

Public Infrastructure Financing Models in Emerging Economies: A Conceptual and Comparative Review

Jorge Luis Argoty Burbano

Universidad de Nariño, Facultad de Ingeniería, Programa de Ingeniería Civil, Pasto, Colombia, <https://orcid.org/0000-0001-6661-1398>

Abstract

The persistent gap between infrastructure investment needs and fiscal capacity in Latin American countries represents one of the most critical bottlenecks for sustainable economic development. The region requires investing approximately 3.12% of its gross domestic product (GDP) annually through 2030 to maintain and expand infrastructure in key sectors including transportation, energy, water, and sanitation yet historical average investment has not exceeded 1.8% of GDP.

Infrastructure projects face structural challenges stemming from the magnitude of initial capital outlays, multi-decade payback horizons, and complex risk distribution across construction, demand, operations, financing, and regulatory dimensions. Against this backdrop, a diverse family of financing instruments has emerged, evolving from traditional models budgeted public works and classical concessions toward sophisticated schemes that mobilize private capital, such as public-private partnerships, project finance, asset securitization, shadow tolls, turnkey contracts, public leasing, and revolving funds.

This article provides a comprehensive review of these models, integrating standard financial evaluation tools (net present value, internal rate of return, debt service coverage indicators) with contemporary literature on renegotiations, cost overruns, and contingent fiscal risks in infrastructure projects. Additionally, a methodological framework is proposed for comparative empirical research that combines statistical and econometric analysis with project performance assessment. The resulting recommendations aim to strengthen technical capacity in public entities, improve regulatory frameworks for private participation, and establish robust databases for systematic quantitative analysis in Latin American and Colombian contexts.

1. INTRODUCTION

Physical infrastructure, transport routes, ports, airports, energy networks, water and sanitation systems constitute a critical input for productivity, competitiveness and social cohesion in contemporary economies. In the case of Latin America, empirical evidence documents that infrastructure deficits translate into higher logistics costs, trade bottlenecks, less integration into global value chains, and persistence of territorial inequalities (Kogan & Bondorevsky, 2016; World Bank, 2017). The Organization for Economic Cooperation and Development (OECD) and multilateral development banks have pointed out that, without a significant increase in investment in infrastructure, the region will not be able to achieve the Sustainable Development Goals (SDGs) or maintain economic growth rates compatible with its development potential (World Bank, 2017).

The core of the problem is fundamentally financial. Infrastructure projects require large upfront outlays often between \$10 million and \$50 million in road transportation, and hundreds of millions in energy or water along with payback horizons of 15 to 40 years and complex risk structures including uncertainties in demand, variability in construction costs, operational risks, exposure to interest rate and exchange rate volatility. as well as unpredictable regulatory and political changes (De la Riva, 2017; Vives et al., 2006).

Traditional schemes based on public works financed through the general government budget, often complemented by sovereign debt, have proven to be insufficient to sustain an investment rate compatible with the identified needs, especially in contexts of structural fiscal constraints and debt limits (CAF, 2015; World Bank, 2017).

In response to these constraints, numerous governments in Latin America and other emerging economy regions have adopted instruments that seek to mobilize private capital for infrastructure financing, construction, operation, and maintenance. The specialized literature documents the evolution from the classic concession where the private finances, builds and operates a specific infrastructure in exchange for receiving tariffs or tolls to more sophisticated schemes that include public-private partnerships, structured project finance through special purpose vehicles, securitization of assets in capital markets, shadow tolls that transfer demand risk to the State, turnkey contracts that integrate design and construction under a single responsibility, public leasing where the private party maintains ownership during the term, and revolving funds that reuse recovered resources (De la Riva, 2017; Latypova, 2018).

Despite the multiplicity of instruments available, the comparative experience in Latin America reveals significant challenges. Studies on renegotiation patterns in public-private partnership projects show that between 50% and 70% of contracts undergo renegotiations in the first five years of execution, frequently associated with problems in demand estimation, macroeconomic changes, weaknesses in contract design, or inefficient risk allocation (Neto & Cruz, 2017; Rouhani et al., 2018). In addition, recent research documents the generation of considerable contingent liabilities for the public sector, often hidden or underestimated in initial budget analyses, which compromises fiscal sustainability in the medium and long term (Cruz & Marques, 2017).

