Why Private Capital Fails to Scale Climate Adaptation Investment: Evidence from Infrastructure

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Abstract

Mobilizing private capital is widely viewed as essential to scaling investment in climate adaptation. Yet private participation remains limited and uneven, particularly in infrastructure sectors where investment needs are substantial. This raises a central question: does the limited scale of private adaptation finance reflect measurement gaps, or deeper constraints in the investment case for adaptation?

This paper examines the extent to which private capital can be mobilized for climate-resilient infrastructure, drawing on evidence from transport investments in developing countries. Using climate finance data and transaction-level analysis, it shows that existing accounting frameworks understate private participation, as adaptation investments are often embedded within broader infrastructure projects or span multiple sectors and are not captured in conventional statistics.

At the same time, the analysis demonstrates that the scope for private investment is structurally constrained by the underlying risk–return profile of adaptation assets. Unlike mitigation investments, adaptation generates value primarily through avoided losses and system resilience rather than stable, monetizable cash flows, limiting its compatibility with asset-based financing models. As a result, private capital is concentrated in a narrow subset of bankable projects and typically depends on public guarantees, concessional finance, or other risk-sharing mechanisms.

By linking measurement issues to these structural features, the paper explains why private capital markets have not scaled adaptation investment despite policy efforts to mobilize finance. The findings suggest that the adaptation gap reflects a fundamental challenge in funding rather than financing, with implications for capital allocation, blended finance design, and the role of public balance sheets in supporting resilience investments.

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1. Introduction

Climate adaptation finance is widely framed as a problem of mobilizing capital, yet the central constraint lies in how adaptation investments are funded. Despite large and growing financing needs, available adaptation finance remains far below required levels and is not increasing at a pace consistent with projected demand (UNEP, 2025; Climate Policy Initiative, 2025; OECD, 2025). This gap is especially acute in developing countries, where adaptation continues to rely overwhelmingly on public and concessional finance, with private capital playing only a marginal role. Public actors account for an estimated 98 percent of tracked adaptation finance, highlighting a persistent mismatch between financing needs and available funding (Climate Policy Initiative, 2025; Global Center on Adaptation, 2024).

Despite this, policy frameworks increasingly position private investment as a central solution to scaling adaptation, reflecting a broader shift in development finance toward mobilizing private capital (Mawdsley, 2018), especially through efforts to expand climate-resilient infrastructure and blended finance. However, private participation remains uneven and well below both estimated needs and mitigation investment (Convergence, 2025). These constraints are especially pronounced in infrastructure sectors, where high capital intensity, elevated risks, and weak cost-recovery mechanisms limit commercial viability—particularly in low- and middle-income countries (OECD, 2018; Hallegatte et al., 2019). Within infrastructure, transport presents a particularly acute case. It provides a critical test case because it combines high climate exposure, systemic economic importance, and limited opportunities to monetize resilience benefits, yet attracts a disproportionately small share of adaptation finance. While transport accounts for roughly 12 percent of adaptation actions identified in national strategies, it receives less than 2 percent of global adaptation finance—approximately USD 1 billion out of USD 63 billion in total flows (Diaz Fanas et al., 2025).

Moreover, aggregate estimates are likely to understate the scale and composition of adaptation investment. Much of transport-related adaptation is embedded within routine infrastructure development and maintenance rather than identified as discrete climate finance. Differences in reporting methodologies further obscure both the level and distribution of investment,

particularly private participation (Climate Policy Initiative, 2025). As a result, existing statistics provide only a partial view of how adaptation is financed in practice.

Against this backdrop, a central question arises: does the limited scale of private adaptation finance reflect measurement and definitional challenges, or deeper structural constraints on the investment case for adaptation? This question reflects a broader tension in the literature and policy debate. On the one hand, measurement challenges suggest that private participation may be systematically underestimated. On the other, policy frameworks and market assessments increasingly portray adaptation—notably in infrastructure sectors such as transport—as a significant investment opportunity capable of attracting private capital. Reconciling these perspectives requires distinguishing between financing—the provision of upfront capital—and funding—the revenue streams used to service that capital over time. This distinction reflects deeper structural differences between adaptation and mitigation investments—particularly in terms of value creation, revenue models, and asset structure—which shape their compatibility with private finance, as summarized in Table 1 and discussed in Section 3.

This paper argues that both factors are important but insufficient in isolation. Private participation is likely underestimated due to embedded investments, cross-sector activities, and constraints in existing tracking systems. At the same time, its scale is fundamentally constrained by the economic characteristics of adaptation investments, which limit their compatibility with private investment models, especially in infrastructure sectors such as transport and in developing country contexts where revenue constraints are most binding.

Many adaptation investments—notably in transport—cannot be structured as independent, revenue-generating assets. Unlike mitigation investments, which often produce identifiable cash flows, adaptation measures such as elevating roads or reinforcing bridges generate value primarily through avoided losses and service continuity (Ford & Berrang-Ford, 2016; Mechler & Bouwer, 2015). These benefits are diffuse, non-excludable, and difficult to monetize, reducing their attractiveness to private investors, especially in developing countries (Kling et al., 2021).

