortega & Taspinar (2018)	Miami-Dade, US – subtropical, high income	Sea-level rise	Financing	Rising sea levels caused a sharp increase in the number of low-price home sales and a decrease in high-price sales in higher-elevation areas.	Market segmentation; high climate risk, declining RCI in exposed sub-markets.
Billings, Gallagher & Ricketts (2022)	Boulder County, US – temperate, high income	Wildfire	Insurance & Regulation	After a destructive wildfire, property values increased inside a new, stricter "wildfire urban interface" code area due to perceived safety benefits.	High climate risk, high resilience (Quadrant 3); robust regulation stabilizes prices.
Gibbons, Mourato & Resende (2014)	London, UK – temperate, high income	River flooding	Information & Infrastructure	Property prices are discounted by 1-2% in high-flood-risk areas, but this discount is largely eliminated by the presence of robust flood defenses.	High climate risk, high resilience (Quadrant 3); public infrastructure underpins RCI.

4.2 Cross-country patterns in insurance, finance, and infrastructure

4.2.1 Insurance

Across market contexts, protection gaps widen where affordability constraints, limited risk pooling, and reinsurance capacity issues restrict coverage in high-risk zones. High-income markets typically sustain higher penetration through diversified risk transfer and public–private arrangements, while lower-income markets face larger uninsured exposures and stronger reliance on informal coping and fiscal relief (European Central Bank, 2025; Golnaraghi, 2023). In Indonesia-linked contexts, this matters because limited insurance uptake can translate into household-level fragility and post-disaster fiscal pressure, even when asset values are high in tourism corridors (Warren, 2012).

4.2.2 Finance

Credit responses range from risk-based repricing to outright rationing. In mature markets, studies document that risk recognition can appear in spreads, collateral haircuts, and lending standards—often with "wake-up call" dynamics after salient disasters (Murfin & Spiegel, 2020; Ling et al., 2024). In many developing markets, the dominant margin is frequently access rather than price: smaller developers and households may face exclusion from formal credit in exposed areas, pushing financing into higher-cost or informal channels (Amos, 2015; Ogedengbe, 2003).

4.2.3 Infrastructure

Infrastructure quality is a key moderator of realised losses and recovery speed. Evidence from resilient "lifeline" systems shows that well-maintained drainage, coastal protection, and reliable services reduce disruption and indirectly stabilise insurance and financing conditions (Hallegatte & Rentschler, 2019). Conversely, deferred maintenance and fragmented governance can convert moderate hazards into systemic shocks that undermine occupancies, cash flows, and collateral performance.

4.2.4 Conflicting findings and explanatory factors

The empirical literature does not yield a single uniform pricing signal. Some studies report significant price discounts or tighter credit conditions in exposed areas, while others find muted or delayed effects. Differences are partly explained by: (i) measurement choices (coarse indices vs. asset-level exposure), (ii) hazard type (slow-onset risks capitalised more weakly than acute floods or storms), and (iii) institutional context, including disclosure rules, insurance regulation, and expectations of public support (Baldauf et al., 2020; Bernstein et al., 2019; Ling et al., 2024). These heterogeneities justify the comparative approach used here: evidence is interpreted through the CFI lens and organised by climate zone and development level to separate structural differences from data and method artefacts.

4.3 Resilience Capacity Index (RCI) and comparative patterns

The comparative evidence suggests that development level often differentiates resilience capacity more strongly than climate zone alone, because it conditions insurance depth, credit system sophistication, and the ability to invest in and maintain infrastructure (Warren, 2012; Hallegatte & Rentschler, 2019). To operationalise this insight, the article introduces a Resilience Capacity Index (RCI) as a diagnostic device that maps markets across three dimensions: (i) insurance penetration/protection gaps, (ii) climate-sensitive financing conditions, and (iii) infrastructure reliability and maintenance capacity. The RCI is not intended as a definitive quantitative ranking; it is used to structure comparison and to clarify where "climate–finance traps" are more likely.