This article is proposed as a critical-analytical review of the financing models of infrastructure projects available in emerging economies, with particular emphasis on Latin America and the Colombian context. Unlike purely descriptive approaches, the paper begins with a systematic characterization of the structural financing problems facing these economies. It then proceeds to a comparative analysis of traditional and emerging models, examining their contractual and financial characteristics and risk-sharing mechanisms. The article also formalizes financial evaluation equations and metrics applicable to these schemes, tools that are complemented by a synthesis of the empirical evidence on renegotiations and project performance documented in the recent literature. Finally, the document proposes methodologies for future quantitative research that allow for a comparative evaluation of the performance of the different models according to their institutional context, the characteristics of the capital market, and the specific attributes of the project.

The article is structured in sections that advance from the problem statement and the theoretical framework, through the description of the models, the formalization of analysis tools, the review of empirical evidence, and culminating in recommendations aimed at public policy makers, project structurers and researchers. In particular, it seeks to contribute to reducing the gap between the sophistication of the available financing instruments and the technical and institutional capacity of the public entities responsible for their use.

2. THEORETICAL AND CONCEPTUAL FRAMEWORK

The financing of infrastructure projects in emerging economies is nourished by four main conceptual frameworks: the economics of infrastructure and public goods, the theory of

project finance, the theory of contracts applied to public-private partnerships, and the economic and financial evaluation of long-term investments.

From the perspective of public economics, infrastructure is conceptualized as a good with characteristics of a public good or quasi-public indivisibility, economies of scale, and positive externalities that justify a relevant intervention by the State in its provision, planning, and regulation (Kogan & Bondorevsky, 2016). However, state provision does not necessarily imply exclusive public funding; Fiscal constraints and the magnitude of the resources required have driven models where financing comes from private sources, often under contractual frameworks that specify rights, obligations, and risk sharing between public and private actors.

In the field of corporate and project finance, project finance differs from traditional corporate finance by structuring the financing around a Special Purpose Vehicle (SPV) whose viability is assessed on the basis of the expected cash flows of the specific project, rather than the balance sheet of the sponsors (Vives et al., 2006).

The project's free cash flow in period t can be formally expressed as:

$$FCF_t = I_t - C_t - T_t$$

where it represents revenues (fees, availability payments, grants), operating and maintenance costs, and taxes. $I_t C_t T_t$

Financial viability is assessed using net present value (NPV):

$$VPN = \sum_{t=0}^N \frac{FCF_t}{(1+r)^t} - I_0$$

where I_0 is the initial investment and r the discount rate that reflects the opportunity cost of capital and the risk profile, t time period in years. N Project duration in years. A $NPV > 0$ indicates financial attraction for investors (Vives et al., 2006). I_0

The internal rate of return (IRR), the rate that satisfies $NPV = 0$, allows the implied profitability of the project to be compared with market rates or with the Weighted Average Cost of Capital (WACC). In projects with high financial leverage, the Debt Service Coverage Ratio (DSCR) is important:

$$DSCR_t = \frac{FCF_t}{SD_t}$$

where SD_t is the debt service (interest plus amortization) in period t . Creditors typically require that you exceed minimum thresholds (1.2 to 1.3) to consider credit risk acceptable (Rouhani et al., 2018). $DSCR_t$

From contract theory and the literature on public-private partnerships, the central challenge is to design long-term contractual structures that allocate risks efficiently. The vector of key risks, demand, construction, operation, financial and regulatory, must be distributed among actors (State, concessionaire, financiers) in such a way that whoever can best manage it assumes it, receiving remuneration according to the risk assumed (CAF, 2015; De la Riva, 2017). $R = (r_d, r_c, r_o, r_f, r_{eg})$

In this context, mechanisms such as shadow tolls and availability payments restructure revenue streams. In the shadow toll, the concessionaire receives payments from the State based on actual traffic, so that:

$$I_t = p_s \cdot Q_t$$

Where I_t is the income in period t , p_s is an implicit rate and Q_t is the volume of traffic, partially transferring the risk of demand to the State. In pay-for-availability contracts, revenues are linked to compliance with performance indicators, reducing exposure to demand, but maintaining incentives in operation and maintenance. $I_t p_s Q_t$

Asset securitization allows relatively stable future cash flows to be transformed into marketable securities. If is the expected flow in favor of the security holders, the notional price () is: $CF_t P_0$

$$P_0 = \sum_{t=1}^N \frac{CF_t}{(1+k)^t}$$

where k is the required rate of return, a function of the issuer's risks and the macroeconomic environment (De la Riva, 2017; Pinto, 2023).