While a growing body of literature examines adaptation finance—particularly in developing countries—it has focused primarily on aggregate flows and institutional arrangements, with

limited attention to sectoral dynamics (Climate Policy Initiative, 2025; OECD, 2023; Barrett, 2023). Existing research on adaptation more broadly tends to emphasize sectors such as agriculture and water, where interventions are more readily identified and assessed, while transport has received comparatively limited attention in both the adaptation and finance literatures (Ford & Berrang-Ford, 2016; Eriksen et al., 2021). Yet transport systems are central to economic activity and highly exposed to climate risks, with implications for resilience and development outcomes, especially in climate-vulnerable countries (Hallegatte et al., 2019; Lawrence et al., 2020). This gap constrains understanding of how sector-specific investment characteristics shape the role of private capital in adaptation finance. Although measurement challenges and structural constraints have been examined separately, their interaction remains underexplored, leading to incomplete and sometimes inconsistent interpretations of the role of private finance in adaptation.

At the same time, existing analyses often treat adaptation finance constraints as primarily financial—focused on mobilizing capital—or examine sectoral investment patterns in isolation. This paper contributes by integrating these perspectives and linking measurement challenges to underlying funding constraints.

Focusing on transport infrastructure in developing countries, this paper examines the conditions under which private capital participates in adaptation. It combines climate finance data with transaction-level evidence to identify three channels of engagement: (i) market-based investment in revenue-generating assets, (ii) private capital mobilized through public risk-sharing mechanisms, and (iii) hybrid public–private structures.

The paper makes three main contributions. First, it shows that private participation in transport adaptation is systematically underestimated in existing data due to embedded investments, cross-sector activities, and limitations in current tracking systems. Second, it demonstrates that even when these measurement gaps are addressed, the scope for private finance remains structurally constrained by the economic characteristics of adaptation investments, particularly in developing country contexts where revenue limitations are most binding. Third, by linking these measurement limitations to underlying funding constraints, the paper provides an integrated explanation that resolves a central paradox in the adaptation finance debate: private participation

in transport adaptation is both underestimated and inherently limited in scale, with implications for climate-resilient infrastructure investment in developing countries.

In doing so, the paper advances the literature by distinguishing between financing—the provision of capital—and funding—the revenue streams required to support repayment. This distinction helps resolve an apparent paradox in the adaptation finance debate: while measurement-based estimates suggest that private participation may be underestimated, policy and market narratives emphasize the potential to scale private investment, yet its expansion remains constrained by the absence of sustainable funding mechanisms. By linking measurement limitations to these underlying economic constraints, the paper provides a more comprehensive explanation for the limited role of private finance in transport adaptation, particularly in developing countries, where weaker revenue generation and higher risk profiles further restrict the scope for private participation.

2. The Measurement Problem in Adaptation Finance

Estimates of adaptation finance in transport infrastructure are subject to significant measurement limitations, complicating assessments of scale, composition, and the role of private capital (Barrett, 2023). Finance is tracked using heterogeneous methodologies and reporting standards across multilateral development banks (MDBs), climate funds, bilateral donors, domestic institutions, and private actors (Leiter & Pringle, 2018). Existing systems rely primarily on activity-based classifications, labeling expenditures as adaptation when they correspond to predefined categories such as climate-resilient infrastructure or flood protection. While this enables comparability, it captures only a partial view of how resilience is embedded in practice. Resilience—defined as the capacity of systems to anticipate, absorb, recover from, and adapt to climate shocks (IPCC, 2022)—is typically integrated within broader investment processes rather than implemented as discrete activities.

These limitations arise from several distinct but interrelated sources of bias, including the embedded nature of adaptation investments, their cross-sectoral distribution, methodological constraints in accounting practices, and gaps in coverage.

A first source of bias arises from the embedded nature of adaptation within infrastructure systems. In transport, resilience is incorporated across the asset lifecycle—from planning and design to construction and maintenance—rather than undertaken as standalone investments. For example, road rehabilitation may include upgraded drainage, slope stabilization, or heat-resistant materials, yet these components are typically recorded as standard capital expenditure (Ebinger & Vandycke, 2015). As a result, a substantial share of adaptation investment remains untagged and effectively invisible, particularly in developing countries where tracking capacity is limited (Leiter, 2021).

A second source of bias stems from the cross-sectoral nature of resilience investments. Activities that support transport resilience—such as stormwater management, coastal protection, climate risk analytics, and resilient materials—are often classified under other sectors. Sector-based reporting therefore understates both the scale and diversity of adaptation investment in transport, including private participation, which is frequently concentrated in these adjacent segments rather than in core infrastructure assets.

A third limitation relates to accounting methodologies. Under current approaches, including the MDB climate finance tracking and reporting methodology, only the incremental costs of project components intended to reduce vulnerability and build resilience are counted as adaptation finance (MDBs, 2024). While this improves precision, it fragments adaptation across project components and reduces its visibility—for example, in a road project, only the additional cost of flood-resilient drainage or heat-resistant materials is recorded as adaptation. This contrasts with mitigation finance, where the full cost of qualifying projects is typically counted. The absence of standardized metrics to assess adaptation outcomes further complicates tracking and financial structuring (Ford & Berrang-Ford, 2016).

