Assessing the Welfare and Distributional Impacts of Private Sector Participation in Infrastructure Interventions

Reference Paper for World Bank Group Staff

November 16, 2020

Infrastructure Finance, PPPs and Guarantees Global Practice
Poverty and Equity Global Practice

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Acknowledgement

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Abbreviations and Acronyms

AIMM – Anticipated Impact Measurement and Monitoring
ASEAN – Association of Southeast Asian Nations
BRT – bus rapid transit
CBA – cost-benefit analysis
CGE – computable general equilibrium (model)
DD – Difference-in-Differences
ERR – economic rate of return
FCGE – financial computable general equilibrium (model)
FSAM – Financial Social Accounting Matrix
GDP – gross domestic product
GHGs – greenhouse gases
ICT – information and communications technology
IFC – International Finance Corporation
IMF – International Monetary Fund
IV – Instrumental Variable
MDB – multilateral development bank
MFD – Maximizing Finance for Development
MFI – microfinance institution
MIGA – Multilateral Investment Guarantee Agency
NPV – net present value
PSIA – Poverty and Social Impact Analysis
PPP – public-private partnership
PSM – Propensity Score Matching
RDD – Regression Discontinuity Design
SOE – state-owned enterprise
SDGs – Sustainable Development Goals
SAM – Social Accounting Matrix
UN – United Nations
WBG – World Bank Group
WTA – willingness to accept (compensation)
WTP – willingness to pay

1. Introduction

This Reference Paper aims to help World Bank Group (WBG) teams assess the welfare and distributional impacts of private sector participation in interventions in infrastructure sectors.[1] It serves as a background and detailed reference for the *"Technical Guidance Note on Assessing the Welfare and Distributional Impacts of Private Sector Participation in Infrastructure Interventions."* The proposed theory of change and methodologies are relevant for projects when they are funded entirely by the government, entirely by the private sector, have a combination of both public and private finance, or are funded by the government and managed by the private sector. Assessing both types of impact is important, as the extent to which infrastructure improves the welfare of the target population can vary depending on people's income, gender, age, connectivity, vulnerability, access to land, and other factors. This paper focuses on infrastructure sectors because bridging the infrastructure gap is essential to achieve the WBG's twin goals of poverty reduction and shared prosperity, as well as the United Nations Sustainable Development Goals (SDGs).

Maximizing Finance for Development (MFD) was developed by the World Bank Group with the intention of supporting countries maximize their development resources by drawing on private financing and sustainable private sector solutions to provide value for money and meet the highest environmental, social, and fiscal responsibility standards, and reserve scarce public financing for those areas where private sector engagement is not optimal or available. The MFD is part of the WBG's efforts to implement the Finance for Development (FfD) agenda formalized at the United Nations Conference on Financing for Development, held in Addis Ababa in July 2015, when policy makers agreed that development finance should be reoriented to strategically unlock, leverage, and catalyze domestic and foreign flows of private finance.[2] To implement MFD, the Cascade algorithm asks WBG staff to consider if there is a sustainable private sector solution that limits public debt and contingent liabilities. If this exists, it should be pursued; if not, policy changes, then risk mitigation then public funding should be considered. In making this assessment, WBG staff are advised to ensure that the costs and benefits of private versus public solutions are properly assessed, and that equity and affordability concerns for consumers are properly addressed. Given this mandate, impact analysis for WBG-supported interventions must quantify not just the average effects, but also how the costs and benefits are distributed, both directly and indirectly, across various populations groups.

Looking at infrastructure through a welfare and distributional lens to identify impact, and how it may vary across the target population, also requires considering the financial and delivery modalities. Considering the total cost for capital, as well as for long-term, recurring expenditures is necessary as the financing typically comes from the government's general budget, user fees, or taxes. This can affect not only the sustainability of the infrastructure, but also people's welfare as the government may have less to spend on social services such as education and healthcare and, hence, the cost of financing a project is one of the costs that should be included in calculating a project's net benefits.

Policymakers and other stakeholders are interested in knowing whether, and to what extent, private sector involvement could affect the well-being of beneficiaries, and how both the benefits and costs of the intervention would be distributed across different groups. Funding and financing are the defining issues in this context. Funding refers to who ultimately pays for the full cost of infrastructure services—the users or the taxpayers. Financing refers to who provides the upfront resources to build and start operating the infrastructure. Financing could be fully public, or fully private, or a mix of both. A key consideration in assessing the impact of private sector involvement is the interdependence between funding and financing, both of which are driven by the potential for cost recovery, pricing, and other regulatory decisions, as well as the timeline of the cash flow. This interdependence may lead to a trade-off between financial viability and inclusion. For example, the risk of excluding poor or credit-constrained consumers by increasing users' fees could limit the extent to which policymakers can pursue a project's financial viability.

1.1. Objective and scope of this Paper

The objective of this Reference Paper is to set out the requirements regarding assessment of the distributional impacts from infrastructure services that include private sector participation. However, the theory of change and methodologies for assessing impacts presented are equally relevant for projects independently of its financing sources. Effective policymaking, and all investments for development, require a sound evidence base for the design and implementation of policy, regulatory, and investment interventions to address key development constraints.

This paper presents a theory of change to identify the causal impacts of infrastructure interventions with private sector participation, and evaluation approaches and methods to address key questions about whether private sector participation in infrastructure interventions improves people's well-being (welfare), who is impacted, how this occurs, and at what cost. Addressing these questions requires measuring how the intervention impacts key aspects of well-being—a multi-dimensional concept encompassing income and non-income aspects (i.e. consumption versus human development). Assessing how these impacts are distributed across different policy-relevant socioeconomic groups such as rural and urban residents, men and women,[3] rich and poor, and specific vulnerable groups who are directly or indirectly affected, is critically important to better understand the impact of infrastructure, and of private sector participation.

Establishing this type of evidence aims to help WBG teams to enhance policy dialogue on private sector investments in infrastructure sectors. For example, a WBG digital development team in a given country might use a distributional impact analysis to promote understanding about how to unlock benefits of digital technologies, and under which optimal conditions. It should be stressed again that although this paper focuses on private sector participation in infrastructure, the guidance applies equally to interventions with public finance.

The intended audience of this paper are technical staff in World Bank, IFC and MIGA as well as in client governments and other development agencies. While the paper can also serve as a useful entry point and introduction for development practitioners and researchers thinking about assessing distributional impacts of infrastructure projects, it is not intended to serve as an instructional manual or a rigorous review of the evaluation literature (several of the references cited in this paper serve that purpose to a varying degree). Instead, the purpose of this paper is twofold. First, it seeks to emphasize the importance of assessing impacts of infrastructure projects on well-being, and doing so in a manner that considers (a) variations in net benefits across types of individuals and households, and (b) the mode of financing of the project, to the extent that has implications for the size and distribution of net benefits. Second, to help project teams and other decision-makers make decisions about what, when and how to evaluate, the paper discusses the applicability and limitations of different methods. These discussions are not comprehensive, but rather intended to distill the main points in an intuitive and non-technical way, leaving it to the readers to delve into the technical nuances of the methods they are most interested in, using the many references cited here. The paper is not a substitute for (or a summary of) the vast literature on ex ante assessments and impact evaluations, including the vigorous academic debates about the pros and cons of randomized controlled trials (RCTs). The discussion on RCTs is deliberately muted here, except to explain how they serve as a gold standard or benchmark for ex post evaluations but are seldom applicable to large infrastructure projects.

1.2 Impact of infrastructure development on growth and distribution

The growth and distributional effects of infrastructure development define the two main channels through which infrastructure can reduce poverty. Sustainable infrastructure investment is crucial for medium- and long-term economic growth, and the adequate provision of infrastructure-related services (such as those for power generation and transmission, irrigation, transport, water and sanitation, education, and health) is essential for achieving the development outcomes that improve people's lives.[4] Analysis of the impact of infrastructure must move beyond assessing only efficiency to consider quality dimensions such as sustainability and safety, and how these impacts affect different groups in the population.

The links between infrastructure and development outcomes are complex. Importantly, they depend on the local context, which adds to the difficulty of identifying impacts at the aggregate level. Evidence about the impact of infrastructure on inequality is mixed. An analysis of panel data gathered in 136 countries between 1960 and 2005, found that an increase in the volume of infrastructure stocks, along with an improvement in the quality of infrastructure services, can have a positive impact on economic growth in the long run, and also reduce income inequality.[5] However, a 2014 review of theoretical and empirical literature on the effects of infrastructure development on growth and income distribution in developing countries, found only suggestive evidence that infrastructure development is equity-enhancing.[6] The review also found little information on whether improving access to, and the affordability of, infrastructure services varies for households at different percentiles of income distribution. Although an assessment of the poverty impact of rural roads in Bangladesh found that the intervention was pro-poor, in the sense that the benefits were proportionately higher for the poor than for the non-poor,[7] another Bangladesh study on improving access to paved roads and irrigation showed that richer households benefited more than poorer ones.[8]

The literature on impact assessment identifies several channels through which infrastructure interventions contribute to economic growth. These include: productivity, complementarity, and crowding-in of private sector financing; investment adjustment costs; the durability of private capital; and the delivery of social services such as health and education.[9] If the factors of production are considered as gross complements, an increase in the stock of infrastructure will likely increase the productivity of labor and capital. Accordingly, the rate of return on physical capital (such as a factory) will be higher when significant investments have been made in infrastructure such as power generation, transport, and telecommunications. Improving infrastructure can also reduce the adjustment costs that prevent firms from modifying their capital stock in response to changes in the relative price of capital, or an increase in productivity. Conversely, unreliable infrastructure impedes the delivery of dependable services (e.g. electricity and telecommunications), and in some cases can affect the durability of the equipment that relies on such services.

Finally, improving infrastructure supports the provision of social services that lead to better health and education outcomes, both of which underlie human capital development—an important driver of economic growth. For example, the availability of safe water and sanitation in schools can increase girls' attendance;[10] better transport systems and road safety can increase all students' school attendance; and access to electricity can improve students' learning outcomes.

Expanding access to, and the quality of, economic and social infrastructure services (e.g. transport, energy, water, sanitation, telecommunications,[11] health, and education) can improve productivity in various sectors of the economy, and also have a direct and positive impact on people's quality of life (the non-income dimensions of well-being).[12] For example, a study conducted in India on the health gains from piped water showed that for children under age five, the prevalence and duration of diarrhea was lower in households with piped water, compared to similar households without piped water.[13] Electricity can improve households' quality of life by supplying power for appliances that make life more comfortable, healthy, and safe; transport infrastructure can reduce travel time, and also improve comfort and safety; and digital development,[14] notably broadband, can improve economic opportunities for the poor, while helping achieve key development outcomes such as health coverage and women's empowerment.[15]

According to the literature on economic geography, including the *World Development Report 2009*,[16] location is the most important correlate of a person's welfare, and socioeconomic development is driven by transformations in density, distance, and division.[17] However, development does not spread prosperity evenly across space because market forces tend to favor some places over others. As a result, economic activity is more intense in urban areas, and in areas that are closer to domestic and international markets. Within a given country, areas that are economically lagging are those that are distant from prosperous areas. Thus, the challenge for policy makers is how to design and implement policies that improve connectivity between lagging areas and areas of economic density. This implies that infrastructure investments are crucial for economic development as they involve making decisions about the location of physical structures, equipment, and organizations that connect defined geographic areas. In line with the *World*

Development Report 2009's policy framework,[18] investments in transport infrastructure improve mobility and connectivity, and ultimately, integrate lagging areas with prosperous ones.

However, as already noted, infrastructure investments may benefit some more than others. An analysis conducted to establish a pipeline of connective infrastructure projects across the Association of Southeast Asian Nations (ASEAN) region showed that the benefits of transportation corridor investments vary across the population.[19] Thus, it is important to conduct an "equity assessment" as part of the pre-feasibility studies for potential projects. Such an assessment would analyze the distributional benefits of transportation corridor investments, with emphasis on social inclusion. The ASEAN analysis also noted that failure to identify the relative and absolute winners and losers from an intervention could lead to inequitable impacts on the well-being of different segments of the population.

In the context of infrastructure development, digital infrastructure merits special attention as it has taken on increasing importance in recent years. Robust and accessible digital infrastructure is one of the key preconditions for an inclusive and growing digital economy. One critical aspect of digital infrastructure is the penetration of high-speed, reliable, and robust broadband infrastructure; a second critical aspect is the coverage of mobile phone services.

Empirical evidence on the impact of mobile phones and the internet highlight economic gains through various channels, as well as the unequal distribution of these gains.[20] A few studies found that greater mobile phone coverage reduces differences in consumer prices across geographic areas for certain commodities, and particularly for remote markets and markets that are connected by poor-quality roads. Mobile phone coverage can also reduce geographic differences in producers' prices.[21] The literature on the welfare impacts of the internet suggests positive gains in wages and employment, but with significant variation with respect to workers' skills and location. For example, Hjort and Poulson[22] used the gradual arrival of submarine internet cables on the African coast, and maps of the terrestrial cable network in 12 African countries, to show the positive effect of high-speed internet on the employment rate, with little or no job displacement across space. Evidence also indicates that greater internet access disproportionately benefits workers with more education. According to a recent study in Brazil, most wage increases accrued to workers engaged in non-routine cognitive tasks, while workers engaged in routine cognitive tasks experienced negative returns.[23] In the above study for Africa, the sample-wide positive impact resulted from greater employment in higher-skill occupations, while less-educated workers experienced lower gains.[24]

1.3 Role of the state and the private sector

To make its full contribution to development, infrastructure needs to deliver services that meet users' needs, and do so efficiently. According to welfare economics theory, competitive markets lead to efficient allocation of resources. However, the fact that infrastructure is inherently a public good is usually invoked as a rationale for non-competitive, public provision. The role of the public sector in providing infrastructure is also justified by the occurrence of market failures. In addition, infrastructure investments require a long project cycle and time horizon and, hence, long-term financing, which is usually not available to private firms, and especially not to those in developing countries.[25]

The occurrence of market failures implies the potential for government to improve living standards.[26] However, while it is the responsibility of government to ensure that infrastructure services are delivered at a socially optimal level, government delivery can fail, just as commercial delivery can. Government intervention is warranted if it addresses a significant market imperfection, or an equity issue, and it is designed in such a way that the perceived benefits outweigh the costs. This requires identifying and analyzing the imperfection, and demonstrating that the social benefits of public intervention outweigh its social costs.

While infrastructure development is primarily the responsibility of the state, pure public provision does not always work well. Inefficient or non-transparent procurement, inadequate technical and management resources, and/or limited fiscal space may result in poor public sector performance. Poor physical and social infrastructure services may be due to constraints that public agencies face—for example, lack of public funds, and weak planning and analysis underpinning project preparation, execution, and maintenance. Problems with the performance of the public sector have led to calls for private sector participation in providing infrastructure assets and services—for example, using public-private partnerships (PPPs) to overcome constraints faced with public provision of infrastructure services through leveraging both the finance and skills of the private sector (for project planning, execution, maintenance, and delivery).[27] By bundling all these steps with one provider, or a consortium, PPPs can provide whole-of-life asset management and achieve efficiency gains.[28]

It is important to give serious consideration to the allocation of risks among the parties involved. Allocating project risk efficiently is one of the main ways of achieving better value for money through PPPs.[29] In short, effective risk allocation is critical to the project's success. There are a number of risks that a project may face. These include political, legal, regulatory, completion, performance, financing, offtake, environmental, and social risks. Private developers will only enter an arrangement if they assess that the risks are worth taking—in other words, that the expected rewards will be adequate, given their risks. A central principle of risk allocation is that each risk should be allocated to whoever can manage it best..[30] In this context, risk management entails the ability to: (i) influence the likelihood of the risk occurring; (ii) control the impact of the risk; or (iii) absorb the impact of the risk at the lowest cost.

1.4 The potential gains from private sector participation in infrastructure

The question of whether private sector participation in infrastructure development leads to better outcomes underpins the "Cascade algorithm",[31] which helps to identify a range of financing and delivery options that leverage the private sector, while ensuring the judicious use of scarce public resources and concessional finance, i.e. sustainable private solutions that limit public debt and contingent liabilities. Alternatively, WBG teams could determine that weaknesses in the policy or regulatory environment, or the risks involved will present binding constraints to private sector solutions, and then, if needed, devise interventions to address these constraints. According to the Cascade algorithm, WBG teams should pursue the public option only after concluding that this is the best alternative, given the availability and effectiveness of private solutions.