The economic evaluation complements the financial evaluation by incorporating social benefits and costs. The benefit-cost ratio (B/C) is defined as:

$$\frac{B}{C} = \frac{\sum_{t=0}^N \frac{B_t}{(1+\rho)^t}}{\sum_{t=0}^N \frac{C_t}{(1+\rho)^t}}$$

where B_t and C_t are socioeconomic benefits and costs discounted at the social discount rate ρ (rho: typically 5-8% in Latin America). Unlike the r -financial rate (8-12%), this social rate reflects the value that society assigns to the present versus the future (World Bank, 2017). A project may be financially viable but socially undesirable, or vice versa. $B_t C_t$

3. Traditional Financing Models

Historically, two traditional systems have predominated in the financing of public infrastructure in Latin American economies: budgeted public works and the classic public works concession (De la Riva, 2017).

3.1 Budgeted Public Works

In this model, the public sector is responsible for the financing, design, construction, operation and maintenance of the infrastructure. Financing comes from the general state budget, occasionally supplemented by sovereign debt or resources from multilateral organizations. The model has advantages in terms of direct public control, relative transparency and avoids transaction costs associated with structuring complex contracts. However, it faces severe limitations: it absorbs limited fiscal resources, generating crowding-out effects with respect to other social expenditures; investment tends to be prioritized over maintenance, generating accelerated deterioration of existing assets; budget constraints often prevent the execution of the required volume of investment; and the lack of market pressure can lead to operating inefficiencies and high unit costs (Kogan & Bondorevsky, 2016; World Bank, 2017).

3.2 Classic Concession

In the classic concession, the private sector often a consortium of construction and service companies, financed by local and international commercial banks, undertakes to finance, design, build, operate and maintain a specific infrastructure for a defined period (typically 15-40 years), in exchange for revenue through tariffs or tolls charged to end users. At the end of the term, the infrastructure reverts to the State.

The model transfers responsibility for financial and operational management to the private sector, which theoretically incentivizes efficiency. In addition, private investment does not directly increase the State's debt or fiscal deficit. However, it presents challenges: it requires the infrastructure to generate sufficient income to amortize investment, pay financing and generate a return on private capital, which implies frequently high fees and can limit access to low-income users; it concentrates demand risk in the concessionaire, which may face insolvency in the face of adverse shocks; it can generate dependence on implicit or explicit state guarantees that recreate fiscal risks; and requires robust regulatory frameworks to control monopolistic practices and protect users (De la Riva, 2017; CAF, 2015).

4. Emerging Financing Models

4.1 Public-Private Partnerships (PPPs/PPPs)

Public-private partnerships represent an extension and sophistication of the classic concession. They are defined as "forms of collaboration between public authorities and private companies, aimed at facing both the construction of infrastructure works and the provision of public services, in which the State maintains ultimate responsibility for the provision of services, but transfers part of the execution and risk to the private sector" (Dorrego & Martínez, 2009, p. 45).

PPPs can take multiple contractual forms. In a traditional Design-Build-Finance-Operate-Maintain (DBFOM) PPP, the private sector assumes comprehensive responsibilities. In simpler variants, the State partially finances and the private manages operation and maintenance. The distinguishing element is the greater contractual precision regarding risk distribution, payment mechanisms (often by availability rather than by demand) and rules for renegotiation.

The model has the advantage that it allows the State to execute projects without generating direct debt although it does generate contingent debt, mobilizes private expertise in the management of complex projects, and establishes incentives for operational efficiency. The disadvantage is that transaction costs including legal structuring, due diligence, financial consulting are substantially higher than in public works or classic concessions; they often range from 2-5% of the value of the project. In addition, contractual complexity can generate information asymmetries that favor the private party in subsequent negotiations.

4.2 Project Finance

Project finance is a financing structuring technique where a special purpose entity (SPV), with limited equity, finances a specific project based on the cash flows generated by that project. Creditors have limited claims on sponsors "non-recourse" or limited recourse, which implies that their recovery depends critically on the financial viability of the project (Vives et al., 2006).