4.3.1 Four-quadrant typology of market responses

Building on the RCI logic, market responses can be organised into a four-quadrant typology along two axes—climate zone (temperate vs. tropical) and development level (high-income vs. low/middle-income):

- Quadrant I (Temperate, high-income): repricing and regulatory intervention; strong reinsurance and building codes.
- Quadrant II (Temperate, low/middle-income): underinsurance and reliance on public/donor support; constrained capital and uneven enforcement.
- Quadrant III (Tropical, high-income): selective withdrawal and price spikes in exposed segments; greater use of specialised covers and private adaptation.
- Quadrant IV (Tropical, low/middle-income): systemic underinsurance/uninsurability and credit rationing; coping relies more on informal risk sharing and external support.

Table 3: Four-quadrant typology

Quadrant	Climate Zone	Development Level	Characteristic Pattern	Dominant Risk Response
I	Temperate	High-income Country	Premium repricing, regulation	Reinsurance, building codes
II	Temperate	Low/Middle-income Country	Underinsurance, public reliance	Public pooling, donor aid
III	Tropical	High-income Country	Price spikes, selective withdrawal	Parametric covers, private adaptation
IV	Tropical	Low/Middle-income Country	Systemic unisurability, credit rationing	External aid, community coping

4.3.2 Case illustrations

Bali (Quadrant IV tendency in high-value coastal assets). Bali illustrates how high-exposure coastal development can face constraints in insurability and finance when protection and maintenance are uneven and when risk is concentrated locally. The key mechanism is not hazards alone but the interaction between coverage limitations, lender requirements, and infrastructure stress, which can increase equity demands and reduce leverage in exposed locations (Warren, 2012; Hallegatte & Rentschler, 2019; Angelina, 2025).

Southern India (Quadrant II/IV features with infrastructure leverage). Evidence on urban drainage and flood management demonstrates how infrastructure upgrades can reduce disruption and improve the viability of insurance and lending, suggesting a pathway from vulnerability toward resilience when investment and maintenance are sustained (Hallegatte & Rentschler, 2019; Ling et al., 2024).

Urban China (Quadrant III features). China provides an illustration of how operational risks (e.g., drought and heat impacts on construction and services) can motivate resilience-linked finance and targeted risk transfer, although systematic evidence on long-term performance and scalability remains limited (Ling et al., 2024).

4.3.3 Synthesis

Overall, the review provides strong qualitative support for H1–H3 in contexts where data and market signals exist, while evidence for H4 and especially H5 remains more case-based. Protection gaps and underwriting tightening (H1–H2) appear most binding in lower-income settings; credit tightening and rationing (H3) are salient both in advanced markets after risk salience increases and in developing markets where collateral-based systems dominate (Ling et al., 2024; Amos, 2015; Ogedengbe, 2003). Infrastructure improvements (H4) show clear benefits in well-documented cases (Hallegatte & Rentschler, 2019), while rigorous evaluation of adaptation payoffs in real-estate finance (H5) remains comparatively scarce.

4.4 Adaptation pathways and strategic responses

The reviewed evidence shows that adaptation outcomes vary substantially across market contexts, largely depending on whether policy instruments, financial mechanisms, and institutional capacity are aligned across the three CFI channels (Hallegatte & Rentschler, 2019; Ling et al., 2024). Rather than implying a universal "best practice", the literature points to context-specific packages of interventions that are most effective when they jointly improve insurability, financeability, and infrastructure reliability.

4.4.1 Policy and spatial-planning measures

Building codes that mandate elevated foundations, wind-resistant designs, and flood-resilient materials consistently reduce damages where enforcement is credible. Post-implementation evaluations report substantial declines in loss severity in hazard-prone settings, and the effects can translate into improved insurance terms and stronger collateral performance when insurers and lenders recognise compliance (Hallegatte & Rentschler, 2019; European Central Bank, 2025). However, enforcement remains a binding constraint in many LMICs (low- and middle-income countries), where local governments face limited inspection capacity and fragmented permitting systems. Digital permitting and compliance monitoring can improve adherence, but require baseline administrative capacity and reliable cadastral and hazard information (Turner, 2017; Ribeiro & Souza, 2023).