This logic ensures discipline in evaluating the effect of private sector participation in infrastructure interventions, relative to the public option. Efficiency gains are what typically motivates the inclusion of the private sector. The proposed core theory of change (Section 2) leads to considering key questions regarding potential efficiency gains from private sector participation: Do such gains exist? Do they imply any trade-off between access and affordability? Will they lead to improvements in equity, and to poverty reduction?

A study by Gassner et al.[32] on private sector participation in public electricity, water, and sanitation projects found credible evidence of improvements in efficiency, access, and affordability.[33] In the electricity sector, these were increases per worker of: 42 percent for residential electricity connections, 32 percent for electricity sold, and 45 percent for bill collection. Private sector participation also achieved an 11 percent reduction in electricity distribution losses. In the water sector, private sector participation increased water connections per worker by 54 percent, and water sold per worker by 18 percent. In the case of sanitation, connections per worker increased by 37 percent.

Thus, private sector participation can induce large efficiency gains. However, these can vary depending on the contract type and sector. The study by Gassner and co-authors considered four types of private sector participation: privatization or full divestiture; partial divestiture; or a concession, lease, or management contract. For electricity, the greater role of the private sector, the stronger the productivity gains. Utilities that underwent full or partial divestiture experienced the largest gains, except with regard to bill collection, for which concessions had the largest improvement. For water and sanitation, utilities under a concession, a lease, or a management contract realized the biggest productivity gains. It may be that contractual obligations such as improving service quality and expanding coverage, which are traditionally associated with concessions, leases, and management contracts, help to achieve better outcomes from private sector participation in water and sanitation.

Andrés et al.[34] studied the impact of private sector participation in infrastructure in Latin America that resulted from a significant policy shift in the 1990s. Across 181 electricity, water, and telecommunications firms, they assessed a range of performance measures such as output, labor productivity, quality, coverage, and prices (see Box 8 in Section 4). They found that while private sector participation led to overall improvements in sector performance, including large gains in productivity, quality of service, and coverage, to varying degrees regulatory and contract characteristics impacted the extent of these gains. For example, the presence of a fully autonomous regulatory body positively influenced performance. The authors' findings demonstrated that gains in performance due to private sector participation were influenced by the type of contractual arrangement, institutional capacity, and the regulatory environment that supported the design and implementation of the contracts with the private sector. Andrés and co-authors also suggested that efficiency gains do not necessarily improve affordability and coverage, which are typically needed to improve welfare and distribution.

Conversely, for the three sectors that Gassner and co-authors assessed,[35] private sector participation had no significant impact on the average residential tariff even though there were efficiency gains. One explanation is that services were originally so underpriced that efficiency gains were still not enough to achieve financial equilibrium as well as a price reduction.[36] A second explanation is that most of the efficiency gains accrued to the private firms as profits. The study by Gassner et al. also found that even when private sector participation led to an increase in operational efficiency, in the long term, it did not necessarily lead to additional investments that increased capacity and coverage.

The few studies on the welfare and distributional impacts of private sector participation suggest widely varying impacts. For example, a study on privatization of water and electricity in Bolivia and Argentina found positive welfare and distributional impacts, with people at the lower end of income distribution benefiting the most.[37] Whereas a study on privatization of electricity in Nicaragua showed that the increase in the price of electricity reduced welfare at all expenditure levels, with the bigger losses occurring at the top of the distribution.[38]

Consistent with how efficiency is generally understood, the focus of Gassner et al. was on the ratio of output to labor input as an indicator of performance or efficiency. The improvement in labor productivity in electricity and water distribution occurred, in part, due to staff reductions that came with private sector involvement. While the loss of jobs can have immediate adverse welfare and distributional effects, a broader (and longer-term) perspective is needed to fully account for the employment effects of private sector participation in the development of infrastructure. Infrastructure can generate jobs both directly and indirectly through induced economic growth. Moreover, with regard to employment, as well as other determinants of well-being, a distinction must be made between the effect of the infrastructure itself, and that of the contractual arrangement with the private sector. Given this distinction, an analytical framework should be adopted that accounts for all the types of effects from infrastructure development so that the effect of the contractual or financing arrangement for infrastructure development can be assessed.

Mobilizing resources to invest in infrastructure will likely become an even bigger challenge given the current health pandemic caused by COVID-19 and its economic and fiscal fallout. COVD-19 response and recovery measures will strain the fiscal capacity of many developing economies, which would imply a greater need for private sector participation and public-private partnerships. Expanding the role of the private sector in infrastructure provision while promoting an inclusive recovery from COVID-19 would require placing greater emphasis on project selection, prioritization and design that take into account the needs of the poor and broader equity considerations.

1.5 The role of complementary policies for efficiency and equity gains

When making decisions about, and evaluating, the private sector's role in a specific intervention, it is also important to view the welfare and distributional implications of this intervention in the context of the impacts of broader policies. Consider the hypothetical scenario where the private sector's role in an infrastructure project produces efficiency gains but has adverse equity effects on the user tariffs that are essential for cost recovery. Complementary policies such as providing targeted subsidies for poorer users (for example, in the form of transfers or vouchers) can mitigate or reverse these adverse impacts. This can be achieved without giving up the efficiency gains from private sector participation or weakening the beneficial outcomes of the project. Another example is the case of a highway development project with private sector participation, for which immediate direct benefits are expected to accrue largely to the richer segments of the society who are more likely to commute on the highway. Complementary investments, such as those that improve or build feeder roads and/or public transport systems can play a key role in expanding the benefits of the highway to serve broader segments of society. Likewise, in line with *World Development Report 2009* on reshaping economic geography, follow up work on spatial economics, and *World Development Report 2020* on global value chains, many interventions are moving the focus from single sector interventions to spatially coordinated investments.

The above examples illustrate that to achieve broad welfare and equity gains in a society, it is not necessary for every project (with or without private sector participation) to achieve the socially optimum mix of efficiency and equity gains. Rather, to attain such a mix, policies and investments must complement each other by adopting objectives and design features that add up to a consistent vision for achieving society's development goals. Therefore, in making decisions about private sector participation in an infrastructure intervention, it is important to (i) quantify the likely efficiency and equity implications of private sector participation in the project; and (ii) use the estimates of (i) in the context of broader policymaking that takes into account the effects of complementary policies (actual or potential) on efficiency and equity—for example, by mitigating adverse distributional impacts or strengthening positive ones.

This implies the need to consider the distributional implications of a broad set of policies that can complement infrastructure investments in an evidence-based way in order to make decisions about, and evaluate, individual projects. A rich set of World Bank materials for Poverty and Social Impact Analysis (PSIA)[39] provide rigorous and practical approaches for evaluating, ex ante (before the intervention), the welfare and distributional impacts of policies. These materials also include many examples of how these approaches have been applied to assess the impacts of national and sectoral reforms.[40] To sum up, the PSIA site provides guidance on how to assess the distributional and social impacts that policy reforms have on the well-being of different groups of the population, and particularly on the well-being of the poorest and most vulnerable.

1.6 Key questions in distributional impact analysis

Assessing the welfare and distributional impacts of an intervention requires an evaluation that produces evidence to answer the critical policy and investment questions that decision makers and other stakeholders care about concerning the design, implementation, and results of an intervention.[41, 42] Well-posed questions that focus on relevant issues determine the appropriate evaluation design and methods. To establish whether an intervention works, policy makers need to identify the causal relationship between the intervention and the outcomes of interest, and how that relationship changes across different groups and locations to produce different outcomes. In turn, identifying causal relationships requires accounting for the contextual factors that affect the intervention, and the channels through which impact on the outcomes occurs.[43] A theory of change is the main tool to use for determining what could cause the expected outcomes of the policy, regulatory, and investment interventions under consideration.

As public resources are scarce, the allocation of resources must be efficient; this means that policy makers must quantify the benefits of an intervention and compare these to the costs. Furthermore, promoting shared prosperity requires the broadening of cost-benefit analysis to account for the distributional impact of the alternatives. These issues remain relevant throughout the reform and project development cycle: ex ante (at the design stage, before implementation), during implementation, and ex post (after implementation).

Evaluating the welfare and distributional impacts of private sector participation in infrastructure interventions requires focus not only decision-making at the project level, but also at the sector and country level. This includes reform programs that, over time, expand the options for private sector solutions to help achieve development goals through different types of private sector engagement—e.g. catalyzing private financing in physical assets through policy reform or demonstrating the viability of new technology.

A country's infrastructure is a collection of physical and organizational structures and facilities designed to supply commodities and services that support human activities and living conditions in the country. There are two broad categories of infrastructure—social and economic.[44] Social infrastructure supports services in the health, education, culture, sport, public administration, and security sectors. Economic infrastructure includes transport (land, water, air, and multimodal); energy (conventional and renewable); water and sanitation; and communications. Most economic infrastructure comprises physical networks characterized by technologies and physical assets (e.g. roads, transmission lines, pipelines, power plants), and institutions that regulate access and quality norms.[45] The nature of the network is important for evaluation because it helps determine the scope of the intervention and, hence, the exposure of targeted beneficiaries.

This Paper focuses on three broad categories of interventions: (i) small-scale infrastructure interventions (e.g. rural electrification, rural road improvement, and some urban transport systems); (ii) large infrastructure interventions (e.g. port development, power distribution networks, and transnational railways); and (iii) policy interventions, namely private sector participation-enabling, or upstream reforms (e.g. adoption of a public-private partnership model). These categories differ, depending on whether or not the intervention can be assigned to some observational units (such as households, firms, or communities)—in other words, small-scale interventions are assignable, while large-scale ones are not. Assignable interventions can be evaluated within a partial equilibrium framework, while non-assignable interventions require either multimarket or general equilibrium modeling to cater for the potential significant spillover effects.

As the methods discussed in this Reference Paper apply mostly to large investment projects and market-oriented reforms at the country or sector levels, they fall into the latter category of evaluation. Computable general equilibrium (CGE) modeling is an appropriate analytical approach for a full accounting of impacts, while a financial computable general equilibrium (FCGE) model allows consideration of their financial flows.[46] Private sector participation in infrastructure interventions widens the scope of the evaluation, given the need to consider the welfare and distributional impacts of various financing and contractual arrangements for service delivery in specific sectors.

Another relevant distinction is whether infrastructure supplies private goods and services (e.g. housing) that can be sold and bought in well-functioning markets. Information on market transactions can be used to value such goods and services. While non-market outcomes or public goods require different valuation techniques, infrastructure interventions considered in this paper are presumed to produce public goods.

1.7 Outline for this Paper

The rest of the paper is structured follows: **Section 2** explains, conceptually, the causal link that may exist between private sector interventions and their intended outcomes. A proposed theory of change describes the causal processes, and the conditions under which an intervention is supposed to solve the target development problem. **Section 3** presents ex ante impact analysis within the logic of cost-benefit analysis, focusing on quantification of policy outcomes, and using simulation models, valuation methods, and distributional and aggregation approaches. **Section 4** focuses on ex post impact analysis to account for the possibility that the impact of an intervention may vary substantially across segments of the population that have different socioeconomic characteristics and/or who live in different geographic areas (impact heterogeneity). **Section 5** provides a summary. The **Annex** provides theory of change frameworks for three projects and short explanations about each of them.

2. Theory of Change: Linking Private Sector Participation in Interventions to Intended Outcomes

Policy and infrastructure interventions, including those with private finance, are designed to solve particular development problems. An intervention can be thought of as a means-ends relationship wherein public resources are transformed into individual and societal outcomes through a set of activities that are subject to the influence of contextual factors.[47] Therefore, assessing the welfare and distributional impacts of a policy or infrastructure intervention requires understanding the causal relationship between the intervention and the intended outcomes. Such an understanding is commonly expressed as a *theory of change*. This section presents a core theory of change model, and how it can be applied to private sector participation in infrastructure interventions. It also discusses the link between a theory of change and a results framework that can guide the development of monitoring and evaluation systems.

A theory of change has three components: (i) a causal chain, (ii) outside conditions and influences, and (iii) key assumptions.[48] The causal chain is based on an understanding of the technical and behavioral relationships that determine how the resources provided by the intervention are transformed into outcomes for the individual, as well as for society as a whole. The theory of change provides a rationale for the intervention to the extent that it answers the key question: Why undertake this particular intervention? Policymakers and other stakeholders need the answer to this question to determine whether, given the problem and circumstances, the intervention is timely and appropriate for the beneficiaries, and for the economy at large. Thus, the development of a theory of change starts by identifying the motivation that underlies the decision to undertake the intervention. This hypothesis can be stated in a series of observations and assumptions known as rationale assumptions.[49]

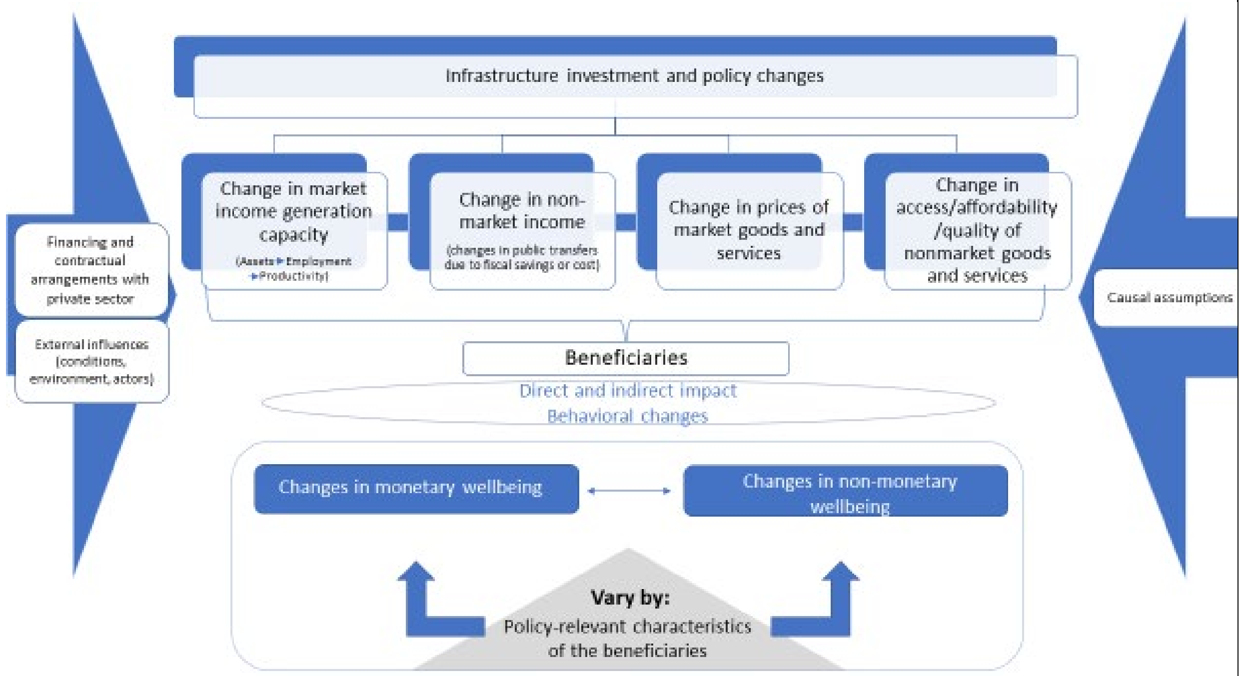
The development of a theory of change for private sector participation in an infrastructure intervention requires a clear understanding of the relevant technical, behavioral, and institutional arrangements. Technical relationships are derived from the literature about the sector under consideration (e.g. transport, energy, water, sanitation, and telecommunications). Behavioral relationships stem from responses by socioeconomic agents to the incentive structure presented by the intervention, subject to market and nonmarket institutional constraints. Parts of the theory of change dealing with the funding issue must reflect the characteristics of the sector under consideration. For instance, the potential for cost recovery may be higher for an electricity project than for one that improves rural roads or sanitation. Furthermore, as mentioned earlier, attracting private finance depends on pricing and regulatory decisions. A realistic treatment of this issue in the theory of change must account for institutional factors such as the extent of corruption and the capacity of the public sector to enforce regulations. These institutional factors determine the extent to which public policy can crowd-in private involvement in infrastructure development (e.g. financing or service delivery).