A fourth limitation relates to coverage. Current estimates of adaptation finance primarily capture international public flows to developing countries, while domestic spending remains poorly tracked, limiting the completeness and comparability of global adaptation finance data and contributing to underestimation of total adaptation investment (UNEP, 2025).

More fundamentally, adaptation measurement faces a 'dependent variable problem,' reflecting the absence of a consistent definition of what constitutes adaptation (Dupuis & Biesbroek, 2013). Because adaptation spans both climate-specific interventions and broader development and risk-reduction activities, the boundary of what is counted remains fluid. This leads to inconsistent labeling, limits comparability across institutions, and creates risks of misclassification (Eriksen et al., 2021). Institutional fragmentation further compounds these issues, as finance is delivered through multiple channels with distinct mandates and reporting practices (Kalaidjian & Robinson, 2022). As a result, observed adaptation finance reflects not only underlying investment patterns, but also definitional and methodological choices.

These challenges are particularly pronounced in transport infrastructure, where resilience is inherently system-wide and distributed across interconnected components. At the same time, private investment often concentrates in commercially oriented segments—such as logistics, materials, and technology—where its contribution to adaptation is indirect and dispersed. Taken together, these factors create a structural visibility problem: existing tracking systems understate both the scale of adaptation investment in transport and the extent of private sector involvement.

However, improving measurement alone does not resolve the underlying constraint. Even with more granular data, adaptation investments do not map neatly onto conventional categories of finance, reflecting their embedded and context-specific nature. Measurement challenges are therefore not purely technical but reflect deeper structural features of adaptation as a development process. Understanding the role of private capital in transport adaptation thus requires not only better data, but also a clearer account of the economic conditions under which such investment is viable.

Recent global assessments confirm that these measurement challenges are not merely technical but systemic. Climate finance tracking frameworks continue to face significant limitations in capturing adaptation-related expenditures, particularly where investments are embedded within broader development activities or financed through domestic public budgets. As a result, available estimates likely understate both the scale of adaptation finance and the extent of private sector engagement (Climate Policy Initiative, 2025).

While these measurement challenges obscure the scale and composition of adaptation finance, they do not alter the underlying funding constraints that limit private participation. Understanding these constraints requires moving beyond measurement issues to examine the economic characteristics of adaptation investments, which shape their compatibility with private finance.

3. Economic Constraints and the Limits of Private Finance

Building on this distinction, measurement limitations alone do not explain observed financing patterns. Even after accounting for underreporting and cross-sector investment, private participation remains concentrated in specific segments and does not extend across the full range of adaptation needs. This indicates that the constraint is not primarily one of financing, but of funding: the absence of sustainable revenue streams to support repayment limits the scope for private investment. In contrast to mitigation, adaptation is defined by value creation through avoided losses rather than revenue generation, weak or indirect revenue models, and asset structures that are embedded within broader systems rather than standalone investments. These features result in uncertain and non-contractable cash flows, limiting their compatibility with private finance. Table 1 summarizes the key economic characteristics that differentiate adaptation from mitigation investments and shape their compatibility with private finance, highlighting their implications for private investment. While these distinctions apply broadly, they are particularly pronounced in infrastructure sectors such as transport, especially in developing country contexts where revenue models are weak and fiscal constraints are binding.

[Insert Table 1 here]

Recent evidence reinforces this interpretation. While global climate finance exceeded USD 1 trillion in 2023, private finance remains overwhelmingly concentrated in mitigation sectors—such as energy, transport electrification, and buildings—where revenue streams are more readily identifiable (Climate Policy Initiative, 2025). By contrast, adaptation finance remains limited in scale and predominantly publicly funded, with private participation accounting for only a small fraction of total flows (Global Center on Adaptation, 2024; OECD, 2025).

This imbalance is reflected in the scale of the adaptation finance gap. Current flows to developing countries are estimated at roughly USD 20–30 billion annually, compared to projected needs exceeding USD 300 billion by 2030 (UNEP, 2024; OECD, 2025). The persistence of such a gap—despite sustained efforts to mobilize private capital—suggests that the constraint is not simply one of capital availability but reflects deeper structural limits in the ability of adaptation investments to generate bankable returns.

Private participation remains modest even where mobilization mechanisms are in place. Across climate finance, private investment accounts for only a limited share of total needs and remains marginal in adaptation contexts (OECD, 2025). Blended finance has not fundamentally altered this pattern. Although climate-related transactions are increasing, adaptation represents only about 6–7 percent of climate blended finance by volume, with deals typically smaller and more reliant on concessional support due to weak revenue models and limited bankability (OECD, 2025; Convergence, 2025). Adaptation investments are generally embedded within broader projects rather than financed as standalone activities. As a result, blended finance functions primarily as a mechanism for risk reallocation—using public capital to absorb downside exposure—rather than a tool for mobilizing private investment at scale (Griffiths et al., 2020).

These patterns reflect a fundamental revenue asymmetry. Unlike mitigation, which often generates identifiable cash flows, adaptation investments create value primarily through avoided losses and service continuity. As a result, most adaptation measures cannot be structured as independent, revenue-generating assets with predictable and contractable cash flows.