Spatial planning delivers mixed results depending on timing and political feasibility. Proactive zoning that restricts development in high-risk areas is most effective when implemented early and paired with credible alternatives for growth and housing supply; retrofitting restrictions into already built-up coastal zones often triggers legal disputes and political resistance (Turner, 2017). Nature-based solutions (e.g., wetland restoration and mangrove belts) can yield high benefit–cost ratios by attenuating flood peaks and reducing inundation in appropriate contexts, but their performance depends on sustained maintenance and protection from encroachment—conditions that are frequently underfunded or contested (Hallegatte & Rentschler, 2019; Warren, 2012). In CFI terms, these measures shape the risk landscape that insurers and lenders respond to, and therefore condition both insurability and financing conditions.

4.4.2 Social protection and risk sharing

Social protection tools can buffer climate shocks, but design trade-offs are central. Parametric schemes can deliver rapid liquidity after trigger events and reduce post-disaster distress, yet basis risk and affordability constraints often limit uptake without explicit subsidies or complementary safety nets (Golnaraghi, 2023; Hallegatte & Rentschler, 2019). The literature also cautions that unconditional post-disaster compensation may weaken incentives for ex-ante risk reduction and perpetuate settlement in high-risk locations. More effective designs link support to risk reduction—such as retrofitting, adherence to building standards, or relocation pathways—so that liquidity support reinforces, rather than undermines, longer-term resilience (Hallegatte & Rentschler, 2019). Within the CFI framework, these instruments can either stabilise the insurance/finance channels (by preventing default cascades) or amplify long-run exposure if they subsidise continued vulnerability.

4.4.3 Financial sector instruments and risk transfer

Financial institutions are increasingly incorporating physical risk into portfolio management, but practice remains uneven across regions and asset classes. In advanced markets, climate-related pricing and underwriting adjustments are becoming more systematic, while in many LMIC settings the dominant outcome is often credit rationing rather than fine-grained repricing, pushing high-risk borrowers toward informal finance at much higher costs (Ling et al., 2024; Amos, 2015; Ogedengbe, 2003). A key emerging theme is the "adaptation return": resilience investments can protect cash flows and collateral values, but translating resilience into better financing conditions requires verification standards and market conventions that are still developing (Hallegatte & Rentschler, 2019; UNEP FI, 2025). Risk-transfer innovation faces structural limits. Parametric products work best for acute hazards with observable triggers (e.g., wind speed, rainfall thresholds), while slow-onset stressors such as sea-level rise and chronic heat are harder to insure on comparable terms. Insurance-linked securities can expand risk-bearing capacity, but require market depth, transparency, and investor sophistication that many LMICs lack (Sukaatmadja, 2021). Across contexts, the evidence supports a consistent conclusion: financial innovation is most effective when it is anchored in physical risk reduction and infrastructure reliability rather than treated as a substitute for adaptation "on the ground" (Hallegatte & Rentschler, 2019).

4.4.4 Adaptation infrastructure, financing, and maintenance

Cities face major challenges in delivering and sustaining adaptation infrastructure. Drainage upgrades repeatedly appear among the most cost-effective measures in flood-prone urban contexts, yet municipalities often struggle with project preparation, procurement, and asset management (Hallegatte & Rentschler, 2019). Coastal protection shows more heterogeneous returns: hard defences can be cost-effective in dense, high-value corridors but may be fiscally and environmentally unsustainable in lower-density regions, increasing the importance of phased strategies and complementary land-use controls (Warren, 2012; European Central Bank, 2025). Access to finance remains a key bottleneck. Blended finance and concessional instruments can reduce capital costs, but transaction complexity and technical requirements often exclude smaller municipalities. Public–private partnerships can scale delivery, yet require advanced contracting capacity and credible O&M arrangements to avoid performance deterioration (Parker, 2025; Ribeiro & Souza, 2023). Maintenance funding is particularly decisive: empirical work highlights that infrastructure performance can degrade materially within a few years if O&M budgets are inadequate, eroding the initial resilience benefits of capital investment (Hallegatte & Rentschler, 2019). In CFI terms, sustained maintenance is what keeps infrastructure functioning as a stabiliser of both insurability and financing over time.