Arguably, the *results chain* is the simplest and clearest representation of the theory of change in the operational context of development programs.[50] Such a chain shows the sequence of *inputs*, *activities*, and *outputs* that are supposed to lead to *outcomes* and *impacts*. Each link in this chain is potentially influenced by contextual factors and is subject to causal assumptions. Consider the case of an investment in electricity infrastructure. The results chain might include the following elements:[51]

- ***Inputs***: Financing and other resources
- ***Activities***: Investment in electricity generation, transmission, and distribution
- ***Outputs***: Expanded electricity network
- ***Outcomes***: Improved indoor air quality, better educational and health outcomes, improved employment possibilities
- ***Impacts***: Improved socioeconomic welfare

Examples of causal assumptions underlying this process include: (i) the legal and regulatory framework governing the energy sector is favorable; (ii) the intervention is well designed; (iii) electricity provision is properly targeted and the associated infrastructure is well maintained; (iv) polluting sources of energy are replaced by electricity (improving indoor air quality); (v) better lighting increases children's study time (improving educational outcomes).

Figure 2: Core Theory of Change



Source: World Bank Group staff

Figure 1 focuses on the logic underlying any infrastructure intervention. Thus inputs, activities, outputs are all grouped together in the top block labeled: "Infrastructure and policy changes". Outcomes reflect socioeconomic agents' response to policy and institutional changes induced by the intervention. Changes in market income generation capacity, nonmarket income, prices, and access to, or quality of, nonmarket goods are the first order policy outcomes. Impacts are the long-term results indicating whether the program goals were met. The ultimate goal of public policy is to improve the well-being of the beneficiaries. Thus, impacts are represented in Figure 1 by changes in monetary and non-monetary well-being. The distributional impact is determined by the characteristics of the beneficiaries.

Individuals are believed to derive improvement in their welfare from the best bundles of market and non-market commodities they can afford, given their socioeconomic constraints. The basic economic model of individual behavior and social interaction draws a link between individual welfare and the exogenous parameters that affect people's patterns of consumption. It is through these channels that policy and investment infrastructure interventions affect individual welfare. Thus, the channels comprise the socioeconomic environment that mediates the welfare effects of policy interventions. The distributional impact of infrastructure depends on the ability of governments, and of the planning and regulatory authorities, to design measures that ensure that the benefits of an intervention do not go only to the wealthy, and that the intervention increases opportunities, access, and the quality of services for the intended beneficiaries

It is worth emphasizing that Figure 1 is only a model—a logical picture of a process, a simplified view of reality. It demonstrates the flow of causal influence among the variables of interest. In general, this representation is based on a substantive theory that is viewed with consensus by the scientific community.[52] In the case of socioeconomic impact analysis, the causal model has been derived from the economic theory of individual behavior and social interaction. This theory implies that *market and individual behavioral adjustments* induced by policy interventions are the main channels through which policy affects individual and social well-being.

Therefore, components of the core theory of change presented in Figure 1 stand for complex subsystems in the supply and demand sides of the economy that interact to produce outcomes. While the four channels of causal influence are presented separately in Figure 1, it is important to keep in mind that they are interrelated and interact to produce simultaneous effects. For instance, changes in the prices of market goods and services are an outcome of changes in the supply and demand factors in relevant markets. Changes in supply and demand are driven by changes in assets, productivity, and employment. Finally, changes in price determine changes in income and consumption. Computable general equilibrium (CGE) models discussed in the next sections are an interpretation of the theory of change underlying Figure 1. They provide an analytical framework to handle the complex and simultaneous causal relationships that drive policy impact.

The potential to foster inclusion through the adoption of certain infrastructure services (e.g. digital technology) may or may not be realized, depending on the socioeconomic characteristics of households and individuals, the characteristics of firms, and the environment enabling inclusion to happen. Thus, the bottom block of the core theory of change depicted by Figure 1 indicates that the welfare impact varies depending on the policy-relevant characteristics of the beneficiaries. These characteristics are the key determinants of the distribution of impacts. The impact of an intervention on a household depends on the household's attributes and the circumstances it faces. For instance, which households end up benefiting from electrification depends on the attributes of the households, as well as the characteristics of their communities.

If the activities and outputs are properly targeted, the intended outcomes will emerge from the behavioral changes that are expected to occur among the various categories of direct and indirect beneficiaries. Therefore, the distributional impact of an infrastructure project depends on changes with regard to access, and the affordability and quality of services, as experienced by the various categories of direct beneficiaries. It also depends on economic impact—how the effects of the project on prices, employment, and productivity are spread across all direct and indirect beneficiaries. For example, with PPPs that typically rely on user fees, the efficiency gains should be transferred to the end users, and services should be provided in an inclusive way. Also, infrastructure investments and policies can affect all dimensions of welfare. For example, electrification leads to higher incomes and consumption by increasing productivity, but it improves health too by reducing indoor pollution because people stop using kerosene lamps.

In the Annex are illustrations of how the core theory of change framework depicted in Figure 1 applies to private sector participation in World Bank projects in three countries:[53] Internet connectivity in Afghanistan (A-1), electricity in Yemen (A-2), and urban mobility in Cote d'Ivoire (A-3). These figures depict the intended distributional impact of a specific private sector-related policy and infrastructure intervention; and the red font denotes the potential impact of private sector interventions, as opposed to the impact of general infrastructure investment and policy changes.

2.1 Transmission channels of impact

In a market economy, each person's claim to available goods and services is limited to the amount of income that person can obtain from successfully selling something of value in the market.[54] Thus, the capacity of a household to generate income is determined by the assets it owns, or has access to, the intensity of using those assets, and the returns earned on the assets.[55] Assets include tangible and intangible capital such as human capital (e.g. health, level of education, and years of experience in the labor market); financial assets (e.g. stocks, bonds, and savings); physical assets (e.g. machinery); social capital (e.g. activity in social networks); and natural capital (e.g. rivers and forests). The intensity of use of these assets depends on market demand. This is especially the case in the labor market, which determines the extent to which human capital—the most abundant asset for the poor—is employed. Returns on assets are determined by their productivity. Investing in infrastructure can improve the intensity of asset use, as well as the returns on assets by enabling better access to product and factor markets, and reducing costs (e.g. for energy, transport, and telecommunications). All these aspects can be expected to have an effect on market income. Box 1 provides an example of an infrastructure project that raised the value of, and returns on, household assets, which led to tangible gains in consumption (a key measure of welfare).

Box 1: Mexico Urban Street Pavement Project

A study carried out in poor residential neighborhoods in Acayucan, Mexico, illustrates the impact that an urban street pavement project can have on well-being through changes that occurred in the value of property and land, and possibly through improvements in peoples' welfare. Home values on the paved streets increased by 17 percent, land values rose by 72 percent, and rents for properties located on the paved (treatment) streets were 36 percent higher than rents on the control (non-treatment) streets. Furthermore, the study indicated a possible increase in people's welfare, as within two years of the intervention, beneficiary households responded to their greater property wealth by increasing their consumption of durable goods such as household appliances and motorized vehicles, and their spending on home improvements.

Source: Gonzalez-Navarro and Quintana-Domeque 2016.

In most countries, labor income is the main source of market income for households. Thus, employment and earnings (labor market outcomes) are the key transmission channels in the impact causal process. Changes in employment reflect changes in the intensity of human capital use, while changes in earnings indicate changes in productivity (returns).[56] Note that the jobs provided in the course of building infrastructure may result in the temporary rise in labor earnings, both for project workers and other workers who gain from the tightening labor market.[57]

There are also medium and long-term impacts after infrastructure construction ends. In the case of transport infrastructure, it is well known that costs, both in money and time, are an important determinant of location, as well as decisions about whether to migrate for work.[58] Increased mobility resulting from the reduction in transport costs affects economic geography. For instance, an improvement in rural roads helps inhabitants gain greater access to urban centers, increases rural-urban trade, and expands non-farm income opportunities in rural areas.[59] These outcomes can also lead to changes in how labor is allocated to farm and non-farm activities.

Private and public transfers are the two main sources of non-market income. The factors that affect market income can affect private transfers, while the impact of interventions on the fiscal resources of government can affect public transfers. Private sector participation is generally expected to improve the efficiency of public resource allocation, leading to greater fiscal space, which may, in turn, affect the way public transfers are made to households and firms. For private sector participation in infrastructure projects involving commercial debt or bond-financing, the business model affects the repayment of debt, which affects the fiscal impact of the intervention. Finally, investments in infrastructure affect market prices by improving access to, and the operation of markets, and by reducing transaction costs. Specific infrastructure can also affect the availability or quality of nonmarket goods and services. For example, a transport project may affect congestion, greenhouse gas (GHG) emissions, air pollution, and road safety.

2.2 Assumptions

A description of causal pathways, alone, does not constitute a theory of change. As already noted, the above theory of change is a simplified representation of a complex causal system that is driven by economic structures, policy, technical relationships, social interactions, and individual behavior. Complexity stems from a variety of considerations, such as: (i) infrastructure can affect many outcomes simultaneously, and these effects can be geographically dispersed; (ii) stakeholders (e.g. public versus private; national versus local) may pursue conflicting objectives; and (iii) the impacts of private sector infrastructure interventions are sensitive to both initial conditions, and to the changing context. The changing context relates to infrastructure creating opportunities for welfare improvement but, as already noted, the beneficiary population must have complementary, enabling endowments. In the end, the welfare and distributional impacts of an infrastructure intervention emerge from the market, and the individual behavioral adjustments that are induced by the intervention through the casual pathways that are described in the theory of change.

Further, causal assumptions must be added to identify what needs to happen for a pathway to work as expected.[60] These causal assumptions identify factors that are critical for the proper, or improper, operation of the mechanisms underpinning the causal pathway. Consider the assessment of the poverty impact of an irrigation project in Andhra Pradesh in India,[61] which constructed a causal pathway with five channels through which irrigation can reduce poverty. These were: (i) direct impact on income; (ii) increased agricultural employment and wages; (iii) multiplier effects through irrigation-induced growth; (iv) lower food prices; and (v) empowerment through increasing the assets of the poor, including their access to social capital through community organizations.[62] Given that construction delays and cost overruns undermine the economic viability of irrigation investments, and that water pricing policy can distort incentives, leading to the wasting of water, causal assumptions that rule out these known constraints can overestimate a project's expected benefits. The ex post economic analysis of the Andhra Pradesh Irrigation Project demonstrated the extent to which factors such as construction delays and cost overruns constrained irrigation project outcomes. The project's analysis found that the economic rate of return was just 2 percent, rather than the 19 percent expected at appraisal.[63] This finding underscores the challenge of formulating realistic assumptions, ex ante.

Along these lines, the International Finance Corporation (IFC)'s development impact assessment framework, AIMM (Anticipated Impact Measurement and Monitoring) provides a way to reflect the relevant elements of the project's theory of change, as well as the uncertainty around the realization of potential effects. Regarding the former, sector-specific infrastructure, AIMM frameworks include a variety of components that describe different effects of a comprehensive theory of change for such sub-sector (e.g. power and transport infrastructure such as airports, ports or roads), from which the most relevant ones for a specific project can be selected to anchor the development impact analysis. In addition, a likelihood assessment that includes implementation, sector-specific, country-specific, and policy-related risks is included in the analysis, to reflect the uncertainty around ex-ante expectations and, ultimately, provide risk-adjusted development impact assessments.[64]

Most causal assumptions about infrastructure interventions recognize that the prospective benefits from infrastructure investments are derived and conditional. The effectiveness of the causal mechanisms depends, critically, on their interaction with: other policies, regulations, and institutions; other physical investments; and geographic, community, and household characteristics or endowments. For instance, the multiplier effects associated with an irrigation scheme may not materialize unless there are profitable economic opportunities in the catchment area, and households have the capacity to respond to these opportunities. The structure and operation of the labor market determine the extent to which irrigation leads to increased agricultural employment and wages. Similarly, the benefits from electrification depend, crucially, on complementary infrastructure such as roads and markets, and on the ownership or leasing of relevant equipment and appliances. Finally, a study of the impact of private sector participation in infrastructure in Latin America (see Box 8) found that the regulatory framework and contract characteristics do matter. In particular, the presence of a fully autonomous regulatory body improved performance more than any other regulatory aspects. These factors also underpin the heterogeneity of (differences in) effects that explain the distributional impact of interventions. It is, therefore, clear that the state of contextual factors is an important source of causal assumptions.

All causal assumptions should take such considerations into account. For example, an irrigation project may benefit better-off farmers as they are likely to own most of the land. Since most poor households have no land to irrigate, their benefits from irrigation are more likely to be indirect (for example, more employment on farms or higher wages). The evaluation of the Andhra Pradesh Irrigation Project found that farmers with large pieces of land were those with the highest incomes, and they captured most of the higher farm income resulting from the project.

2.3 Attribution and counterfactuals

The core theory of change in this paper aims to support decision makers in conducting a contribution analysis to demonstrate the difference an intervention makes in the lives of its beneficiaries.[65] The notion of contribution is based on the concept that an intervention works alongside contextual factors to produce the observed outcomes. This approach to causal inference requires seeking alternative explanations to check whether the outcomes of the intervention are consistent with the theory of change. If the outcomes are consistent with the theory of change, then there is a plausible association between the intervention and the observed outcomes. However, this does not provide enough evidence to show that the outcomes were caused by the intervention. To infer a causal relationship between the intervention and the observed outcomes, project teams should identify the most plausible alternative explanations for the outcomes (the counterfactuals) and rule them out on the basis of evidence or logical arguments.

Another way of dealing with causal inference is by including hypotheses in the intervention's theory of change,[66] and testing these hypotheses, based on counterfactual, context-specific comparisons. For this paper, the counterfactuals include the different contractual or financing arrangements along the continuum from public to private sector financing, and from public to private methods of delivery. The four high-level categories of procurement for addressing development problems or policy objectives and their matching potential impacts are: (i) a fully public solution (a public budget-financed solution that is executed by the public sector); (ii) a publicly-financed solution that is executed by the private sector (e.g. competitive public procurement for construction, and for a management contract for operation; (iii) PPPs (a partially publicly-financed solution that is executed by the private sector); (iv) a fully private solution (with regulated prices to avoid monopoly pricing). These determine the direction and magnitude of effects, both positive and negative. Project teams should consider the pathways through which such counterfactuals could emerge. Considering the time lag between interventions and the desired outcomes, a contribution analysis is particularly important for infrastructure.

2.4 From the theory of change to the results framework

A results framework depicts the logical connections between the different levels of expected results,[67] and it should reflect the causal mechanisms described in the theory of change. Thus, the theory of change provides a framework for guiding decisions about which aspects of an implementation's performance or results to monitor on a regular basis, and to constantly review because project circumstances may change over time due to the long duration of infrastructure interventions. The framework also indicates what to assess through an impact evaluation.[68] Each element of the theory (inputs, activities, outputs, outcomes, and causal mechanisms) requires relevant performance indicators.[69] For example, by measuring indicators such as a reduction in travel time or travel costs, it is possible to measure the impact of transport infrastructure that is expected to improve connectivity among socioeconomic agents.[70]

An indicator is a measurable or observable construct that reflects a state of affairs. Therefore, a performance indicator can be viewed as a gauge that shows how the intervention is working.[71] There are two basic categories of indicators. Process indicators relate to activities and provide evidence of progress toward the outputs; outcome indicators provide evidence of progress toward the achievement of the intervention's objectives. What ends up being measured in a given situation depends on the evaluation questions, and the design of the indicators chosen to answer them. However, there must always be a tight link between the intervention theory and the performance indicators. Both the acronyms SMART[72] and CREAM[73] provide guidance on the key attributes that performance indicators should have. While both process and outcome indicators are useful for a comprehensive performance monitoring system, a results framework focuses mainly on outcomes at three levels: short term, medium term, and long term. For this distinction to be meaningful, it must be based on a realistic estimate of how long it takes to reach a given stage of the intervention, and how much of the outcome is likely to be achieved at that stage. The long-term outcomes are critical for infrastructure interventions, because, as already noted, infrastructure benefits may take a long time to materialize.

There is a close relationship between policymaking, the design (investment and modalities of delivery) and the implementation of interventions; the sources of financing (which can, reciprocally, influence program design and implementation); and evaluation. The development objectives of a policy or infrastructure intervention define the desirable outcomes for the beneficiaries; the design, implementation, and mode of financing allow the objectives to be reached; and a credible evaluation produces reliable information for making better decisions on what works, and why.