Project finance typically involves a heterogeneous capital structure, with senior debt with repayment privilege, subordinated debt and equity of the promoters; offtake contracts (production purchase agreements) or availability contracts that guarantee minimum revenues; covenants (contractual restrictions) that protect creditors, such as leverage limits, minimum debt coverage rates (DSCRs), dividend distribution restrictions, and insurance and guarantee requirements; and risk-sharing arrangements to mitigate exposure to exchange rates, interest rates, or commodity prices (Vives et al., 2006; Rouhani et al., 2018). The appeal of project finance lies in the fact that it allows the mobilization of capital from specialized investors (pension funds, insurance, development banks) that seek long-term assets with predictable flows, typically without requiring collateral from sponsors. However, contractual complexity and the need to generate certainty about cash flows for funders imply substantial costs. In Latin America, project finance has been predominantly used in sectors such as renewable energy, water treatment plants, and road projects with predictable demand (Latypova, 2018; CAF, 2015).

4.3 Securitization of Assets.

Securitization is a financial process that transforms assets that can generate income streams into marketable securities. In infrastructure, it is used to anticipate future cash flows from a concession, allowing construction debt to be refinanced through the placement in stock markets of instruments backed by expected tolls, royalties or availability payments (De la Riva, 2017; Pinto, 2023).

The process typically involves an originator entity, i.e., the concessionaire, assigning future receivables to a securitization vehicle; a risk rating agency that assesses the solvency of ceded flows; structuring of differentiated risk tranches senior tranches with lower risk and

lower return, intermediate mezzanine tranches, and equity or junior tranches with maximum risk but higher return potential; and institutional investors (pension funds, insurance companies, asset managers) who acquire the securities. This technique has allowed infrastructure in Latin America to access domestic and international capital markets, mobilizing resources from investors who previously did not participate in direct project finance (AIIB, 2022; Pinto, 2023).

4.4 Shadow Toll

The shadow toll is a remuneration mechanism where the private sector does not charge the end user directly, but receives payments from the State based on the actual traffic on the infrastructure. Formally, if Q_t is the volume of traffic in period t and p_s is the implicit unit rate, the revenues are (Olmeda, 2004; De la Riva, 2017): $p_s I_t = p_s \cdot Q_t$

This structure solves problems of accessibility and equity. Low-income users are not excluded by high rates, but it transfers the risk of demand partially to the State, which must provide funds according to actual traffic. The amount of payment is unknown ex-ante, being determined ex-post according to actual demand. In contexts of fiscal constraints, the shadow toll can generate considerable contingent liabilities if traffic is significantly higher than projected (De la Riva, 2017; CAF, 2015).

4.5 Availability-Based Payment

In this variant, revenue is linked to indicators of availability and technical performance of the infrastructure, for example, a percentage of daily availability for the user, safety conditions, response times for maintenance instead of depending on traffic or demand. The State guarantees basic payments if availability standards are met, reducing exposure to demand for the concessionaire, but maintaining incentives to maintain high operational standards (CAF, 2015; World Bank, 2017).

4.6 Turnkey Contract

In this model, often referred to as "German", a company (or consortium) contracts the integral responsibility of design and construction of a work (combined design-build), taking responsibility for quality, deadlines and costs. Unlike project finance, turnkey typically does not include private financing or operation; the State finances the work or contracts additional financing. This model reduces design risks and subsequent changes by making a single entity responsible (Ducci, 2013; De la Riva, 2017).

4.7 Leasing Público

In this structure, a private entity finances, builds and maintains the ownership of an infrastructure for a defined period, while the State (or users) makes periodic payments (leasing fee) that allow the private sector to recover investment and generate returns. At the end of the contract, the infrastructure reverts to the State. The private sector maintains ownership and residual rights (residual value), transferring part of the long-term risk (Ariño & López de Castro, 2001; De la Riva, 2017).

4.8 Revolving Funds

Revolving funds are mechanisms where financial resources are used to finance specific projects, often targeting priority sectors (e.g., environmental infrastructure, renewable energy). The cash flows generated by the projects are reinvested in new projects, allowing continuous expansion without requiring additional budgetary contributions (Latypova, 2018). This model has shown potential in countries such as Russia for solid waste infrastructure, allowing conservative investors to access attractive returns with low risk.