4.4.5 Implementation and evidence gaps

Several persistent barriers recur across the literature: institutional fragmentation across government tiers and sectors, financing gaps for O&M, and limited technical capacity for risk assessment and contract management—especially in rapidly growing secondary cities (Turner, 2017; Warren, 2012; Ribeiro & Souza, 2023). Evidence gaps remain notable. Many studies evaluate project-level outputs rather than system-wide resilience, few track performance beyond initial implementation phases, and distributional effects (e.g., displacement or inequality impacts) are rarely assessed systematically (Hallegatte & Rentschler, 2019). Overall, these gaps limit comparability across the climate–development quadrants and reinforce the need for better measurement and longer time horizons in evaluating adaptation effectiveness.

4.4.6 Characteristics of successful adaptation pathways

Despite context differences, successful pathways tend to share three characteristics. First, they bundle interventions across regulation, infrastructure, finance, and social protection rather than relying on a single instrument (Hallegatte & Rentschler, 2019). Second, they sequence investments to deliver early, visible risk reduction while keeping options open as hazard information and local preferences evolve (Turner, 2017). Third, they align incentives by ensuring that risk reduction is recognised in insurance and credit conditions, while safeguarding affordability through targeted and conditional support (European Central Bank, 2025; UNEP FI, 2025). Together, these findings underline that adaptation in real estate markets is not only a technical design problem but an institutional and financial coordination challenge that must be managed across the interacting CFI channels.

4.5 Implications

The CFI synthesis implies that climate risk in real estate is amplified by feedback loops across insurance, finance, and infrastructure. When rising hazards lead to insurance repricing or withdrawal, lenders respond with tighter terms and higher equity requirements; constrained finance then limits investment in protective infrastructure; and infrastructure deficits increase realised losses and perceived risk, reinforcing the initial tightening in insurance and credit markets (Angelina, 2025; Hallegatte & Rentschler, 2019; Ling et al., 2024). These dynamics create climate–finance traps in which exposure and weak resilience reinforce each other rather than being gradually reduced.

This interaction is particularly acute in tropical LMIC contexts corresponding to Quadrant IV, where protection gaps, constrained credit, and infrastructure maintenance shortfalls can concentrate risk on households, developers, and local governments (Warren, 2012; Hallegatte & Rentschler, 2019). At the same time, evidence of premium spikes and selective withdrawal in exposed sub-markets of advanced economies indicates that milder forms of these dynamics may also emerge in parts of Quadrants I and III (European Central Bank, 2025; Climate Foresight, 2025). Breaking these trajectories requires coordinated action across public investment, market design, and targeted support.

4.5.1 Implications for investors and lenders

For investors and lenders, the CFI framework implies that climate risk cannot be assessed at the property level alone. Asset exposure must be evaluated jointly with local insurance depth, infrastructure reliability, and public capacity to sustain protective systems and recovery (European Central Bank, 2025; Ling et al., 2024). Three priorities follow. First, integrate CFI-aligned metrics—local protection gaps, infrastructure reliability proxies, and adaptation governance signals—into due diligence and stress testing, rather than relying only on hazard maps or historical losses. Second, design financing products and covenants that recognise verified resilience measures, thereby improving the "bankability" of adaptation (Ling et al., 2024; UNEP FI, 2025). Third, explicitly incorporate policy and market transition scenarios (e.g., stricter codes, managed retreat, mandatory insurance) into valuation, collateral frameworks, and exit strategies (Hallegatte & Rentschler, 2019).