Building a valid results framework requires WBG teams to have:[74] (i) a clear articulation of the problem that the infrastructure intervention is designed to address; (ii) a plausible theory of change; (iii) working knowledge of the evidence required for measuring and assessing desired outcomes; and (iv) data sources and proven data collection approaches that are relevant for the intervention. Furthermore, for the purpose of distributional analysis, data should be collected in a disaggregated form in order to capture the differences between policy-relevant socioeconomic groups such as rural and urban people, men and women, young and older people, rich and poor, and vulnerable groups.

3. Ex ante Evaluation – Expanding the Cost-benefit Analysis Framework

This section focuses on issues related to the quantification of effects, valuation of policy outcomes, distribution of net effects, and aggregation of the effects across individuals. To address perceived societal problems, decision makers need to identify the best course of action from feasible alternatives. Ex ante impact analysis aims to inform such policy choices, and it is commonly framed within the logic of cost-benefit analysis (CBA), as CBA provides a systematic framework for identifying and evaluating the likely outcomes from the identified or prioritized interventions.[75] The 2013 WBG Economic Guidance Note, *Investment Project Financing*, argues that economic analysis is an integral part of project development, and the paper considers CBA "the most comprehensive approach and, in many ways, the gold standard."[76]

Based on the set of feasible options, and the likely consequences from their implementation, CBA can produce evidence to help decision makers determine the most efficient option for society.[77] CBA involves four basic steps: (i) identification and specification of feasible options for achieving the given policy objectives; (ii) computation of the consequences of each option; (iii) valuation of the policy effects;[78] and, (iv) ranking of the policy options on the basis of some overarching criterion. These steps are consistent with the following three principles that are characteristic of CBA's underlying evaluative approach.[79] First, the approach relies on consequential reasoning to evaluate the consequences of decisions and classify them as costs and benefits. Second, the approach requires explicit valuation of all the costs and benefits. Finally, CBA uses addition to aggregate properly valued costs and benefits to provide a basis for overall judgment.[80]

A disaggregated CBA—one that is able to differentiate between relevant groups—is necessary for assessing distributional effects. Typically, conventional CBA does not attempt to provide a valuation of the costs and benefits of an intervention for different segments of the population. But a CBA conducted, ex ante, to assess the distributional impacts of interventions needs to disaggregate the value of the net effects across the relevant socioeconomic groups and geographic regions. Each alternative represents a set of activities that can plausibly lead to attaining the policy objective. For instance, to achieve greater connectivity, alternatives might include upgrading the existing rail infrastructure to high-speed rail, building a new highway, increasing airport capacity, or doing nothing.[81] All the activities under each alternative must be described in sufficient detail to allow for meaningful analysis.[82] Choosing among alternative policies requires determining the favorable (beneficial) and adverse (costly) physical, social, and economic consequences that could result from each policy option. For instance, a transport project could affect income, travel time, fatal accidents, and air pollution—all of which are measured in different units. However, assessing the desirability of policy options requires that the favorable and adverse consequences be made commensurate. This, in turn, requires defining and estimating commensurate measures of value for the policy outcomes. Finally, the selection of the most desirable policy option entails ranking the alternative policy outcomes based on their social value, which requires aggregating the individual value of each outcome.

Consistent with the logic of causal inference, effectively identifying the costs and benefits of an intervention is based on the consideration of alternatives.[83] Thus, CBA can be viewed as comparing outcomes in two states of the world: one with the intervention, and one without.[84] This assumes that on the basis of a valid situation analysis, the project team has properly considered all relevant alternatives, and selected the one that is most likely to prevail in the absence of the intervention. CBA may determine that in order to increase generating capacity to meet electricity demand, a coal-fired thermal power station is the next feasible alternative to a hydropower project. CBA would then focus on these two alternatives. In the context of private sector participation, the alternatives should also be defined by how they are financed (private versus public). This is necessary as each mode of financing would have differing direct and indirect benefits, as well as costs. Correctly identifying the alternatives is equally important because neglecting a meaningful alternative (particularly a low-cost and effective solution) would bias the CBA.[85] Therefore, CBA assumes that all relevant alternatives have been considered, and the one that is most likely to prevail in the absence of the intervention is the next best. The likely consequences of the intervention are then relative to this counterfactual.

Finally, comparing the distributional impacts of the alternatives implies assessing not just the aggregate or average impacts of each alternative, but also their impacts on the well-being of relevant groups such as those in different geographic regions, the poor/non-poor/bottom 40 percent, men and women, and so on. For both equity and financial sustainability, analysis must move beyond efficiency to consider the distribution of costs and benefits.

As noted previously, mainstream CBA focuses on demonstrating that the intervention will achieve economic efficiency, with little attention paid to how the costs and benefits will be distributed across policy-relevant socioeconomic groups. However, in the context of private sector participation, various contracting or risk transfer models can entail different impacts that must be assessed. For example, under a PPP contract, a significant transfer of the demand risk to the private operator should see a greater number of end users, including low-income users. Or through using new technology, the private operator could increase convenience for the disabled people who use the infrastructure. Other key private sector-related design dimensions (e.g. the criteria for awarding the contract), as well as the broader regulatory framework, can affect the incentives of the private investor, and ultimately, the distributional impact of the intervention.

3.1 Quantifying the effects of interventions

The costs associated with an intervention are the benefits that must be given up by allocating resources to the chosen intervention. This is consistent with the idea of assessing the return on a resource engaged in a socioeconomic activity, based on its opportunity cost, which indicates what the resource would have earned under the next best alternative use. For example, the development of hydroelectric power may have environmental costs such as biodiversity loss in the areas flooded by the project. These must be estimated, and then added to the capital and operating costs, or their avoidance should be reflected as a benefit in the economic analysis. Indeed, quantifying and monetizing the potential environmental damage can be difficult—for example, quantifying the leaching from solid waste disposal sites into the groundwater.[86] Similarly, the only benefits that matter in CBA are marginal (incremental) benefits. These are the benefits that would accrue over and above those that would have accrued in the counterfactual state. The only benefits from hydroelectric power generation that matter are those over and above the benefits of coal-fired generation, if the latter is the valid counterfactual.

In the case of a road transport project aiming to improve travel conditions for goods and passengers, the quality of the environment, and ultimately the well-being of the population, is measured through the following intermediate outcomes: (i) less congestion within the road network, (ii) better performance of the road network through higher travel speeds and lower operating costs, (iii) lower GHG emissions and pollution,[87] and (iv) lower transport costs. Thus, the most common direct benefits of road transport projects include:[88] (a) lower vehicle operating costs; (b) saving time; (c) fewer and less severe accidents; and (d) greater comfort, convenience, and reliable service. There may also be indirect effects related to economic development and the environment—for example, an increase in pollution counts as a cost, while a reduction in pollution is a benefit.

Once the consequences of an intervention have been identified, they must be measured as validly and reliably as possible.[89] Consistent with the proposed core theory of change, the quantification of benefits and costs relies, fundamentally, on modeling the behavior of socioeconomic agents and their social interaction. The conventional CBA approach uses a simple supply-and-demand framework that represents the primary market in order to conceptualize, measure, and value the consequences of an intervention. Primary markets are those that are directly affected by a policy intervention.[90] The theory of change implies that interventions affect people by changing the prices they pay, and the incomes they receive. In a perfectly competitive market, with all participants acting in their self-interest, prices are supposed to adjust until supply is equal to demand (i.e. until the market reaches equilibrium).

Within this framework, any shift in supply or demand will move the market to a new equilibrium, with prices, quantities, or both, adjusting to the new situation. An effective intervention is expected to change supply and/or demand and cause the market to move to reach a new equilibrium. Markets adjust through the response of participants to the new conditions created by the intervention. The change in quantities from the initial to the final equilibrium provides the basis for measuring the consequences of the intervention, while the change in prices can be used to value those consequences (assuming perfect competition).[91] For a discussion of valuation issues, see Subsection 3.3.

3.2 Modeling approaches

In the case of an infrastructure intervention, the framework described above calls for modeling the supply of, and the demand for, infrastructure services. For example, for a road project that aims to reduce transport costs, it is necessary to relate equilibrium quantities to the generalized transport costs, which include vehicle operating costs, travel time, tolls, and the cost of accidents. For infrastructure, the costs and benefits that result from a given intervention depend on changes in demand, or in the use of the related services. A critical step in estimating the benefits of a transport project is predicting demand over the life of the project.[92] Demand for a road can be measured using traffic volume per unit of time. A traffic model is necessary to forecast demand patterns that show how, over time, trips will respond to the changes in transport supply and demand that result from the intervention. Such a model is used to predict the travel choices made by most users.[93]

An important limitation of conventional CBA is that it considers the consequences of each intervention in the context of a single market (i.e. the primary market). CBA can provide a reasonable approximation of the impacts of small projects because the majority of the effects are likely to impact one sector, primarily, or a relatively small geographic area. However, in the case of large infrastructure projects, the effects are bound to spill over beyond the primary market. In addition to impacting end users, due to backward and forward linkages, the intervention could affect the suppliers of inputs to the project. Large infrastructure projects can also reduce the cost of production in some industries, leading to direct and indirect effects as a result of lower prices for some goods and services. To capture both the direct and the indirect effects, the frame of analysis needs to be widened from partial equilibrium to multimarket analysis, or general equilibrium modeling. Computable general equilibrium (CGE) models have been used to analyze transportation networks—notably road pricing, changes in coverage and speed, infrastructure financing, land-use impacts, transport costs, and infrastructure dependencies.[94] CGE modeling allows consideration of the impact that the change in transport costs has on flows in the network, as well as on the pattern of production and consumption as relative prices change (Box 2). Overall, a CGE framework is suitable to analyze the policy consequences that are generated by adjustments in individual behavior and social interaction.

Box 2: What is a General Equilibrium Model?

A general equilibrium model is a logical representation of a socioeconomic system wherein the behavior of all participants is compatible. The basic Walrasian framework serves as a template for most applied general equilibrium models. There are two categories of agents: consumers and producers (or households and firms). According to the optimization principle, each household buys the best bundle of commodities it can afford. Choices made by firms are driven by profit maximization, subject to technological and market constraints. Socioeconomic agents interact through a network of perfectly competitive markets. Behavioral compatibility is defined in terms of market equilibrium. General equilibrium is achieved by the configuration of relative prices such that, for each market, demand is equal to supply. Policy analysis requires a computable or applied model that usually takes the form of a system of equations describing the supply and demand sides of the economy, along with budget constraints and equilibrium conditions. The necessary data are usually organized in a Social Accounting Matrix that reflects the circular flow of economic activity over the chosen time period.

Source: Essama-Nssah 2006.

However, challenges commonly arise when appraising large infrastructure projects due to the long time horizon for realizing benefits, the scale of these projects, the different impacts across geographic space, and the financing structures (public versus private).[95] Hence, a framework that enables analysis of the welfare and distributional impacts of projects, as well as their financing options, is especially suitable for large infrastructure interventions with private sector participation. A financial computable general equilibrium (FCGE) model can be used to analyze the impact that infrastructure investments and their financing options are likely to have on growth and income distribution.[96] Because FCGE models integrate the real and financial sectors of the economy, they can be used to trace the flows of financial and real resources among socioeconomic agents (see Box 3).

For example, an FCGE model was used in Indonesia to evaluate three financing options for a highway project in Jakarta, and another in East Kalimantan.[97] In both cases, the options were (i) tax revenues, (ii) government bonds, and (iii) private financing. The FCGE model enabled quantification of changes in the supply and demand of commodities that resulted from changes in the transportation network, as well as in the chosen financing method. Evaluation of the impact of the three financing options on GDP revealed that government financing would have the greatest positive effect on GDP, as the private sector faces higher financing costs than the public sector. The FCGE model also showed that financing construction with government bonds would be the second-best option.

Box 3: Financial Computable General Equilibrium Model

As noted in Box 2, a general equilibrium model is a representation of a socioeconomic system that can be viewed as a set of market and nonmarket institutions that help society cope with scarcity of resources. Two broad categories of sectors underlie a socioeconomic system: the real and financial sectors. The real side of an economy deals with the production of goods and services, the generation and distribution of value added, and the use of disposable income for final consumption and savings (UNSD 2002). Through financial intermediation, the financial sector provides the financial resources necessary for the operation of the real sector. The Walrasian template for CGE modeling discussed in Box 2 focuses mostly on transactions in the real sector of the economy. In that framework, the working of the financial sector remains implicit, and is summarized by the savings-investment balance. This feature severely constrains the ability of a standard CGE model to deal with flow-of-funds issues related to the determination of aggregate savings and the allocation of investment across productive sectors.

Analysis of flow-of-funds issues, as well as the evaluation of the differential impacts of financing the same infrastructure project in various ways (including private sector financing), is best handled through a financial CGE (FCGE) that incorporates both the real and financial sides of the economy and their interactions. In that sense, an FCGE can be viewed as an extension of a standard CGE representing the real side of the economy. The analytical framework relies on the optimizing behavior of agents and market equilibrium to explain the circular flow of real and financial transactions among socioeconomic agents in the economy. Real transactions cover supply and demand interactions across commodity and factor markets, while financial transactions relate to the operation of the loanable fund market, reflecting choices made by agents about the composition of their portfolios.

The empirical implementation of a CGE model requires a data set representing the circular flow of economic activity for the period under consideration. Such data are usually organized within a Social Accounting Matrix (SAM). The data matrix for a financial CGE is known as a financial SAM (or FSAM). It provides an analytically integrated data set in the form of accounts, including: (1) production accounts representing the supply side of the economy; (2) commodity accounts related to the markets for goods and services; (3) factor accounts showing the distribution of value-added to primary factors of production; (4) current accounts for institutions (e.g. firms, households, government, and the rest of the world) describing income and the current expenditure for each institution; (5) capital accounts of institutions showing savings from, and investments by the institutions; and (6) financial accounts of institutions describing changes in the financial assets and liabilities that govern the intermediation between savings and investment. In essence, an FCGE is an analytical expression of these accounts and the relationships among them. Within this framework, it is the intermediation between savings and investment that links the real side to the financial side of the economy.

Sources: Aray, Pedauga, and Velázque 2017; Robinson 1991; and UNSD 2002.

In the Republic of Korea, an FCGE model was used to compare the impacts on economic growth of two options for financing and operating the South-East Highway.[98] These were: (i) public financing and operation, and (ii) private financing (with bonds) and operation. Private financing and operation was found to be the more beneficial, but only if private sector operational efficiency was greater than that of the public sector by at least 7 percent.

3.3 Valuating market and non-market outcomes

CBA is based on the idea that a course of action is worth taking if the benefits resulting from the action outweigh its costs.[99] Benefits are the net willingness to pay, while costs include the real resource cost to society (i.e. opportunity costs). Individuals derive well-being from bundles of market and nonmarket commodities, and choose the most preferred bundle, based on the socioeconomic constraints they face. In this context, policy outcomes have an instrumental value as they are valued only as a means to achieving the ultimate policy goal of improving social welfare, and that is based on individual well-being.[100] In other words, well-being is the source of value, both at the individual and the societal level. The value of the effects resulting from a transport project such as saving time or reducing accidents is measured in terms of the contribution to beneficiaries' well-being. Assessing the value of these outcomes is done by measuring the changes in individuals' well-being that result from these outcomes.

For valuation,[101] the key consideration is the distinction between market and non-market goods. Infrastructure affects people's lives in a variety of ways. An electricity project that affects domestic use of power for lighting and appliances can improve human capital (health and knowledge), as well as have environmental benefits. The availability of electricity also affects how individuals use their time, which can impact human capital development. For goods that are traded in a market, valuation is based on information about demand for the project. For example, if a project increases electricity supply, which reduces users' cost for energy, then the value of that benefit is the corresponding consumer surplus (i.e. the difference between what the consumers are willing to pay, and what they actually pay).