This constraint is particularly evident in infrastructure sectors such as transport. Empirical evidence shows that the economic value of adaptation is realized through reductions in expected damages rather than direct revenue generation, with annual losses to road and rail infrastructure from natural hazards estimated at USD 3.1–22 billion globally (Koks et al., 2019). Financial sector assessments similarly highlight persistent challenges in identifying bankable opportunities, driven by uncertain revenue streams, difficulties in quantifying benefits, and high perceived risks (UNEP FI, 2016).

From an investment perspective, assets attract private capital when they can be structured as a distinct asset class characterized by stable, predictable cash flows and contractual revenue arrangements (Inderst, 2010; Inderst & Stewart, 2014). While transport infrastructure can sometimes meet these conditions, adaptation components within these assets typically do not: they do not generate dedicated revenues, cannot be separately priced, and are not contractually isolated from the underlying asset. Adaptation therefore remains embedded within investable assets rather than constituting an asset class in its own right.

These constraints are particularly binding in developing countries, where weaker revenue bases, higher risks, and limited fiscal space constrain private investment. As a result, capital concentrates in sectors with clearer revenue models—particularly energy—while transport and other resilience-critical sectors attract limited investment. World Bank PPI data reflects this pattern, with investment concentrated in energy and information and communication technology (ICT), and only a small, volatile share directed to transport. Within transport, private participation is largely confined to revenue-generating assets—such as toll roads, ports, and airports—while rail and urban transit systems remain predominantly publicly and concessionally financed (World Bank, 2025).

More fundamentally, this reflects a structural misalignment between the economic characteristics of adaptation and the requirements of private capital. Adaptation investments generate value through avoided losses, system resilience, and broader economic stability rather than direct financial returns (Stern, 2007; Fankhauser, 1995). These benefits are diffuse, long-term, and often extend beyond individual assets—for example, through avoided disruptions to transport networks and supply chains (Koks et al., 2019). As a result, many adaptation investments exhibit characteristics of public goods, leading to systematic underprovision by private markets (Arrow et al., 2013). Private participation depends on the ability to allocate risk and secure predictable revenue streams through contractual arrangements (Engel et al., 2014). The low degree of standardization in adaptation investments further limits scalability and aggregation into investable portfolios, reinforcing barriers to private capital.

Taken together, these patterns indicate that constraints to scaling private finance in adaptation are not primarily financial, but rooted in the underlying economic characteristics of adaptation

investments. While financial instruments can facilitate participation in specific contexts, they do not resolve the fundamental challenge of how adaptation investments generate—or fail to generate—sustainable funding. This reinforces the central distinction: the limitation is not primarily in accessing financing, but in the absence of viable funding mechanisms to support repayment.

4. Private Participation in Transport Adaptation: Evidence and Patterns

Recent global evidence—particularly for developing countries—highlights a dual imbalance in adaptation and infrastructure finance. Private infrastructure investment has averaged around USD 100 billion annually but remains heavily concentrated in energy, with transport attracting a comparatively small and more volatile share (World Bank, 2025). A similar pattern is observed in climate finance: of approximately USD 63 billion in tracked adaptation finance, public sources account for around 98 percent, with private flows representing only a marginal share (Diaz Fanas et al., 2025).

Project-level evidence from infrastructure investment databases, development finance, and market analyses (e.g., Convergence, 2025) further reinforces this pattern: private investment is concentrated in sectors with clearer revenue models, while transport attracts more limited and uneven participation. This alignment between infrastructure investment patterns and adaptation finance flows provides an empirical backdrop for interpreting private participation in transport adaptation, particularly in developing countries where funding constraints are most pronounced.

Building on the economic constraints identified in Section 3, this section examines how these features translate into private participation. It identifies three main channels: (i) market-based investment in revenue-generating assets, (ii) private capital mobilized through public risk-sharing mechanisms, and (iii) publicly funded systems in which resilience is embedded within broader infrastructure investments. Consistent with the economic characteristics outlined in Table 1, private participation is concentrated in assets that can be structured around revenue generation and remains limited where benefits are diffuse or non-monetizable. This reflects the distinction between financing and funding: while private capital can be mobilized under certain conditions, participation ultimately depends on the presence of credible funding mechanisms.

Table 2 presents illustrative cases of transport adaptation, showing how variation in adaptation functions and revenue models shapes financing structures and the extent of private participation. Given the fragmented and heterogeneous nature of adaptation finance data, the analysis adopts a synthesis-based approach, combining aggregate and project-level evidence to identify consistent patterns of private participation. The analysis is interpretive and draws on documented cases where adaptation components and financing arrangements can be clearly identified, rather than aiming to provide a representative sample. As shown in Table 2, cases with high private participation are associated with identifiable revenue models—such as toll roads, ports, and airports—and embedded adaptation within revenue-generating assets, while projects without such mechanisms rely predominantly on public or concessional funding.

Beyond infrastructure financing, private participation is often more pronounced in risk-transfer instruments—such as catastrophe bonds and insurance mechanisms—where capital engages through financial intermediation rather than direct asset investment. This highlights a divergence between where private finance is active and where infrastructure adaptation needs are greatest.