4.5.2 Implications for policymakers and regulators

For policymakers and regulators, the evidence underscores that foundational protective infrastructure—and, crucially, its maintenance—can be a precondition for sustainable private investment. Upgrading drainage, coastal defences, and critical urban systems reduces losses and disruption and can stabilise insurance and lending conditions (Hallegatte & Rentschler, 2019; Warren, 2012). However, physical investment alone is insufficient without coherent regulatory design: pricing signals must reflect both risk and resilience so that adaptation investments can translate into improved premiums and financing terms, while distributional risks require carefully designed affordability and solidarity mechanisms (European Central Bank, 2025; Hallegatte & Rentschler, 2019; Climate Foresight, 2025). Land-use decisions should align with long-term scenarios and discourage new exposure in locations likely to become uninsurable or unfinanceable (Turner, 2017).

4.5.3 Implications for international organisations and development finance

For international organisations and development finance institutions, the analysis highlights the value of targeting systemic bottlenecks rather than only project-level adaptation. In Quadrant IV settings, concessional finance and technical assistance can support risk information, strengthen regulatory capacity, and co-finance protective infrastructure pipelines that crowd in private capital (Hallegatte & Rentschler, 2019; Parker, 2025). A further priority is the provision of public goods: detailed hazard mapping, asset registries, and infrastructure condition data enable both private risk assessment and public investment planning, improving allocation across the three CFI dimensions.

4.5.4 Strategic priorities: breaking climate–finance traps

Three coordinated levers stand out. First, sustained public investment in protective infrastructure and O&M, particularly in rapidly urbanising tropical LMICs, to reduce expected losses and anchor private confidence (Hallegatte & Rentschler, 2019; Warren, 2012). Second, risk- and resilience-sensitive insurance and credit pricing that recognises verified adaptation while protecting vulnerable groups through targeted support (European Central Bank, 2025; Climate Foresight, 2025). Third, instruments that bridge affordability and capacity gaps—conditional premium support, resilience-linked finance, and technical assistance—so that households and smaller developers can invest in resilience rather than being forced into informal coping. When aligned, these levers can shift markets from vicious to virtuous cycles in which resilience investment improves creditworthiness, stabilises public finances, and attracts long-term capital (Ling et al., 2024; Hallegatte & Rentschler, 2019).

4.6 Robustness, limitations, and research needs

This study develops an integrated framework for analysing physical climate risk in real estate, but several limitations are important. First, cross-country comparison is constrained by heterogeneous definitions and reporting conventions for insurance penetration, protection gaps, and lending standards. Second, reliance on secondary sources can introduce selection effects: international datasets and (re)insurance reporting often capture catastrophic events more clearly than frequent, lower-severity impacts that cumulatively affect asset performance and local credit risk (European Central Bank, 2025; Hallegatte & Rentschler, 2019). Third, the non-stationary nature of climate hazards limits the usefulness of purely historical loss data and strengthens the case for scenario-based approaches that incorporate deep uncertainty (Ling et al., 2024).

Evidence gaps remain substantial in linking loan-level performance to granular hazard exposure and insurance contract terms, particularly in developing markets where registries and disclosure are limited. Infrastructure datasets also tend to measure capital stocks rather than service reliability and maintenance quality, constraining the ability to quantify how infrastructure moderates insurability and financing conditions (Hallegatte & Rentschler, 2019). Taken together, these constraints imply that empirical support for H1–H3 is stronger in well-documented high-income contexts than in many tropical LMIC settings, while evidence for H4 and especially H5 remains more case-based.