The substitutability property of preferences (Box 4) implies that economic values are based on tradeoffs that are designed to keep an individual's well-being constant. These values are commonly expressed in terms of either their willingness to pay (WTP) for a desirable outcome, or their willingness to accept (WTA) compensation for an undesirable outcome. The revealed preference approach to valuation derives values from the tradeoffs that individuals make in markets. WTP and WTA are money-metric measures of individual well-being, to the extent that the amount of money a person is willing to pay for something (or to accept as compensation for going without), reveals how much a thing increases the person's well-being.[102]

Revealed preference methods can be direct or indirect. Direct methods use the market price of a commodity that is directly related to the nonmarket good under valuation. Indirect methods, such as hedonic pricing, averted behavior, substitution methods, and measuring travel cost use surrogate markets to value nonmarket goods and services.[103] For example, the hedonic pricing method is based on the assumption that if a nonmarket outcome such as a change in noise pollution affects prices in some market (e.g. the housing market), and its effect can be identified and estimated, then the estimate provides a basis for measuring WTP for the outcome (e.g. noise reduction). For benefits that are related to some economic activity, revealed preference methods can be used for valuation.

Box 4: The Logic of Economic Valuation

The basic economic approach to valuation relies on a market analogy. Economic models of individual choice within and outside markets are based on the fundamental assumption that when choosing among alternative bundles of commodities, people make choices according to well-defined preferences, and that their preferences for the market and nonmarket goods included in the bundles under consideration, have the property of substitutability. This implies that a decrease in the quantity of one commodity in an individual's bundle can be compensated for by an increase in the quantity of some other commodity, which leaves the individual at the same level of well-being as before the change. Thus, substitutability establishes tradeoff ratios between the pairs of commodities that people care about. When people choose less of one commodity, and substitute more of another, they reveal something about the relative worth that those commodities have for them. If the monetary value of one of the commodities involved in a tradeoff is available, then the monetary value of the other commodity can be inferred from the observed tradeoff ratio. In the context of a competitive market, the money price of a market good can be interpreted as a tradeoff ratio: the amount of money given up to get one unit of a commodity in the bundle represents the quantity of some other commodity that must be reduced to make the purchase possible.

Source: Freeman et al. 2014.

Revealed preference methods fail when the values of non-market goods cannot be linked to the use of market goods. In these situations, stated preference methods can be used to infer the values that people would assign to different policy outcomes. These values can be determined by asking people questions about what their preferences would be in hypothetical situations. Stated preference methods are classified according to the type of question involved.

Contingent valuation methods seek to elicit monetary values for a given commodity. Contingent behavior methods ask individuals how they would adjust their behavior in response to a policy change. Choice experiments, also known as attribute-based methods, ask individuals to select their most preferred alternative from a set of alternatives, or to rank alternatives in the order of their preference, or according to a scale.[104] With regard to the value of time saved in transport, this is usually valued with reference to the purpose of the trip. While savings in work time may be valued at the cost to the employer,[105] no market price can be used to value the time saved in trips undertaken for leisure, since no explicit market exists for time spent on leisure. Thus, leisure time falls under the category of nonmarket goods, the value of which must be inferred from other methods such as contingent valuation.

Another benefit that is difficult to value in the context of transport infrastructure is the reduction in accidents. In the case of fatal accidents, benefit can be determined by estimating the value of changes in the risk of mortality.[106] The estimated value is usually referred to as the value of a statistical life, or the value per statistical life.[107] Both revealed preference and stated preference methods are useful to estimate the value per statistical life. Estimation based on revealed preference relies primarily on the wage differential approach, which uses information on the wage premium attached to high-risk jobs, such as construction.[108] Information on self-insurance can also be used to infer what an individual is willing to pay to avoid premature death.[109] This, too, is consistent with revealed preference methods. Finally, stated preference methods, such as contingent valuation, can ask respondents to state their WTP for lower mortality risks under hypothetical settings.

3.4 Distributional considerations

Broadening CBA to address distributional issues involves both positive and normative elements.[110] The positive aspects seek to identify the winners and losers, and quantify their gains and losses. This identification is an important first step in distributional analysis because it allows determination of the proportion of net benefits going to various groups of stakeholders. In the case of an energy project, for instance, it is useful to determine what portion of the net benefits go to consumers versus other stakeholders. The analysis can then focus on the distributional implications of the project within the consumer group.[111]

The 2015 World Bank guidelines[112] on economic appraisal of energy projects explain that the identification of winners and losers requires a good counterfactual because what matters is the net impact of the project on stakeholders, relative to the counterfactual. The guidelines also require the reconciliation of economic and financial flows, given that stakeholders perceive impact as financial. Thus, whether the net economic benefits of a project can be obtained at all depends critically upon the financial impacts on stakeholders. The WBG guidelines illustrate the basic idea with an example from Indonesia's geothermal projects. The financial and economic costs and benefits, and externalities were estimated for the World Bank's Indonesia Geothermal Investment Project, relative to the coal project it was supposed to replace (the counterfactual). The corresponding costs and benefits were allocated to three stakeholders: the government, the local community, and the global community. A comparison of the distribution of economic and financial flows across these stakeholders reveals that the financial loss of $74 million by the government of Indonesia would be offset by a net gain of $45 million from improvements in local people's health. The cost would ultimately be borne by the electricity consumers, given that in 2014, the tariffs were set at the full-cost recovery level.

The normative aspects relate to making value judgments on the social desirability of the observed changes in the distribution of net benefits. Such judgments can be formulated by using a theory of distributive justice, or the notion of fairness or equity.

Assessing private sector participation in infrastructure interventions should include analysis of how the burden of financing real resource costs (e.g. through taxes or user fees) is distributed across the population, relative to the net benefits. Estimating the distributional consequences of infrastructure interventions uses the same analytical frameworks as those for quantifying the effects of interventions. To identify the spillover effects associated with the intervention, analysis (both partial equilibrium and multimarket or general equilibrium) should be conducted at the household level, or with policy-relevant socioeconomic groups.[113]

The World Bank has developed a suite of tools for ex ante analysis of the distributional impacts of private sector interventions,[114] and among these are ADePT[115] and WELCOM.[116] The ADePT tool is designed to assess the distributional impacts of changes in sectoral growth and employment patterns. The simulation package produces full distributional impacts that can be disaggregated by individual and household characteristics, as well as by geographic region. The required data comprise a household survey and macro projections at the sectoral level. The main impact channels include labor market adjustments in employment and earnings, in non-labor income, and in relative prices.

The WELCOM (Welfare and Competition) tool allows estimation of aggregate changes in poverty and inequality measures resulting from changes in market competition in specific sectors—an integral consideration when the private sector is involved. Through the price, this tool can assess these impacts on consumers' welfare through changes in product prices that are based on an absolute and relative incidence analysis of the effects of competition on policy reforms. Changes in competition policy are reflected in changes in market power. With regard to inputs, the WELCOM tool requires a representative household survey, along with information on demand price elasticity, the number of firms in the market, and the market shares of different types of firms. The ADePT and WELCOM simulation tools use a partial equilibrium approach that limits their ability to handle situations involving backward and forward linkages, as well as spillover effects.

In cases where a relevant CGE model exists with limited disaggregation for the household sector, to enhance capacity to account for indirect effects, the output from such a model can be linked to the ADePT or WELCOM tools (as described in Box 5). In general terms, a microsimulation model uses historical microdata to model the impact of changes in macro variables on household and individual level outcomes, which allows for projections of highly disaggregated impacts. One example of macro-micro integrated models to assess distributional impact ex ante is the EPIQ (Economy-wide Private Impact Quantification) model developed by IFC, which includes a special dedicated module on the power sector.[117] IFC and the World Bank are currently working together to build an integrated macro-micro tool – combining macro models with a microsimulation tool with top down or one-way linkages – to assess the distributional impacts of private sector investments, which can be potentially used for large infrastructure projects as well.

A three-module framework was used to assess the distributional impact that transportation improvements could have in the Sao Paulo Metropolitan Region. This comprised a spatial CGE model, integrated with a travel demand model, and a microsimulation module.[118] The first group of interventions entailed expanding transportation infrastructure, while the second group implied reducing the city's private car users during weekday rush hours by excluding a different sequence of license plate numbers each day. The simulation showed that expanding transportation infrastructure could result in a significant increase in the gross regional product, but have only a modest effect on income distribution. The second group of policies that would restrict cars could entail some tradeoffs between efficiency and equity.

Box 5: Linking CGE Models to Microsimulation Models

Any policy intervention with some macroeconomic dimensions is likely to affect all individuals. For large infrastructure, this requires a macro-micro framework that can account for the direct and general equilibrium effects of the intervention, as well as heterogeneity within the population. This requires linking a CGE model with a microsimulation module. The performance of such a combined model hinges, critically, on the nature of the linkage, which could be one-way or two-way. The most commonly implemented one-way linkage is top-down, where a few variables computed by the CGE model (e.g. changes in the level of wages or returns on wealth) are transmitted to the microsimulation module, and used to adjust individual or household incomes according to the predictions of the CGE. The top-down approach does not allow any feedback from the microsimulation model to the CGE model. However, macroeconomic developments are presumably affected by decisions at the micro level. This concern can be addressed with a bottom-up approach that applies policy changes to the micro model of household behavior, and the implications of household responses are then fed back to the CGE model for computation of the structural and macroeconomic effects. It is clear that each type of one-way linkage ignores the feedback involved in the other, and this calls for some form of two-way linkage between the two modules.

A great advantage of this approach is the possibility of identifying winners and losers from the implementation of large infrastructure projects. This advantage comes with significant challenges, however. One practical challenge is linked to inconsistencies between macro and micro data. For instance, the income recorded in household surveys does not correspond to the income data used in the national accounts underlying the CGE part of the model. The validity of available household surveys may be limited too, in terms of thematic coverage and frequency. This may limit effective modeling of individual behavior and, hence, the extent to which one can account for the heterogeneity of policy impact. These data issues are bound to create difficulties at the calibration stage. Furthermore, as the number of sectors in the CGE model and the number of households in the microsimulation increase, the likelihood of computational difficulties increases. Finally, when using the two-way approach, one is more likely to run into convergence issues.

Source: Bourguignon and Bussolo 2013.

3.5 Aggregation across individuals and across time

Policy alternatives should be ranked on the basis of their contribution to social welfare. Such a ranking requires specifying a social evaluation function that is commonly referred to as a social welfare function. When this analysis is conducted at the individual or household level, the outcomes for each policy option are represented by a list of individual valuations. Social welfare functions provide rules for aggregating individual values into indicators of social welfare. Therefore, the choice of a social welfare function reveals the value judgments that govern the evaluation, and the most advantageous policy option is the one that yields the highest level of social welfare from a set of alternatives.

When aggregating individual valuations to assess an intervention's benefits for society, the choice of a social welfare function reveals the value judgments that govern how the benefits for different groups are weighted. Measures of poverty (such as the poverty headcount rate or the poverty gap); inequality (such as the Gini Index/coefficient and the Shared Prosperity Premium, both of which measure changes in inequality); incidence (the share of benefits going to a certain group or income quantile); and average levels of well-being (mean or median per capita income or consumption) are all widely used to aggregate the welfare of individuals in order to measure welfare for society, as a whole. Each of these measures represents a different underlying social welfare function.

The most advantageous policy option is the one that yields the highest level of social welfare from a set of alternatives. This decision-making rule can easily incorporate distributional considerations by choosing an appropriate social welfare function. But its operationalization in CBA typically ignores the distributional aspects, and instead aggregates the costs and benefits from each alternative across both individuals, and across time periods. To be acceptable, a project must meet two conditions, ex ante:[119] (i) the expected net present value (NPV) of the project must not be negative; and (ii) the expected NPV must be equal, at least, to the NPV of the next best alternative.

To evaluate and compare policy options on the basis of CBA, one needs a decision-making rule that considers the distribution of benefits and costs. The decision-making rule in conventional CBA typically aggregates the costs and benefits from each alternative across both individuals, and across time periods to arrive at a Net Present Value (NPV), and then compare that with the NPV of the next best alternative. This rule implicitly values only efficiency in resource allocation, and not the distribution of net benefits. In fact, such a rule, even though it appears to be neutral, has a built-in bias against low-income winners and losers. This is because people with a higher income typically have higher willingness to pay for a favorable outcome (or demand higher compensation for an unfavorable outcome) than is the case for low-income individuals. This influences the economic valuation of policy outcomes, and implies that policy options that generate value for high income groups will be seen as more valuable than those that generate value for low-income groups, i.e. when the benefits and costs are added up, the benefits going to wealthier individuals count more than those going to the poor.[120]

This built-in bias can be addressed through the use of distributional weights, which are also known as social weights. These are assigned to the outcomes for individuals or groups to reflect the value that society places on such outcomes (see Box 6). They are analogous to the prices used to indicate the value of units of commodities that are bought and sold in a market. The use of social weights requires a disaggregated analysis of the change in net value created by the project, into changes for different policy-relevant socioeconomic groups. Meaningful weights can then be assigned to the net value going to each group, and the results can be aggregated up to a weighted sum of net values. Results from a disaggregated analysis can also be displayed using a Lorenz curve.[121] Distributional impact can then be assessed by comparing the Lorenz curve representing the distribution of benefits from the project, with the counterfactual Lorenz curve. Similarly, the Lorenz curve for net benefits can be compared to the Lorenz curve for income distribution. A poverty-focused evaluation should estimate the proportion of net benefits going to the poor versus the non-poor.

Box 6: The Choice of Distributional Weights

Cost-benefit analysis can be viewed as a practical method of implementing a social welfare function (Adler 2016). A social welfare function is a rule for aggregating individual impacts into social impact, and is used to identify the most desirable policy option for society as a whole. Standard CBA implements the utilitarian social welfare function to the extent that it assigns the same weight to all individuals. Standard CBA is, thus, insensitive to equity concerns, which can be addressed through the use of distributional weights.

The choice of such weights is based on value judgments that underpin a society's collective preferences (or social welfare function). Distributional weights can be derived from the priority principle, which requires that resources go to those with the greatest claim (Young 1994). The twin goals of poverty reduction and shared prosperity imply that priority is based on the relative poverty status of individuals or households. Distributional weights must therefore be assigned in such a way that poor people receive higher weights than the non-poor. One simple way to do so is to use a weighting defined as the ratio of mean welfare (e.g. mean income) to the individual welfare level, raised to the power of some coefficient interpreted as a measure of aversion to inequality (Atkinson 1970). Those with below-average income get weights greater than one. Those with above-average income are assigned weights less than one. The poorest individuals then receive the highest weight, while the richest receive the smallest. Setting inequality aversion to zero makes the evaluation ignore equity concerns since every individual gets the same weight of 1.

Another practical way of obtaining weights that respect the priority principle is to rank individuals in the counterfactual state in increasing levels of income, and assign weights based on the corresponding survivor function (one minus the cumulative distribution function in the counterfactual state). This is the weighting system underlying the Gini coefficient (Yitzhaki 1983).

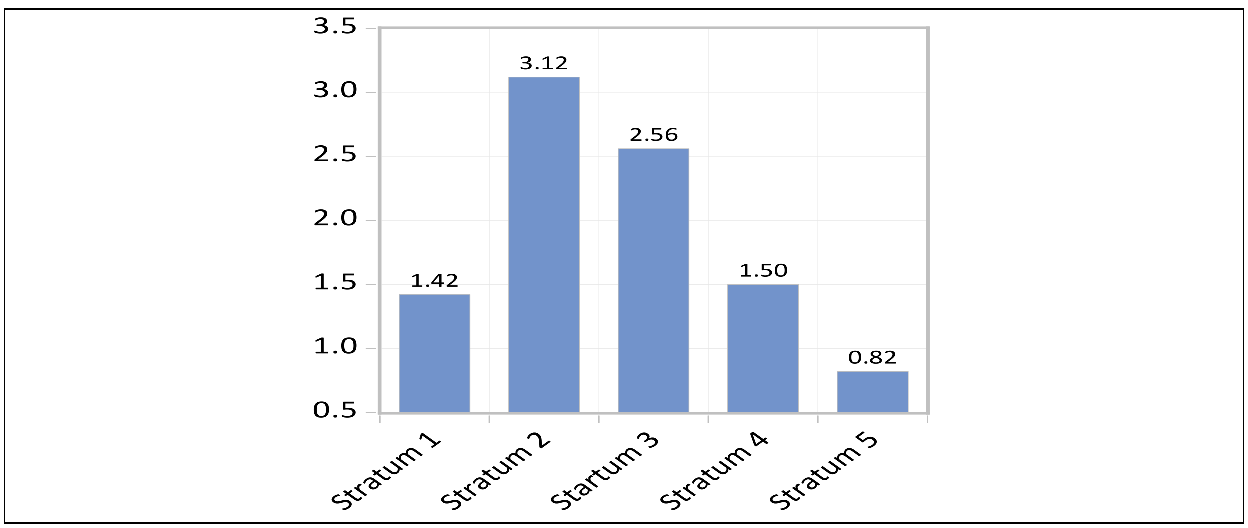
The use of poverty measures is also consistent with the priority principle. The poverty focus of such measures implies that policy evaluation is concerned only with the impacts of specific interventions on the poor. Thus, non-poor individuals are assigned a weight of zero; and only the poor get positive weights. Among well-known poverty measures, the Poverty Gap assigns equal weights in the aggregation of the poverty deficit of the poor, relative to the poverty line. While this measure focuses on the poor, it fails to capture variations in the severity of poverty. The Square Poverty Gap measure, however, does capture this variation, as it is defined by a weighted sum of the poverty gaps (relative to the poverty line) and the weights are the relative poverty gaps, themselves. This weighing scheme implies that the poorest individual gets the highest weight, and the least poor the smallest.