[Insert Table 2 here]

4.1 Market-Driven Resilience in Revenue-Generating Assets

Market-based investment in resilience is concentrated in transport assets with identifiable revenue models, such as toll roads, ports, and airports. In these contexts, private participation reflects underlying asset economics: resilience measures are integrated into project design as part of risk management, as climate disruptions directly affect revenue performance. This is illustrated by projects such as the 4G Toll Road Program in Colombia and the Queen Alia International Airport, where resilience is embedded within commercially driven asset management.

Across cases, adaptation is not financed as a standalone investment but embedded within broader infrastructure development and lifecycle management. It is typically implemented through incremental design modifications—such as enhanced drainage, flood protection, or higher engineering standards—which represent a small share of total project costs (Koks et al., 2019).

No case in the sample involves private capital financing adaptation independently of underlying revenue streams or public risk-sharing mechanisms.

Where revenue mechanisms are insufficient, public intervention remains necessary through concessional finance, guarantees, or viability gap funding. Adaptation in these assets is therefore financed indirectly as part of asset optimization rather than as an independent investment category. Private participation is driven by revenue visibility rather than resilience objectives and remains constrained by the availability of commercially viable opportunities.

This pattern is consistent with broader evidence that private engagement in adaptation is typically indirect, occurring where resilience measures protect or enhance existing revenue streams. More broadly, mobilized private adaptation finance remains concentrated in sectors with clearer revenue models—such as industry, energy, and water—with comparatively limited allocation to transport infrastructure (OECD, 2023). This reinforces the central constraint identified in Section 3: private participation depends on the presence of viable funding mechanisms linked to revenue generation.

4.2 Blended Finance and Hybrid Public-Private Partnership Models

A second channel involves private participation enabled through public risk-sharing mechanisms. In these arrangements, concessional finance, guarantees, and public revenue commitments improve project bankability by aligning risk–return profiles with investor requirements. MDBs and development finance institutions play a central role in structuring these arrangements and absorbing risk.

In practice, private participation depends on structured risk mitigation and predictable funding mechanisms rather than project cash flows alone. In urban transport systems and rail investments, fare revenues are often insufficient to support full cost recovery, limiting private roles to construction, operations, or partial financing. Hybrid structures—such as availability payment PPPs—create stable revenue streams through public commitments, enabling participation where direct monetization of adaptation is not feasible. Cases such as the Karachi and Dakar BRT systems illustrate how public finance and concessional support underpin private participation in systems with limited cost recovery.

At the portfolio level, blended finance vehicles pool risks across assets to attract institutional investors. However, these structures do not fundamentally alter the economics of adaptation; instead, they enable participation by redistributing risk between public and private actors. Even within blended finance—the primary instrument designed to mobilize private capital for development—adaptation remains marginal and transport largely absent, underscoring the structural limits of private participation in these segments (Convergence, 2025). This pattern is reflected in deal composition: adaptation-focused transactions account for only a small share of climate blended finance, while infrastructure-related deals—particularly in transport—remain limited. Where adaptation is included, it is typically embedded within broader projects rather than financed as a standalone investment. While outcomes vary across contexts, available evidence suggests that in adaptation contexts such instruments primarily reallocate risk rather than enable large-scale mobilization of private capital.

Overall, private participation in this category is conditional on public support. Blended finance functions less as a mechanism for scaling private capital than as a tool for risk reallocation, reinforcing the central role of public finance. Evidence suggests that this translates into only modest private mobilization: on average, each dollar of public adaptation finance mobilizes roughly half a dollar of private investment (OECD, 2023). Adaptation-focused blended finance also remains highly selective, with relatively few transactions involving infrastructure or transport components (Convergence, 2025). This is consistent with broader OECD evidence showing that adaptation accounts for only a small share of total private finance mobilized by official development finance interventions, reflecting low financial returns and limited bankable opportunities (OECD, 2023).

These constraints are further reflected in stark differences across country contexts. In low- and middle-income countries, recent MDB reporting indicates that MDB adaptation finance of approximately USD 24.7 billion mobilized only USD 7.6 billion in private capital, whereas in high-income countries, USD 2.5 billion mobilized USD 7.9 billion—indicating an order-of-magnitude difference in mobilization efficiency (MDBs, 2024). This divergence reinforces the central argument: constraints to private participation are not primarily financial, but structural, reflecting differences in risk, revenue visibility, and institutional capacity.

4.3 Publicly-Funded Adaptation and Limits of Private Investments

A third category comprises projects in which adaptation is primarily publicly funded, with private actors engaged in implementation rather than financing. A large share of transport adaptation projects such as rural roads, drainage systems, and resilient bridges does not generate revenue streams, instead creating value through avoided damages and improved system performance.

Programs such as Brazil's CREMA framework illustrate this model: while private contractors are engaged through long-term, performance-based contracts, financing remains public, and resilience measures—such as improved drainage and reinforced pavement—are embedded within routine asset management rather than structured as standalone investments.