5. Empirical Evidence on Renegotiations and Performance in Latin America

An important line of research in the last 15 years has documented patterns of renegotiation, cost overruns, and failures in PPP contracts and concessions in Latin America. Cruz and Marques (2017), in a comprehensive study of PPP renegotiations in infrastructure at a

global level, found that Latin America has one of the highest rates of renegotiation: between 50% and 70% of contracts undergo at least one renegotiation during their first five years of validity. The causes identified include: deficiencies in previous demand studies, unforeseen macroeconomic changes (variation in interest rates, volatility of exchange rates), failures in construction cost estimates, regulatory weaknesses and local political conflict.

Neto and Cruz (2017), using data from PPP projects in Brazil at the state level, found that of 42 projects developed between 2006 and 2016, 27 were renegotiated at least once. The analysis suggests that factors such as election cycles, political shareholder connections, and deficiencies in bidding processes and initial planning significantly increase the likelihood of early renegotiation. These findings underline that these are not simply unavoidable exogenous risks, but rather problems in the quality of ex-ante structuring that could be mitigated through better evaluation, selection, and monitoring processes.

Guevara et al. (2024), in an analysis of Colombia's fourth-generation (4G) road concession program during the COVID-19 pandemic, using content analysis, natural language processing (NLP), and social network analysis (SNA), found that of 29 road projects under PPPs, 13 underwent renegotiation processes during the crisis. The study revealed that most of the renegotiations focused on mechanisms of temporary suspension of works and cessation of toll collection, but with significant differences depending on the complexity of the project, stage of execution and negotiation procedures used. In particular, projects in the early stages of construction showed greater flexibility of adaptation, while projects in operation faced more rigid contractual constraints.

Rouhani et al. (2018), in an analysis of revenue risk sharing strategies on privately participated toll roads, reviewed multiple global approaches to mitigate demand risk, including minimum availability payments, dynamic revenue insurance, and flexible rate adjustments. The study highlights that the selection of the mechanism must be adapted to the level of demand risk, the risk capacity of both parties and specific characteristics of the project. In contexts where demand is highly uncertain and volatile, the authors recommend combined approaches that distribute risk to both the public and private sectors, avoiding extreme transfers that generate perverse incentives or moral hazard.

6. Methodological Framework for Comparative Empirical Research

A four-stage approach is proposed for future research combining individual financial analysis of projects with comparative statistics and econometrics:

Stage 1: Database Construction. Develop a structured and longitudinal database that records for each infrastructure project: sector (road, energy, water, airport), specific financing model, investment amounts, capital structure, contract term, remuneration mechanism (tariffs, availability payments, subsidies), indicators of the country's institutional quality, and execution milestones (starts, delays, renegotiations, changes of operator). This foundation is the cornerstone for any robust analysis.

Stage 2: Standard Financial Assessment. Apply NPV, IRR and DSCR calculation equations to each project under base, pessimistic and optimistic scenarios of demand, costs and interest rates. Perform sensitivity analyses to identify critical risk variables. This makes it possible to characterize the financial vulnerability of each project and compare the relative robustness of financing models.

Stage 3: Descriptive and Multivariate Statistical Analysis. Using the project databases, calculate distributions, means, standard deviations and percentiles of NPV, IRR, DSCR by type of financing model, sector and country. Apply techniques such as cluster analysis to group projects according to similar characteristics and performance. This makes it easier to identify abnormal patterns and deviations.

Stage 4: Econometric analysis. Specify logistic regression models to estimate the likelihood of renegotiation, cost overruns, or additional fiscal support requirements, including variables such as contractual structure, remuneration scheme, institutional quality indices (rule of law index, World Bank corruption control index), macroeconomic stability, and leverage magnitude. Alternatively, duration models (survival analysis) to analyze time until first renegotiation or critical event. The general specification could be:

$$P_r(\text{Renegociación} = 1) = F(\beta_0 + \beta_1 \text{TIPOAPP}_i + \beta_2 \text{PagoDisponibilidad} + \beta_3 \text{IQI}_i + \beta_4 \text{Apalancamiento} + \epsilon_i)$$

where F is a logistic function, IQI is an institutional quality index, and estimated coefficients reveal the marginal effect of each variable on the probability of renegotiation.

7. Implications for the Colombian Context

Colombia has characteristics that make it a particularly relevant case for applying proposed analysis frameworks. The country has executed multiple "generations" of road concessions, culminating in the 4G program (2014-2024) comprising approximately 40 road projects under PPPs, with committed investment of approximately USD 24 billion. This program has made it possible to mobilize both domestic capital through Colombian pension funds of considerable size and international capital.