Sources: Adler 2016; Atkinson 1970; and Yitzhaki 1983.

A disaggregated CBA—one that is able to differentiate between different groups—can be useful for assessing distributional effects. As an example, the disaggregated CBA for the TransMilenio Bus Rapid Transit (BRT) system in Bogota, Colombia, shows how the benefit-cost ratio varies across income strata (Figure 2).[122] The TransMilenio CBA covers phases 1 and 2 of the project over 20 years (1998–2017), and assesses seven categories of benefits and costs: (i) reduced travel time, (ii) time lost during construction, (iii) reduced transit operating costs, (iv) fewer accidents, (v) health improvements as a result of lower vehicle emissions, (vi) physical activity benefits from walking to and from bus stops, and (vii) lower GHG emissions. In order to capture the distributional impact, the costs and benefits were allocated to socioeconomic groups in five strata from low to high income, with each stratum representing a quintile (20 percent of the population). A benefit-cost ratio greater than 1 indicates that benefits are greater than costs. A ratio of less than 1 indicates that the costs are greater than the benefits. The results presented in Figure 2 clearly indicate that the greatest net benefit accrues to groups 2 and 3—those within the second and third lowest quintiles of income.

The costs and benefits of infrastructure interventions are spread out over time and they vary. The money-metric measures of costs and benefits produced by the valuation process are a function of time. Furthermore, the value of money is not constant across time, which requires finding weights that will make future costs and benefits commensurate with those of today. In general, resources that are available at some future date are worth less than if the same resources were available today. Two basic considerations justify this point of view: individual well-being ultimately depends on consumption, and immediate consumption is preferable to future consumption. Also, there is an opportunity attached to spending resources today, rather than investing them for future use. In light of these considerations, the standard approach for aggregating net benefits over time is to use a discounting factor to weight the benefits and costs that occur at different points in time so that the weighted sum of net benefits across time periods measures the total discounted value of the policy outcomes. The appropriate rate of discount depends on a social time preference.[123]

Figure 2: TransMilenio BRT Benefit-cost Ratio by Income Stratum



Source: Carrigan et al. 2013.

4. Measuring Impact Ex Post and Accounting for Impact Heterogeneity

The ex post impact of an intervention is the difference between what happened to beneficiaries in the context of the intervention (based on the outcome of interest), and what would have happened to them in the absence of the intervention (i.e. the counterfactual). Accounting for impact heterogeneity, ex post, entails establishing a causal relationship between the intervention and the induced change in the distribution of the outcome of interest. The credibility of an impact assessment hinges, critically, on the validity of the inferred causal relationship between the intervention and the intended outcomes.

The core theory of change presented in this paper reveals that any intervention, whether involving the private or the public sector, is an open process that interacts with contextual factors to produce outcomes. Therefore, the changes observed in a development outcome may be driven by factors known as confounders that affect both the treatment and outcomes.[124] All strategies commonly deployed to identify and measure the impacts of policy and infrastructure interventions seek to remove any bias due to confounding factors. In particular, they entail establishing a plausible association between the intervention and the outcome of interest, and then ruling out alternative explanations for this association. This is feasible when an independent variation in treatment can be found and linked to the observed variation in the outcome of interest.

This section reviews methods and approaches commonly used to infer causal relationships from observed patterns of association in the data, and the application of these methods to assignable infrastructure interventions. It also discusses approaches to estimate the heterogeneity of impacts, which refers to how the impacts of an intervention vary across different groups in the beneficiary population. On the other hand, when an intervention is non-assignable, causal relationships cannot be inferred from observed patterns in the data since one cannot create a counterfactual from non-exposed units. Such situations demand theory-based approaches to evaluation, guided by an explicit theory that is represented in a structural model (such as a CGE) of how the intervention causes the intended outcomes. This section briefly discusses such approaches with two specific examples.

The authors believe that the methods for ex-post evaluation advocated in this paper will be useful for World Bank, IFC, and Multilateral Investment Guarantee Agency staff. For IFC, ex post evaluations are part of its end-to-end system for assessing the impact of its interventions and providing validation of ex-ante assumptions and lessons learned, which ultimately create a critical feedback loop that, over time, helps to continuously improve the ex ante development toolbox and impact assessments.[125]

4.1 Coping with the attribution problem

The attribution problem arises because a policy or an infrastructure intervention, as a means-ends relationship, is subject to external influences that may change the intended causal link between the intervention and the intended outcomes.[126] When the effects of an infrastructure intervention are confined to specific areas, it is possible, in principle, to construct a counterfactual by using areas that have not been exposed to the intervention. The difference in outcomes between treated and non-treated communities can then be attributed to the intervention, after accounting for any "selection bias" caused by systemic, pre-existing differences in communities that could affect treatment outcomes. The bias can be removed by comparing treated communities with a group of communities that are similar in all respects, except for the infrastructure intervention.

Consider, for example, a new rural road that links economically vibrant villages to a nearby district capital. If the comparison of economic outcomes in "treated" versus untreated villages in the same district does not consider differences in their pre-existing conditions, it will not accurately reflect the differences in outcomes that are attributable to the road. The appropriate comparison group in this case would be villages with similar economic conditions as the ones now connected by the new road. However, identifying such a comparison group may not be easy, as the villages must also be comparable in terms of other important factors that affect economic outcomes such as their geographic location.[127]

4.1.1 Challenges

There are a number of considerations that limit the opportunity to use the outcome for non-treated units as a counterfactual (i.e. what would have happened to the treated community in the absence of the intervention). The associated challenges result from the purposeful placement of development interventions, the dissimilarity of participants from nonparticipants, and difference in the histories of the treated and comparison groups.

By design, the placement of most development interventions is purposeful to the extent that such interventions are targeted at specific segments of the population (e.g. communities). Infrastructure investments involve decisions about where to locate physical structures, equipment, and organizations to serve a defined geographic area, which is known as a zone of influence, or catchment area. The local conditions that are used as a basis for assigning the intervention may also affect the potential benefits, causing an endogeneity or selection bias that needs to be addressed with appropriate estimation methods. For example, agro-climatic endowments can influence public and private investment decisions, as well as agricultural output. A better agro-climate increases the return on investments in farm equipment such as tractors, draft animals, and pump sets.[128] Such regional characteristics are commonly used to assign infrastructure projects, leading to project placement endogeneity.

Furthermore, infrastructure creates opportunities to improve welfare for beneficiaries, provided that they have the will, as well as the means, to exploit these opportunities. For example, building a road in a community is not enough for residents' mobility to improve. Transportation systems must also be available for this outcome to materialize. Fulfillment of the potential benefits from infrastructure depends on other factors, too, such as proximity to markets and household characteristics. Also, the presence of a road in a community will not lead to better health and education outcomes if a health clinic and school are not nearby. Thus, the potential benefits from private sector participation in infrastructure interventions are derived and conditional in nature.[129]

They are derived because beneficiaries must have the means to take advantage of the opportunities created by the availability of the infrastructure. Benefits are conditional because they generally depend on community, household, or individual characteristics. Differences in individual or household characteristics between the treatment and comparison groups are, thus, an additional source of selection bias that must be accounted for in the identification of the effects of an infrastructure intervention.

Finally, the time it takes for the full impact of an intervention to emerge once the infrastructure is operational represents an important source of confounding. This is particularly the case if the outcome of interest is the improvement of living standards. A time frame of several years creates opportunities for shocks and spillover effects from other investment programs to affect the comparison and treatment areas. The emergence of shocks and spillover effects from other interventions implies that the infrastructure intervention is not the only factor causing changes over time in the outcome of interest. In other words, history threatens the validity of any causal inference that ignores these confounders. Furthermore, knowing approximately how long it will take for the full welfare impacts to occur is critical for planning the collection of end-line data. The above discussion suggests that, in the case of assignable infrastructure interventions, attributing impact to a given intervention is challenging due to at least three confounding factors: (i) endogenous placement of infrastructure, (ii) differences in characteristics between treated and untreated units, and (iii) confounding factors linked to history.

4.1.2 Design-based strategies

The methods that are most commonly used to evaluate the impact of assignable interventions belong to the design-based approach to causal inference. This approach relies on knowledge of the data-generating process as the main source of information to identify and estimate causal effects.[130] The assignment mechanism (of the treatment or the intervention) is the key driver of the data-generating process since it determines which unit (e.g. individual, household, or community) receives treatment, and which does not. Ultimately, the exposure to an intervention is either by chance or by choice. The choice may be made by individuals or policymakers, and treatment by chance creates an opportunity for valid causal inference. Treatment by choice raises endogeneity issues. The design-based approach includes both experimental and quasi-experimental methods for identifying and estimating causal effects. These methods seek to control confounding factors so that the treatment can be considered as good as if it were randomized. Such designs include: (a) Randomization; (b) Regression Discontinuity Design (RDD); (c) Instrumental Variable (IV); (d) Propensity Score Matching (PSM), and (e) Difference-in-Differences (DD).

Randomization. When treatment is by chance, the comparison of treated units with untreated units reveals the causal effect of the intervention. A properly designed and implemented randomized controlled trial is meant to implement the idea of treatment by chance. In the case of simple randomization, potential beneficiaries are randomly assigned either to the treatment group or to the comparison group, referred to as the control group. Given a sufficiently large sample, random assignment before the intervention balances observed and unobserved characteristics between the treatment and control groups so that the distribution of such characteristics is the same in both groups.[131] As a result, both groups are similar, on average, and after treatment, any difference in the outcomes observed between the two groups can be safely attributed to the intervention. In this context, the outcome for the control group indicates what would have happened to the treated group, had they not been treated. In other words, this is the counterfactual outcome.

While many infrastructure interventions cannot be assigned randomly for technical reasons or due to the fact that they are small n (e.g. building a port),[132] the literature provides examples where randomized assignment is used to evaluate the impact of certain infrastructure interventions. One such example is the randomized street pavement experiment, the results of which were presented in Box 1.[133] As noted in that box, the intervention took place in Acayucan, Mexico, where the city was planning to expand its pavement grid over time through a series of asphalt paving projects. There were 56 contiguous unpaved street segments that connected with the existing city pavement grid, and with relatively high population densities. The experiment was made possible by the fact that, at the time, the city could afford to pave only half of the unpaved segments. It was then decided to randomly assign 28 streets to the treatment group, and 28 to the control group, using a random number generator.

Regression Discontinuity Design (RDD). RDD exploits discontinuity in the assignment mechanism with respect to an assignment variable, also known as a forcing or running variable. Usually, discontinuities stem from rules that govern eligibility for the intervention. In particular, eligibility is determined on the basis of a threshold or cut-off point in the range of the assignment variable. Units on one side of the cut-off point are eligible, while those located on the other side are excluded from the intervention. This design can be applied with power infrastructure if a particular town size is used as the cut-off for electrification, or an income threshold is used to determine eligibility for a connection subsidy.[134] An RDD is said to be sharp if the likelihood of receiving treatment changes abruptly at the cut-off point from zero to one. The design is said to be fuzzy when the treatment likelihood changes at the cut-off point by less than one.[135]

The key identification assumption underlying RDD is that the units that are very close to the cut-off point, on either side of it, are basically identical. Thus, comparing the outcomes for the treated and untreated units in a small neighborhood on either side of the cut-off point should deliver a reliable estimate of the causal effect of the intervention. The validity of this inference is undermined by a strategic response to the eligibility cut-off point (i.e. self-selection), and by the possibility that other policies apply the same threshold.[136] If potential beneficiaries engage in strategic behavior to get the intervention when, in fact, they are not eligible, individuals in a small neighborhood around the eligibility cut-off would not necessarily be identical, and there would be selection bias. Similarly, the fact that other interventions use the same eligibility cut-off would confound the inferential process, making it difficult to attribute the observed change in outcome to the intervention under evaluation.

Burlig and Preonas[137]used RDD to evaluate the medium-term impact of a rural electrification program in India (Rajiv Gandhi Grameen Vidyutikaran Yojana) using outcomes such as asset ownership, employment, income, and school enrolment. Village size was used as the assignment variable because the national electrification program targeted only villages with more than 300 households. While the study found a substantial increase in the use of electricity, it also found that an increase in use had a limited effect on the outcomes of interest. Another interesting application of RDD was the evaluation of an infrastructure intervention by Casaburi et al.,[138] which is described in Box 7.

Box 7: An Example of Using the RDD Method in Evaluating Impacts of Infrastructure

Casaburi, Glennerster, and Suriy (2013) used a road-level regression discontinuity design in Sierra Leone to analyze the impacts of improvements in rural road infrastructure on crop prices in rural markets. In particular, they focused on a rural road rehabilitation program, financed by the European Union, which was implemented in four districts, comprising about 27 percent of the country's area, and 30 percent of the total population. The project did not build any new roads, but targeted local dirt feeder roads.

The forcing variable governing road selection was a weighted average of five components: (i) economic production per kilometer (an indicator of economic density); (ii) population per kilometer within the area of each road's influence; (iii) a road assessment score ranging from 1 to 5 that indicated road condition prior to the intervention; (iv) a social value score ranging from 1 to 5 that captured the number of schools, health centers, wells, and toilets in the catchment area of the road; and (v) the length of road. The assignment score was used to rank the 47 eligible roads, on the basis of which, 31 roads were selected for rehabilitation. The causal effect of the intervention was estimated by comparing roads "just above" the rehabilitation cut-off point, to roads "just below" the rehabilitation cut-off point. The evaluation found that the quality of the selected roads improved as a result of the rehabilitation program; and in rural markets along the rehabilitated roads, the prices of the two main local staples (rice and cassava) fell significantly due to better road quality. The reduction in price was stronger in markets that were farther away from the main urban centers, and weaker in markets that were located in more productive areas.

Source: Casaburi, Glennerster, and Suriy 2013.

Instrumental Variable (IV). The IV method is commonly used when selection bias stems from endogenous placement or endogenous participation. The IV method is capable of generating independent variation in treatment to the extent that it has a direct effect on the choice of the treatment, but it affects the outcome of interest only through its direct effect on treatment. The second condition, which implies that there is no direct relationship between the instrument(s) and the outcome of interest, is known as the exclusion restriction.[139] Basically, IVs influence the likelihood that an individual will participate in the intervention; IVs are independent of individual characteristics; and they are not under the control of the individual.[140] Estimating the treatment effect through regression analysis entails replacing the endogenous indicator of treatment status with its predicted value from the instruments in the outcome equation.[141]

Box 8: Using the IV Method to Estimate the Impact of Private Sector Participation in Infrastructure in Latin America

The Latin American region made an important policy shift in the 1990s toward private sector participation in infrastructure. Andrés et al. (2008) carried out an in-depth analysis of 181 electricity, water, and telecommunications firms, focusing on a range of performance measures to examine what happened before, during, and after private sector participation. The study analyzed changes in output, labor, efficiency, labor productivity, quality, coverage, and prices. The time frame started five years before private sector participation began, and continued until five years after the policy shift, and the data were divided into three distinct periods: (i) the pre-transition period that began three years before the implementation of the reform; (ii) the transition period that started two years before privatization, or the awarding of a concession; and (iii) the post-transition period that began four years after the transition.