In these contexts, domestic public and concessional finance dominate, while private participation is limited to construction and service provision. This model is particularly prevalent in low-income and high-risk settings, where weak demand, affordability constraints, and high uncertainty further constrain the scope for private financing. Climate-resilience measures are embedded within broader infrastructure programs rather than structured as discrete investments.

These cases represent the most direct expression of the funding constraint: in the absence of monetizable benefits, adaptation investments cannot generate the revenue streams required to support private financing. More broadly, private adaptation finance remains concentrated in corporate investment, with limited participation from institutional investors such as pension funds, further constraining scale and depth (Climate Policy Initiative, 2025). These patterns illustrate the limits of private finance where adaptation benefits cannot be monetized.

4.4 Cross-case patterns

Drawing on the three financing structures identified in Table 2, three cross-cutting patterns emerge, summarized in Table 3. As shown in Table 3, variation in the nature of adaptation—whether it protects revenue-generating assets or provides system-wide resilience—shapes the scope for private participation across transport segments and country contexts.

[Insert Table 3 here]

First, private participation is conditional on revenue visibility or credible risk mitigation. Across all cases, higher participation is associated either with user-based revenue streams (e.g., toll roads, ports, and airports) or with public revenue commitments and risk-sharing mechanisms. Where benefits are diffuse or non-monetizable, investment depends on public support. Participation is therefore high in market-driven cases, conditional in blended structures, and largely absent in publicly funded adaptation.

Second, private investment is geographically and sectorally concentrated. Projects with substantial private participation are concentrated in middle-income and commercially viable contexts, including selected lower-middle-income countries with established revenue-generating assets, while low-income settings—such as rural road programs in Mozambique and Bangladesh—remain almost entirely publicly financed. This reflects a broader pattern in which private capital flows toward environments where risks can be priced and revenues secured. Global evidence reinforces this selectivity: mobilized private climate finance is heavily skewed toward middle-income countries, while least developed countries capture only a small share of flows (OECD, 2025). Sectorally, this concentration is mirrored in infrastructure investment patterns, where transport projects with private participation are limited in number and scale and disproportionately located in more creditworthy markets (Convergence, 2025).

Third, adaptation does not emerge as a standalone investment category. Across all cases, private capital does not finance adaptation independently of an underlying asset or public financing structure. Instead, resilience measures are embedded within broader investments or supported through concessional mechanisms. Private participation occurs primarily when adaptation is linked to revenue-generating assets or combined with mitigation elements (UNEP FI, 2016).

Taken together, these patterns indicate that the compatibility of adaptation investments with private finance varies systematically across contexts. Private capital concentrates in segments that can be structured around stable or contractually secured revenue streams, while investments with diffuse benefits remain publicly funded. This reflects the central distinction between financing and funding: while capital can be mobilized under specific conditions, its deployment ultimately depends on the availability of viable funding mechanisms. These patterns reflect the

structural characteristics summarized in Table 1, particularly weak revenue models and embedded asset structures that limit private participation.

These findings reinforce the arguments developed in Sections 2 and 3. While measurement limitations obscure the extent of private participation, the evidence shows that its scale remains structurally constrained. Across all financing channels, private capital participates only where risks and returns can be aligned with investor requirements.

5. Economic Constraints: Why Financing Does Not Equal Funding

While the literature on blended finance emphasizes financial instruments that improve risk–return profiles and mobilize private capital, it often assumes that the primary constraint lies in financial frictions rather than in the underlying economic viability of investments. In the case of adaptation—especially in transport infrastructure—the constraint is more fundamental: the absence of sustainable revenue streams to support repayment.

This distinction is clarified by separating financing from funding. Financing refers to the provision of upfront capital, while funding concerns who ultimately bears the cost over time—typically through public budgets or, where feasible, through user charges. Blended finance expands the pool of available capital but does not increase the underlying funding available to support repayment. This emphasis on financial structuring over underlying economic viability reflects broader critiques of the financialization of development, which highlight the limits of relying on private capital mobilization in the absence of sustainable funding mechanisms (Gabor, 2021). As shown in Section 3, many adaptation investments—particularly in transport infrastructure, where system-level benefits are difficult to monetize—generate value through avoided losses and system resilience rather than direct revenue streams, limiting their capacity to generate funding. These constraints reflect the structural characteristics summarized in Table 1—particularly weak or indirect revenue models, uncertain cash flows, and embedded asset structures—which prevent financing from translating into sustainable funding.

Recent evidence reinforces this constraint. Even where dedicated funding mechanisms exist, such as infrastructure levies, they often prove difficult to sustain: in a review of national instruments, approximately two-thirds were no longer actively used due to weak revenue

generation and implementation challenges (Diaz Fanas et al., 2025). More broadly, while innovative financial instruments may improve access to capital, they do not resolve the underlying funding gap, which depends on the availability of sustainable revenue sources or public transfers (Mercy Corps, 2025). This analysis focuses primarily on large-scale and internationally visible investments; the role of domestic private actors may be more significant in smaller-scale or informal adaptation activities but remains difficult to capture in available data.