However, the 4G program has faced significant challenges: widespread delays in the construction phase, frequent renegotiations motivated by cost variations, regulatory uncertainties, and, during COVID-19, severe impacts on toll revenues. Systematic analysis of these projects using proposed methodology could identify specific factors that reveal performance variations and guide improvements in future generations of PPPs in transport or other sectors.

In addition, Colombia has relatively developed local capital markets compared to other Latin American countries, allowing experimentation with securitization of infrastructure assets. However, the depth and liquidity of these markets are still limited compared to developed economies, implying higher financing costs and more stringent collateral requirements.

8. Public Policy Recommendations and Professional Practice

A comprehensive approach requires interventions in multiple dimensions. First, it is essential to strengthen technical capacities in public entities through training programs in project finance, risk analysis, contract design, and fiscal impact assessment aimed at public officials responsible for structuring and supervising infrastructure projects. This investment in human capital allows the public sector to negotiate in a more balanced position with respect to private investors and specialized advisors.

In addition, it is a priority for national infrastructure agencies or development banks to create and maintain public, verifiable and auditable longitudinal databases on projects executed or in execution, recording technical, financial, contractual and institutional variables in a standardized manner. This facilitates systematic empirical research and allows for transparent accountability. Without this structured information, it is impossible to identify patterns of renegotiation, cost overruns, or differential performance between models.

At the same time, it should be mandatory to formally apply NPV, IRR, DSCR and sensitivity analysis equations in the approval of projects and in the comparison of financing alternatives. These calculations should be publicly available and reviewed by independent control bodies. The institutionalization of standard financial evaluation ensures comparability and reduces spaces for discretion in public investment decisions.

The improvement of regulatory frameworks is another fundamental pillar. Countries should improve their PPP and concession laws to establish explicit and restrictive rules on when and how renegotiations are allowed, improve accounting records that allow for the monitoring of long-term contingent obligations, strengthen dispute resolution mechanisms (arbitration, mediation) that are expeditious but fair, and reinforce transparency in contractual information. These institutional changes reduce ex-post discretion and align incentives towards operational efficiency.

At the same time, the promotion of comparative empirical research is essential. Universities and research centers, with the support of development banks, should promote quantitative studies that apply econometrics to project databases to identify determinants of renegotiations, cost overruns, and performance. This research must be public and must guide institutional reform processes, closing the gap between academic evidence and public policy.

Finally, the strategic selection of financing models requires recognizing that, although there are multiple models available, their relevance varies significantly according to specific contexts. The magnitude and type of infrastructure, the project's capacity to generate direct revenues, the depth of the local capital market, the quality of the regulatory framework, and the technical capacity of public entities are determining factors in choosing between PPPs, project finance, public works, or hybrid models. Not all projects are candidates for PPPs or project finance; some are better served by traditional public works.

9. CONCLUSIONS

The financing of infrastructure projects in emerging Latin America faces increasing complexity derived from the convergence of persistent fiscal constraints, unprecedented investment needs, and multiplicity of available contractual and financial instruments. While academic literature and comparative experience have documented models and best practices, the gap between the sophistication of instruments and the institutional capacity to implement them remains substantial.

This article attempts to generate the state of knowledge on traditional and emerging financing models, formalized financial evaluation tools, reviewed empirical evidence on project performance in Latin America, and proposed methodological frameworks for future comparative research. The derived recommendations aim to strengthen public capacities, improve regulatory frameworks, institutionalize financial evaluation practices, and generate solid evidence bases.

In the specific case of Colombia, the 4G road concessions program presents a unique opportunity to apply and validate these frameworks, allowing institutional learning that can benefit future generations of infrastructure investment. However, this requires political commitment to transparency, rigorous research, and a willingness to reform processes that have historically operated in an opaque manner.

The pending agenda is ambitious: improve previous demand studies, refine cost estimates, design more adaptive contractual structures, develop deeper capital markets for securitization, strengthen PPP governance, and build a culture of systematic evidence-based assessment. This article seeks to contribute to this agenda, placing itself at the intersection between synthesis of available knowledge and formulation of research questions that need to be answered through rigorous empirical research in the coming years.

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