The authors identified four sources of potential bias affecting attribution of the changes in outcomes associated with the policy shift: (i) the number of connections, output, and coverage could change over time, independent of the ownership type; (ii) observed differences in performance could stem from unobservable firm-level characteristics such as management quality; (iii) the decision to privatize could be endogenous; and (iv) the timing of privatization could be endogenous. They used IVs related to the state of the overall economy, based on the logic that the decision to privatize could be linked to the strength of the economy, although the latter did not directly affect relevant outcome variables. The impact on prices was found to be mixed, in part because prior to the policy change, the prices of many of the services, and especially those in the water sector, were heavily subsidized and not based on cost recovery. Since the new private owners tended to pursue cost recovery, the prices of services usually rose. With regard to sector performance, the study found that private sector participation led to significant improvements and, in particular, to large gains in productivity, quality of service, and coverage.

In considering the determinants of impact, the authors looked at the way transactions were designed (i.e. the method of sale, the award criteria, and the nationality of the firm), as well as features of the subsequent regulatory framework. These factors, which varied a lot across countries and sectors, affected incentives and influenced different aspects of enterprise behavior. The impact of each of the factors was studied by pooling all the available cases for each sector, and including variables that accounted for the transactional and regulatory environment. The results showed that regulatory and contract characteristics do matter. Each characteristic acted differently on each dimension of performance. For example, the presence of a fully autonomous regulatory body influenced performance more than other regulatory aspects. The findings suggest that gains in performance due to private sector participation could have been even greater with better design and implementation, appropriate institutional capacity, and an appropriate legal and regulatory framework.

Source: Andrés et al. 2008.

Dinkelman[142] applied the IV method to an evaluation of the impact of electrification on employment growth in rural communities in South Africa, with a focus on grid extension that occurred between 1996 and 2001 in the KwaZulu-Natal (KZN) Province. All households within a given community received the basic connection once the grid reached the community, making the community the unit of assignment, while households were the units of treatment and analysis. To account for the fact that communities were not chosen at random, the study used an average community land gradient as an instrumental variable to generate exogenous variation in the project's placement in communities. It relied on the assumption that based on relevant community characteristics, the land's gradient had no independent effect on employment growth, except through its effect on project placement. The study found a significant increase in employment in rural KZN, which was predominantly an increase in female employment. Another key example of the use of the IV method, as already noted, was the study carried out by Andrés et al.[143] that evaluated the impact of private sector participation in infrastructure in Latin America (see Box 8).

A major challenge posed in using the IV method is finding good instrumental variable(s), and particularly those that meet the exclusion restriction condition. According to Dinkelman, the land's gradient affects the cost of electricity grid expansion, and is therefore correlated with the likelihood of getting a grid connection. However, at the same time, the land's gradient may also affect the crop varieties that can be cultivated in an area, and hence the profitability of agricultural activities and households' incomes.[144]

Randomized Encouragement Design (RED) has been proposed as an alternative way of generating an instrumental variable that satisfies both of the desirable conditions. Instead of randomizing the intervention of interest, this design entails the random allocation of incentives to participate in the intervention. Consider, for instance, the case of electrification. Given that the connection fees are substantial, it is expected that better-off households will connect first when a grid reaches a community, and this is a source of selection bias. The random assignment of incentives (e.g. discount vouchers) to households could create an exogenous variation in connections that reveals the causal impact of electrification. Barron and Torero[145] used this approach to assess the impact of electrification on time use in northern El Salvador. They found that electrification increased investments in school-age children's education, and also increased adult women's participation in income generating activities. REDs can provide useful ways to evaluate the impacts of some of the many infrastructure interventions when randomized control trials are not possible for practical or ethical reasons.

Propensity Score Matching (PSM). The propensity score for a unit (e.g. individuals or households) is an estimate of the probability of participating in the intervention of interest, given the unit's observable characteristics. The PSM method compares treated units with untreated units with the same conditional probability of participation. The validity of this method hinges on the assumption that matching units on their propensity scores makes them also comparable along unobservable dimensions.[146] This may be too strong an assumption, given that it is virtually impossible to rule out whether there are unobserved characteristics that differ between the treated, and the matched untreated units.

A 2011 World Bank study used PSM to measure the impact of micro-hydroelectricity installations on rural livelihoods in Nepal.[147] The outcomes of interest included income, expenditure, education, health, and women's empowerment. The study found that connection to micro-hydroelectricity led to a significant increase in nonfarm income, household expenditure, children's study time in the evening, and the number of years of girls' education. Other significant effects included reductions in the respiratory illnesses of women and children, reductions in girls' gastrointestinal illnesses, and females making more decisions about more important issues.

Difference-in-Differences (DD). The DD method compares the change over time in the outcomes of the treated, with the change over time of the outcomes of the untreated units. In particular, the intervention's impact is calculated by subtracting the change over time in the outcome for the comparison group, from the change over time in the outcome for the treated group. The key identifying assumption is known as the "common trends" assumption, which implies that in the absence of the intervention, over time the outcomes for both the treated and untreated units would have followed the same trajectory. The DD method controls for all of the time-invariant initial conditions that determine project placement, and are correlated with the level of the outcome variable. Empirical implementation requires adequate baseline and end-line data, which provide information on the conditions prevailing prior to the intervention. The collection of end-line data must be consistent with the time it takes for the outcomes of interest to fully emerge. Meenakshi et al.[148] used the DD method to measure the impact that a shift in electricity pricing policy from a flat-rate tariff, to a metered tariff, had on West Bengal farmers' pumping of groundwater. The study found that the policy shift resulted in farmers' ground water usage in one of the three agricultural seasons, but this had no impact on cropping patterns and output.

Choosing an Evaluation Design. A credible evaluation is based on a design that reliably corrects for the potential sources of endogeneity bias. van de Walle (2009)[149] identified three generic types of endogeneity bias when evaluating the impact of rural roads, and she mapped out design strategies to deal with them. These generic types of endogeneity, which apply to other types of infrastructure too, include:

- Type 1: Time-invariant initial conditions that influence infrastructure placement while also affecting the level of the outcome variable.
- Type 2: Time-invariant initial conditions that determine infrastructure placement also influence the changes in outcomes.
- Type 3: Time-varying factors that affect infrastructure placement also determine changes in the outcome variable.

The identification strategies described above entail either single difference or double difference comparisons. In general, single difference comparisons involve either with-and-without comparisons, or before-and-after comparisons. The effectiveness of a single difference comparison is severely limited due to the common types of placement endogeneity listed above. A with-and-without comparison may well deal with selection bias, but remains vulnerable to the confounding effects of history since the outcomes of an infrastructure intervention tend to take some time to emerge. If sufficient time is allowed for the intervention to produce effects, a before-and-after comparison may eliminate the confounding effects of history, yet remain vulnerable to selection bias.

Given the major challenges involved in identification of the treatment effect of infrastructure interventions, impact evaluation of such interventions relies most often on the DD method (which combines a with-and-without comparison, with a before-and-after comparison), or a combination of DD, with either the PSM or IV method, depending on the likely source of endogeneity. In such settings, the IV or the PSM method controls for cross-sectional confounding, while the DD method controls for confounding due to history. The conventional DD method, alone, can deal with type 1 endogeneity, which is based on the assumption that initial conditions (observed or not) take the form of an additive time-invariant term in the outcome model. The DD method is not appropriate in the case of type 2 or type 3 endogeneity.

If the evaluation faces type 2 or type 3 endogeneity, and all the relevant initial conditions are observed, then combining the DD method with PSM can correct for the corresponding biases. PSM is used first to control for initial observable heterogeneity. This procedure is supposed to produce an initial comparison group that is as similar as possible to the treatment group. The DD method is then applied, using relevant information, with both the treated and the matched untreated comparison groups.[150] Lokshin and Yemtsov[151] used this approach to study the impacts of infrastructure rehabilitation projects (schools, roads, and water supply systems) in Georgia. They found, in particular, that improvements in school infrastructure led to significant and positive impacts on school enrolment rates and attendance, and also reduced the health risks for school-age children. van de Walle and Mu[152] applied the same methodology in their study of the impact of a rural road rehabilitation project in Vietnam. They used data on project and comparison communes over three periods, including a baseline in 1997, and follow-up surveys in 2001 and 2003. They, too, found that the impact of rehabilitating roads (kilometers) was less than expected, but that more roads were rehabilitated in the project communes. Cuong[153] also combined DD with PSM to study the impact of rural roads on household welfare in Vietnam. He found that rural roads had a significant impact on per capita income and hours worked.

When the confounding factors associated with type 2 and type 3 endogeneity are not observable, combining the DD and IV methods is the only approach capable of correcting for the relevant endogeneity bias. As noted earlier, the IV method can remove endogeneity bias if the IV affects the placement of infrastructure, but does not have a direct influence on outcomes. The combination of both methods (DD and IV) is implemented in two steps. First, the IV method is used to predict the infrastructure access variable. Second, the predicted values are used in the DD outcome regression model instead of the infrastructure access variable.[154] van de Walle et al.[155] combined the DD and IV methods to identify the long-term causal impacts of household electrification on consumption in rural India. They found a significant impact for the connected households, and also that village connectivity improved the living standards of even the unconnected households.

4.1.3 Theory-based approach

Non-assignable interventions are usually large-scale, and their impact cannot be evaluated with the design-based methods described above since a counterfactual cannot be created from observed patterns in the data. The theory-based approach is more appropriate for such interventions, examples of which are policy reforms and investment programs with economy-wide or sector-wide impacts. This approach is guided by an explicit theory or model of how the intervention causes the intended outcomes. On the basis of a plausible theory of change, the impact of the intervention is assessed in a way that accounts for both the underlying causal mechanisms and the implementation processes. As discussed in Section 2, such an evaluation can be couched in terms of contribution analysis.

White[156] argues that in every case, conducting a quality impact evaluation requires an analysis of the theory of change underlying the intervention. Furthermore, the analysis of different components of the causal chain, and of the causal assumptions, necessarily involves the use of mixed methods. In this context, qualitative information may shed some light on the factors that drive infrastructure placement and selection bias. Broegaard et al.[157] conducted a theory-based evaluation of a rural transport infrastructure program in Nicaragua. The evaluation design was rooted in a theory of change, and involved both qualitative and quantitative analysis.

Alternatively, the theory of change can be expressed with a structural model (e.g. a general equilibrium model) of individual behavior and social interaction. In the context of analyzing the welfare and distributional impacts of economy-wide policies, a CGE is a mathematical expression of the underlying theory of change. The specification of such models requires causal assumptions for the market structure and other institutions. A CGE model can simulate the counterfactual for infrastructure interventions that have geographically dispersed effects on a variety of variables—for example, a trunk road, a national railroad, or a change in regulations that leads to economy-wide impacts. This approach will lead to the quantification of both direct and indirect effects. Two examples of policy impact analysis within a general equilibrium framework are discussed in Section 4.3.

CGE modeling can establish a causal relationship between interventions and the outcomes of non-assignable interventions. While these are typically average outcomes, to a limited extent, these models can also be used to analyze the distribution of outcomes across different groups such as geographic regions or workers with different levels of education. A full distributional analysis—one that is able to link changes in macroeconomic variables to household and individual-level behavior, and vice-versa—requires linking a microsimulation module to a CGE model. Such an integrated micro-macro approach is the most appropriate framework for analyzing welfare and distributional impacts of non-assignable infrastructure interventions. When the analysis is done ex post, the microsimulation should use information from surveys and other relevant data collected after the intervention, as opposed to relying entirely on historic data, as would the case for ex ante modeling. In other words, the micro-macro modeling approach is similar for ex ante and ex post evaluations, but with different data.

The advantage of using such micro-macro models, both ex ante and ex post, is the ability to construct counterfactuals in such a way that the welfare and distributional impacts of specific scenarios (e.g. of a contractual arrangement or financing) can be assessed. The main disadvantage arises from the fact that the behavioral assumptions underlying the models—both micro and macro—follow standard economic theories and are often untested in the context they are applied, which means that the predictions of these models can be well off the mark when reality does not conform with the assumptions. Calibrating and validating the models with historic data (e.g. by comparing model "predictions" for the past with observed data) provides some degree of confidence in the accuracy of the model, but not fully, since when it comes to the behavior of economic agents, the past is an imperfect predictor of the present or the future.

4.1.4 Implications for data

A credible evaluation of the welfare and distributional impacts of an infrastructure intervention requires both a valid strategy for impact identification and measurement, along with relevant and reliable data. In the case of assignable interventions, the identification and, hence, the estimation strategy depends on the perceived threats to the validity of the resulting causal inference. As noted earlier, given the types of endogeneity that arise in the context of infrastructure interventions, impact evaluation of these interventions has relied, more often than not, on the difference-in-differences method or a combination of DD with either the PSM or IV method, depending on the likely source of endogeneity. Effective implementation of these methods determines the nature of the needed data, and the frequency of data collection.

Consistent with recommendations made by van de Walle,[158] in the context of the evaluation of rural roads, a credible evaluation of the welfare and distributional impacts of assignable infrastructure interventions entails panel data, including pre-intervention baseline data. Information is needed on both the assigned and non-assigned units in order to create an appropriate counterfactual. In particular, the assessment requires data on observables when combining DD with PSM. Such data include baseline characteristics that may affect the selection for the intervention. Additional data are required for controlling for changing circumstances over time, exploring the variation of impact across policy-relevant socioeconomic groups, and accounting for exogenous shocks such as natural disasters or weather-related events. With respect to the frequency of data collection, for impacts to emerge, care should be taken to allow for a sufficiently long time interval between baseline and follow-up surveys.

In the case of non-assignable interventions, the data challenge is to build a SAM or an FSAM that is disaggregated according to the sectors and institutions that are relevant for the policy issue at hand. For the purpose of distributional impact analysis, the SAM (or FSAM) must be consistent with the available household survey data.

New technologies can significantly expand data availability and reduce data costs. For example, detailed mapping of infrastructure quality and availability across geographic locations can greatly help both ex ante and ex post evaluations. Spatially-disaggregated data derived from leveraging new technologies – such as high-resolution satellite images processed with machine learning algorithms – can fill critical data gaps in infrastructure and reduce the cost of data collection.

4.2 Evaluative approaches for addressing impact heterogeneity

Most evaluations of the effects of policy and infrastructure interventions focus on estimating mean impacts such as the average treatment effect, or the average treatment effect on those treated by the intervention. While mean impacts may answer the question of whether or not an intervention worked, they do not provide evidence about who benefited from the intervention, and why they benefited. Infrastructure interventions (and development interventions, in general) are expected to have differential effects on individuals or households, depending on their attributes, and the circumstances they face. This heterogeneity is what drives the distributional impact of such interventions.

Analyzing the distributional impacts of an intervention requires considering those impacts across policy-relevant socioeconomic groups, households, or individuals. A regression model that includes interaction between the treatment, and household or individual characteristics, can provide a framework for analyzing systematic variation in mean impacts across socioeconomic groups. Such a model was used in Vietnam to assess the distributional impact of expanding irrigation infrastructure.[159] Other approaches to assess the distributional impact of interventions include the analysis of quantile treatment effects that capture responses to treatment across the entire distribution of welfare (as in the example below), and general equilibrium modeling.[160]

Khandker et al.[161] provide an illustration of a rigorous evaluative approach for assessing the distributional impact of electrification. Their approach assumed that the electricity grid is extended progressively to communities, with individual households connecting, or not, once the grid is available. This process suggests that identifying who benefits from electrification depends on two factors: the characteristics of the communities, and of the households within them. These two sets of characteristics exemplify the initial conditions, and policy makers use both to prioritize grid extension investments.

When considering financial viability, a least-cost approach is typically used to select which communities to connect to the grid—an approach that tends to favor larger communities that are located closer to the existing grid, roads, and towns. If the population density is low, which is the case in remote areas, the unit costs per household will be high and discourage households from connecting. For example, the Cambodia Rural Electrification and Transmission Project used a combination of factors in applying the least-cost approach. Eligible villages had to be within 40 kilometers of the existing grid, and reasonably accessible by road, and households had to be able to pay their electricity bills.[162] This illustrates that differences in the initial conditions at the community and household levels confound the measurement of the welfare impact of electrification. Most often, these initial conditions also underpin the widely reported finding that electrification benefits the non-poor more than the poor.