The severity of this constraint varies across infrastructure segments. Where revenue streams are weak or absent, private participation depends on public intervention to ensure repayment, transferring risk onto public balance sheets through fiscal commitments and contingent liabilities. Guarantees create future obligations, availability payments establish long-term budgetary commitments, and concessional capital absorbs losses that would otherwise deter private investors. In all cases, public actors remain the ultimate bearers of cost and risk.

These dynamics help explain why adaptation finance remains dominated by public domestic and international flows, particularly in developing countries (Barrett, 2023). Global climate finance patterns reinforce this point: a large share of climate finance is sourced domestically, underscoring the continued reliance on national public budgets to fund adaptation investments (Climate Policy Initiative, 2025). The core constraint therefore lies not in the availability of capital, but in the capacity to generate or allocate sustainable funding sources.

Private finance thus plays a complementary and conditional role. It is most effective where revenues can be stabilized or where public interventions credibly support repayment, while remaining limited in investments with diffuse or non-monetizable benefits. Reframing the debate in terms of financing versus funding clarifies the policy challenge: the central issue is not simply mobilizing capital, but allocating the costs of adaptation in line with its economic characteristics.

6. Conclusion

This paper examined the role of private finance in transport adaptation, addressing a central question in climate finance: whether the limited scale of private investment reflects measurement limitations or deeper structural constraints. The marginal allocation of adaptation finance to transport highlights a persistent mismatch between sectoral needs and financing patterns.

The analysis shows that both factors matter, but in distinct ways. First, existing climate finance tracking systems understate the extent of private participation. Because adaptation investments are often embedded within broader infrastructure projects or occur across sectors, private engagement—particularly in commercially oriented segments—remains only partially visible in current data.

Second, and more fundamentally, the scope for private finance is constrained by the underlying economics of adaptation. Many investments—especially in transport—do not generate direct or predictable revenue streams and instead create value through avoided losses and system resilience. As a result, private participation is limited to contexts where revenues can be secured or risks are mitigated through public intervention, particularly in low-income and climate-vulnerable countries where revenue constraints are most binding.

Distinguishing between financing and funding clarifies these dynamics. While financial instruments can facilitate private participation, they do not address the underlying question of how adaptation investments are paid for over time. In transport infrastructure, where benefits are diffuse and largely non-monetizable, costs are borne primarily through public budgets, with limited scope for cost recovery through user charges.

Taken together, these findings resolve a central paradox in the adaptation finance debate: private participation may be underestimated, but its expansion remains structurally constrained by the absence of sustainable funding mechanisms, despite persistent policy and market narratives emphasizing its scalability.

This resolution has important implications for development policy. Expectations regarding the role of private finance in adaptation must be aligned with underlying economic conditions. Development finance institutions will remain central—not only as providers of capital, but as coordinators of financing structures that combine public, concessional, and private resources. This implies a shift away from mobilization targets toward funding-oriented strategies that reflect public budgetary constraints. Scaling adaptation will therefore depend critically on strengthening domestic public finance, including fiscal capacity, planning systems, and the integration of climate risks into infrastructure investment. This includes expanding fiscal

instruments, improving cost-recovery frameworks where feasible, and integrating adaptation costs into medium-term public investment planning.

Even as global climate finance expands, the continued marginalization of adaptation in sectors such as transport underscores the limits of a financing-led approach. Addressing the adaptation finance gap will therefore require a stronger focus on funding—identifying sustainable mechanisms to allocate the costs of resilience in line with its economic characteristics. In this context, private finance can play a complementary role, but cannot substitute for the central role of public finance in supporting climate-resilient development.

Table 1 - Economic Characteristics of Adaptation and Mitigation Investments and Implications for Private Finance

Dimension	Adaptation	Mitigation	Implications for Private Finance
Value creation	Avoided losses, resilience, service continuity	Revenue generation and cost savings	Limited monetization constrains bankability
Revenue model	Weak, indirect, or absent	Direct and contractable	Limits ability to generate investor returns
Cash-flow profile	Uncertain, contingent, non-contractable	Predictable, contractable	Increases risk and reduces investment viability
Attribution of benefits	Diffuse across users, systems, and time horizons	Attributable to specific assets or outputs	Weakens basis for repayment and performance-linked returns
Asset structure	Embedded in broader systems (e.g., infrastructure networks)	Discrete, stand-alone assets	Limits assetization and project finance structuring
Risk–return profile	High uncertainty, returns realized through avoided losses	Risks and returns can be priced and allocated	Requires public risk-sharing and concessional support
Public good characteristics	High (non-excludable, diffuse benefits)	Lower	Necessitates public funding or subsidy mechanisms
Standardization and scalability	Context-specific, location-dependent	Replicable and standardized	Limits aggregation into scalable investment products
Financial structuring	Project-specific; reliant on public or concessional finance	Standardized project finance (debt/equity)	Reduces compatibility with private investment models

Source: Author’s elaboration based on conceptual and empirical literature.