These limitations motivate three priority research needs aligned with the CFI framework. First, harmonised, geocoded datasets linking property characteristics, financing terms, insurance coverage, and hazard exposure would enable more robust cross-country testing of CFI mechanisms and hypotheses. Second, methodological approaches that explicitly address non-stationarity—through dynamic stress testing and scenario integration across insurance availability, lending standards, and infrastructure quality—are required to strengthen forward-looking inference. Third, standardised evaluation of adaptation and financial instruments is needed, including consistent methods for adaptation ROI, blended finance effectiveness, and parametric-product performance in real estate contexts, as well as more systematic assessment of distributional and system-wide impacts. Addressing these research needs would strengthen the empirical basis for the CFI approach and improve its practical usefulness for investors, regulators, and urban decision-makers.

5. CONCLUSION

The central message of this article is that climate risk in real estate is shaped not by hazards alone, but by the joint dynamics of insurability, financing conditions, and infrastructure quality, and by how these dynamics differ across climate zones and levels of development. Using the Climate–Finance–Infrastructure (CFI) Interaction Framework, the review synthesised empirical and institutional evidence, organised cross-country patterns into a comparative typology, and illustrated mechanisms through cases including Southern India, Bali, and urban China. Climate risk in real estate therefore emerges as a systemic financial and institutional challenge, not merely a physical one.

This article makes three contributions. First, it develops the CFI Interaction Framework, integrating insurance, credit, and infrastructure into a single analytical lens and formalising the feedback mechanisms through which physical risks can produce self-reinforcing climate–finance traps in vulnerable markets (Hallegatte & Rentschler, 2019; Ling et al., 2024). Second, it synthesises evidence across tropical and temperate settings and across high-income and developing contexts, organising heterogeneous findings into a four-quadrant typology that clarifies why similarly exposed markets can follow divergent trajectories. Third, it introduces the Resilience Capacity Index (RCI) as a diagnostic device to position markets along those trajectories and to identify where interventions across the three CFI channels are likely to yield the highest marginal gains.

The case evidence underscores that outcomes depend on the alignment of public policy, private investment, and institutional capacity. Bali illustrates how exposure can translate into vulnerability when low insurance penetration, constrained credit availability, and fragile protective infrastructure concentrate risk locally. By contrast, drainage upgrades in Southern India show how targeted infrastructure investment can shift systems toward more resilient equilibria by reducing disruption and improving the conditions under which insurance and credit remain viable (Hallegatte & Rentschler, 2019; Warren, 2012). Evidence from urban China points to the potential of resilience-linked lending and risk-transfer innovation to embed adaptation into financial decision-making, although systematic evaluation of long-run performance remains limited (Ling et al., 2024).

For stakeholders, the implications are direct. Investors and lenders should move beyond property-level hazard metrics and incorporate CFI-aligned indicators—such as protection gaps, financing frictions, and infrastructure reliability—into due diligence, portfolio construction, and stress testing. Policymakers and regulators need to pair sustained investment in protective infrastructure and maintenance with frameworks that allow risk- and resilience-sensitive pricing while safeguarding affordability and avoiding disorderly withdrawal of coverage and credit. International organisations and development finance institutions can help address systemic bottlenecks in data, regulatory capacity, and project preparation, particularly in tropical LMIC contexts where gaps are greatest (Hallegatte & Rentschler, 2019).

Finally, the review identifies a research agenda. Evidence remains uneven across regions and channels, with especially thin coverage on adaptation payoffs, distributional consequences, and the dynamic interaction between insurance availability, credit standards, and infrastructure performance under non-stationary risk. Expanding harmonised and geocoded datasets, improving forward-looking assessment methods, and standardising evaluation of adaptation and financial instruments would substantially strengthen the empirical basis for the CFI hypotheses and refine the practical use of CFI/RCI diagnostics.

The stability of real estate markets under climate change is inseparable from the resilience of the insurance, financial, and infrastructure systems that support them. Ignoring CFI interactions risks deepening climate–finance traps; using them as a diagnostic lens can guide coordinated adaptation and investment. Whether climate change produces disorderly repricing or a managed adjustment in real estate will depend on how quickly these insights are translated into practice.

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