Table 2 – Revenue Models, Financing Structures, and Private Participation in Transport Adaptation: Illustrative Cases

Project / Program	Country	Income level	Asset type	Adaptation function (embedded vs explicit)	Revenue model (funding source)	Financing structure	Private participation
Market-driven (revenue-generating assets)							
4G Toll Road Program	Colombia	UMIC	Toll roads	Embedded in asset design (climate-resilient corridors)	User fees	PPP / concession	High (finance, construction, operation)
Samakhiali–Gandhidham Toll Road	India	LMIC	Toll roads	Embedded in commercial corridors	User fees	PPP	High
Queen Alia International Airport	Jordan	UMIC	Airport	Embedded in asset design and operations	User fees + commercial revenues	PPP / concession	High
Cai Mep International Terminal	Vietnam	LMIC	Port	Embedded in design and risk management	Port fees	Private / joint venture	High (global operators)
Blended finance / hybrid structures							
Karachi BRT (Red Line)	Pakistan	LMIC	Urban transit	Explicit but embedded in system design (flood and heat resilience)	Fares + public subsidy	Public + MDB + climate finance	Limited (operations)
Dakar BRT	Senegal	LMIC	Urban transit	Explicit but embedded in system design (flood and heat resilience)	Fares + public subsidy	Public + MDB financing	Limited
Cambodia Royal Railway (GuarantCo bond)	Cambodia	LMIC	Rail	Embedded in asset rehabilitation (climate-resilient upgrades)	Public support + tariffs	Blended (guarantee + private finance)	Moderate
SMART Tunnel	Malaysia	UMIC	Road + flood system	Explicit (flood management)	Tolls + public support	PPP / hybrid	High

Project / Program	Country	Income level	Asset type	Adaptation function (embedded vs explicit)	Revenue model (funding source)	Financing structure	Private participation
Lima Metro Line 2	Peru	UMIC	Urban metro	Explicit but embedded in system design (flood resilience)	Public payments (availability)	PPP with guarantees	High (finance + operation)
Climate Investor Two Fund	Multi-country	Mixed	Ports & logistics	Embedded across portfolio investments (project-specific adaptation components)	Project-dependent	Blended (public + institutional)	High (portfolio level)
Publicly funded adaptation							
Roads & Bridges Program	Mozambique	LIC	Rural roads	Embedded in network-level design standards (resilience specifications)	Public budget	Public + concessional	None
Cambodia Rural Roads	Cambodia	LMIC	Rural roads	Embedded in network-level design (flood resilience)	Public budget	Public + concessional	None
Climate Resilient Infrastructure Improvement Program	Bangladesh	LMIC	Rural & peri-urban roads	Embedded in system-wide infrastructure (elevated roads, drainage)	Public budget	Public + concessional	None
CREMA Framework (Contrato de Reabilitação e Manutenção de Estradas Baseado em Desempenho)	Brazil	UMIC	Road rehabilitation and maintenance	Embedded in network-level asset management (performance-based, resilient design standards)	Public budget	Public (performance-based contracts)	Limited (performance-based implementation)

Source: Author's compilation based on MDB and OECD reports, blended finance data (Convergence, 2025), and publicly available project documentation.

Note: The table presents illustrative rather than representative cases and groups them by dominant financing logic rather than institutional form. *Revenue model* refers to the source of

funds used to sustain investment, while *financing structure* refers to the provision of upfront capital. *Private participation* indicates the degree of financial involvement and risk assumption by private actors (high = finance and risk-bearing; limited = operational or implementation roles). *Adaptation function* distinguishes between embedded and explicit integration of resilience measures.

Table 3 - Adaptation Functions, Financing Structures, and Contextual Constraints in Transport Infrastructure

Transport segment	Adaptation function (economic nature)	Revenue model	Dominant financing structure	Private participation modality	Country context pattern
Ports	Asset-level resilience protecting trade flows and terminal operations	Strong user fees	Corporate finance / PPP	High but selective	Middle-income, trade-oriented economies
Airports	Asset-level resilience ensuring continuity of high-value operations	Strong user fees	Corporate finance / PPP	High but selective	Middle-income; major traffic nodes
Freight rail	Corridor-level resilience securing revenue-generating logistics networks	Freight tariffs	PPP / corporate / public hybrid	Moderate; demand-dependent	Middle-income; high-volume corridors
Passenger rail	System-level resilience under public service obligations	Partial cost recovery	Public finance + PPP elements	Limited, structured	Middle-income; subsidy-dependent
Toll roads / corridors	Climate-proofing of revenue-generating assets	User charges (variable)	PPP / blended finance	Conditional on guarantees and demand	Middle-income; limited in high-risk contexts
Urban transit (BRT, metro)	System-level resilience ensuring service continuity	Partial cost recovery	Blended finance / PPP (operations)	Limited, structured	Urban middle-income; requires public support
Urban roads / drainage	Network-level resilience embedded in infrastructure systems with diffuse, public-good benefits	No direct revenue	Public + concessional finance	Minimal	Lower-income, high-exposure urban contexts
Rural roads	Basic access and resilience with high social value	No revenue	Public / donor finance	Absent	Low-income, high vulnerability
Inland waterways	Corridor-level resilience supporting regional connectivity	Mixed (fees + public support)	Public + concessional / PPP	Limited, context-specific	Lower- and middle-income; often donor-supported

Source: Author's elaboration based on the literature and case analysis presented in this paper.

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