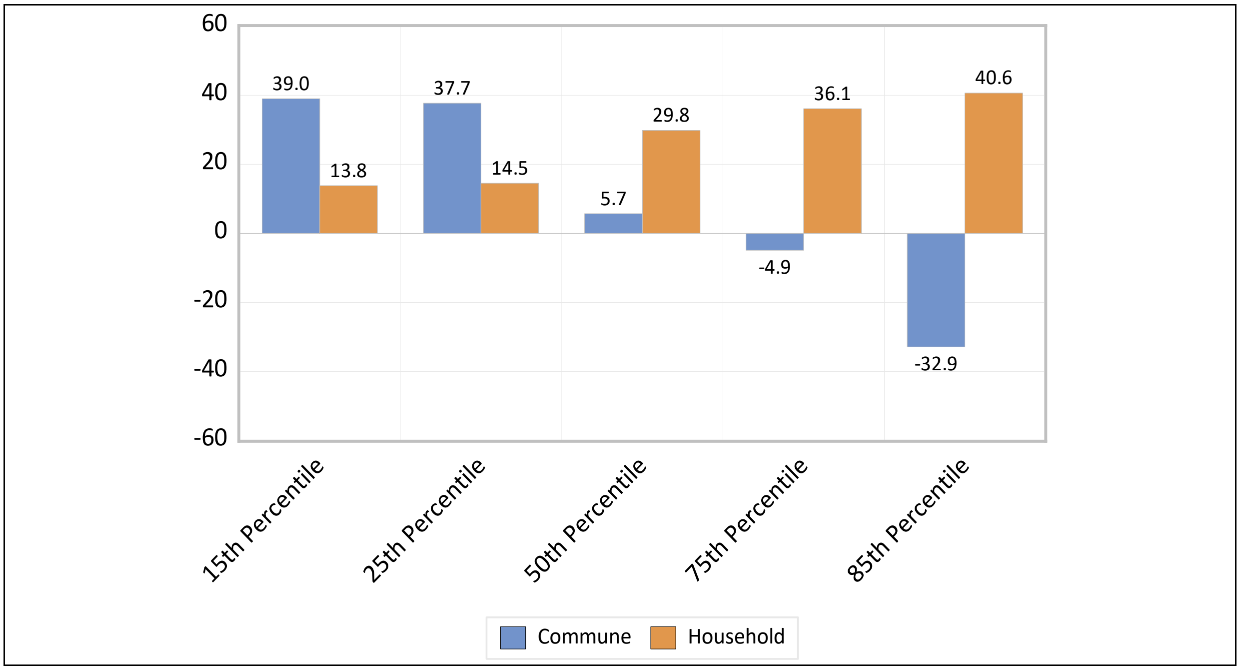
Khandker et al. analyzed the impacts of a Vietnam rural electrification program that aimed to extend grid electricity to rural households, applying a regression model to control for endogeneity bias. The government had initiated institutional restructuring in 1995 that led to the creation of Vietnam Electricity (EVN), a management holding company overseeing electricity sector activities. Following the creation of EVN, its rural electrification department contracted regional companies to implement rural electrification projects, which led to a significant increase in the production and consumption of electricity in rural areas.

To establish a causal link between Vietnam's rural electrification policy, and its intended outcomes, the following sources of bias were identified: (i) in choosing which communes to provide with electricity, policymakers targeted the better off communes ahead of less-prosperous or remote ones; and (ii) once a commune received electricity, the better-off households were likely to connect first. A modified double difference method and panel data allowed for control of the underlying endogeneity bias of grid connection.[163] To account for impact heterogeneity, the authors used a panel quantile regression model that produced estimates of the impact of electrification by distributional quantile.[164]

At the aggregate level, the Vietnam study found that household electrification had a significant causal effect on the outcomes considered. Electrification increased households' total income by 28 percent and their expenditures by about 23 percent. School-enrolment increased by about 9 percent for girls, and 6.3 percent for boys. There were also substantial spillover effects from commune-level electrification, and significant impact heterogeneity. The effects of household-level electrification were statistically significant only for the upper quantiles, starting with the median, while the effects of commune-level electrification were statistically significant only for the 25th percentile. Figure 3, and the underlying pattern of statistical significance, indicate that household-level grid connection benefited upper-income groups the most; whereas the benefit of commune-level electrification was observed only for the 25th percentile, and not for the higher income quantiles, indicating that connecting communes to the grid had significant spillover benefits for the poorer residents only. Poor households who cannot afford an electricity connection may still benefit from electrification if it provides public lighting and improves public services. Poor households may benefit too by socializing with neighbors who have electric light and appliances such as a television.

While it has been commonly found that electrification benefits the non-poor more than the poor, the evaluation strategy used in the Vietnam study enabled the authors to reach a more nuanced conclusion by simultaneously considering electrification at the commune level, as well as at the household level.

Figure 3: Quantile Treatment Effects of Electrification in Vietnam



Source: Khandker, Barnes, and Samad 2013.

4.3 Measuring the distribution of gains and losses from market-oriented reforms

Market-based reforms aim to improve sector performance to deliver efficient, affordable, and sustainable infrastructure services, by introducing or enhancing competition, instead of only the government financing, managing, and setting the rates for state-owned entities (SOEs) and utilities. The extent to which the private sector invests and/or delivers, and the impacts depend on the process of reforming SOEs. The main types of reform are: (i) privatization, (ii) liberalization, (iii) private sector involvement, and (iv) regulation.[165] In addition to assessing the impact of such reforms on efficiency, policymakers are increasingly looking at equity dimensions, which calls for assessments that can identify both winners and losers.

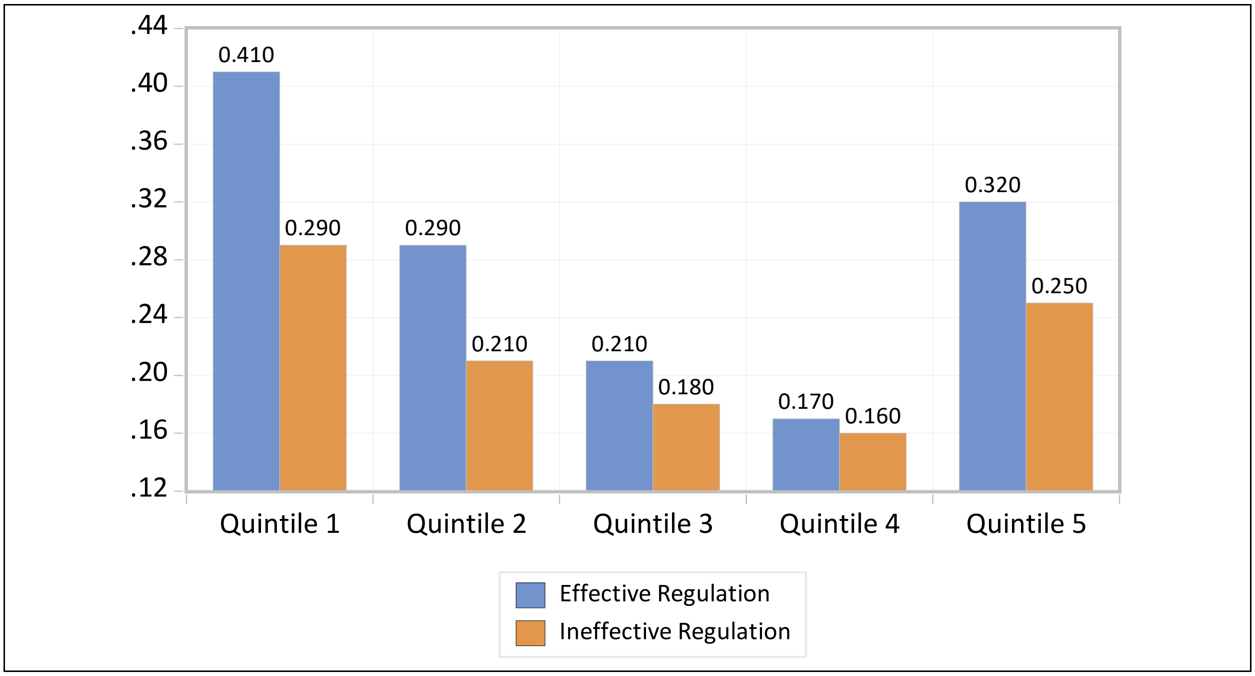
When it comes to the distributional impacts of market-based reforms of infrastructure sectors, an assessment may miss most of the action if not working within a detailed general equilibrium framework. In 1989, when Argentina faced an increasing fiscal burden from public utilities in every province, the government embarked on a ground-breaking reform process to privatize the country's electricity, gas, water, and telecommunications services.[166] Privatization was also driven, in part, by the government's desire to access private sector financing to pay for expanding the services. Privatization of the electricity sector in Argentina led to the separation of generation, transmission, and distribution. Competition was introduced in generation, and transmission and distribution were handed over to regulated private monopolies. The transport and distribution of gas were allocated to local monopolies, two private monopolies took control of telecommunications, and water and sanitation services were privatized through concession contracts. In 1999, a CGE model was used to conduct an early assessment of the macroeconomic and distributional effects of Argentina's market-based reforms. The model allowed for assessment of the direct and indirect effects of all the changes in one utility, or the effects of a similar change across all the utilities. There were four sources of the gains from privatization: (i) efficiency, (ii) productivity, (iii) quality, and (iv) tariffs. These gains were transmitted to the rest of the economy through the following channels:

- Directly, through reduction in the consumer prices for the privatized services.
- Indirectly, via lower input costs for the industries that use the privatized services.
- Indirectly, through lower input prices for the privatized utilities themselves.
- Directly or indirectly, through remuneration for the factors of production.

The model covered 21 domestic production sectors—10 for goods and 11 for services. To analyze each sector separately, the Social Accounting Matrix underlying the model included separate accounts for electricity generation, electricity distribution, gas, water, and telecommunications. The model considered three factors of production: labor, physical capital, and financial capital. To conduct a distributional impact analysis within the CGE model, the authors disaggregated the household account into five categories of households across the distribution of welfare by quintile. The welfare impact was measured in terms of equivalent variation, which is a measure of how much income would have to change in the status quo to allow the consumer to attain the new level of welfare that corresponds with the extent of private sector participation in the intervention. Among other findings, this evaluation showed that the effects of privatization depended on how the privatized utilities were regulated.[167]

Figure 4 shows two different scenarios for the distribution of benefits from privatization of the electricity sector. In one scenario, privatization is accompanied by effective regulation, and in the other scenario, there is no effective regulation. The numbers in the graph represent the equivalent variation in income, based on the total income for the quintile. The results indicate that the lower income groups stand to gain the most from the reforms of the electricity sector, and these gains would be much more significant under effective regulation.

Figure 4: Distributional Impact of Privatization of Electricity, Argentina



Source: Chisari, Estache, and Romero 1999.

For the gas and water sectors, the poor also gained more from privatization. The middle class (quintiles 3 and 4) gained more from the reforms in telecommunications, but only in the case of effective regulation. When reforms across all four utility sectors are considered together, the gains from privatization accrued mainly to those with the highest income, while the gains from effective regulation of the newly privatized entities went mainly to those with the lowest income.

Combining a CGE with microsimulation can help assess distributional impacts, ex post, just as in the case of ex ante assessments. In 2009, a CGE macro-microsimulation model was used to study the distributional impact of pricing reforms in the electricity sector in Senegal,[168] one of the countries in Africa with the longest reform experience. This study developed a two-component simulation model that computed the direct and indirect changes in key variables resulting from adjustment in the goods and factor markets. These changes were then put into a microsimulation model that was based on a large household survey. The microsimulation model used this information to compute changes in household welfare. Having data from a large number of households allowed the authors to compute changes in poverty indicators such as those measured by using poverty measures or changes in measures of inequality. A major finding from the Senegal study was that, compared to general equilibrium effects, electricity price reductions had little impact on poverty and inequality. This is understandable given that few poor households were connected to the electricity grid. For the same reason, few of the poorest people were likely to benefit from grid extension. However, a much larger population was affected by the indirect effects that cheaper and more widely available electricity had on overall economic activity.

5. Summary and Conclusion

Sustainable infrastructure development and adequate provision of infrastructure-related services are critical for achieving the WBG's twin goals and the United Nations' SDGs. Expanding access to infrastructure services can improve productivity in various sectors of the economy, as well as people's quality of life. However, across the developing world, inadequate infrastructure remains one of the critical development constraints. While infrastructure development is primarily the responsibility of the public sector, due to issues such as corruption and lack of capacity, pure public provision has not always worked well. Therefore, in recent decades, private sector involvement has emerged as an integral part of the successful delivery of infrastructure, and of related infrastructure services.

Regardless of whether infrastructure interventions involve private sector participation or not, their design and implementation must have a sound evidence base in order to ensure that they address the key development constraints. An effective evaluation of the welfare and distributional impacts of infrastructure interventions will provide credible evidence to show who benefits (or suffers losses) from an intervention, how and why they benefit, for how long, and at what cost. These questions are relevant throughout the policy cycle: ex ante (at the design stage), during implementation, and ex post (after implementation).

Understanding the causal relationship between the intervention and the outcomes of interest is the foundation of an evaluation that is designed to address the key questions listed above. The theory of change describes the causal pathways through which impacts of an intervention with private sector participation are supposed to occur, the way contextual factors could affect the intervention, and the critical conditions for the proper operation of the underlying causal mechanisms.

Ultimately, infrastructure interventions aim to improve the well-being of the beneficiary population. Individuals derive welfare from the best bundles of market and nonmarket commodities that they can afford, given the prevailing constraints. Furthermore, interventions take place within a socioeconomic system that is characterized by market and nonmarket institutions. Within such a system, infrastructure interventions affect individual and societal well-being through market and individual behavioral adjustments that lead to changes in the determinants of well-being: market income, non-market income, the market prices of consumer goods and services, and access to, and the quality of, non-market goods and services.

Any assessment of the welfare and distributional impacts of a particular infrastructure intervention must address the attribution problem. This requires finding an independent variation in exposure, and linking it to the changes observed in the outcomes of interest. The choice of the approach to impact evaluation depends on the nature of the intervention, a sound understanding of how the intervention is supposed to work to achieve the intended results, and the key evaluation questions. Important considerations here relate to the determinants of individual exposure to the intervention, how impacts come about, and whether the evaluation is conducted ex ante or ex post.

Private sector participation in infrastructure entails the financing and/or contractual arrangements of such participation in delivering services to end users. These arrangements affect the project design and its implementation that, in turn, determine its welfare and distributional impact. Thus, assessing the impact of private sector participation in infrastructure development requires broadening the scope of the evaluation to account for not just the impact of the intervention, per se, but also for how the contractual and/or financing arrangements with the private sector affect welfare and equity. This implies identifying the causal relationship between well-being and those components of the intervention that are influenced by the nature and structure of the involvement of the private sector. The challenge of attribution is heightened because of the difficulty in identifying appropriate counterfactuals (or exogenous changes in exposure), particularly for ex post evaluations that rely on observed patterns in data.

There are three broad categories of infrastructure interventions:[169] (i) small-scale infrastructure interventions (e.g. rural electrification, rural roads improvement, and certain urban transport schemes); (ii) large infrastructure interventions (e.g. port development, power distribution networks, and transnational railways); and (iii) policy interventions (e.g. adoption of a public-private partnership model). An intervention is assignable when it can be assigned to some observational units (such as households, firms, or communities) and not to others. While small-scale interventions tend to be assignable, large-scale ones are typically not.

In the case of assignable interventions, it is possible to create a counterfactual using non-assigned units. However, infrastructure can have geographically dispersed effects on a variety of outcomes, with spillover effects outside the community in which the infrastructure is located. Such externalities make it hard to construct a reliable counterfactual for non-project communities that are close enough to the intervention area, yet far enough away to avoid spillover effects.

Another complication is that the benefits from infrastructure investment are derived—although infrastructure creates opportunities for beneficiaries to improve their welfare, they must have complementary endowments, and/or benefit from complementary policies to take advantage of the opportunities. The benefits from infrastructure are also conditional, given the extent to which they depend on some other infrastructure or policy environment. Both of these considerations must be taken into account when formulating the causal assumptions that underlie the theory of change.

Ex ante estimation of the welfare and distributional impacts of assignable infrastructure interventions is commonly framed within the logic of CBA, which is a systematic approach for identifying and evaluating the likely outcomes of alternative interventions. Determining the most socially desirable policy option out of a set of feasible ones entails quantification and valuation of the consequences of each option. It also requires determining an overarching criterion for ranking the policy alternatives—namely, social welfare, which involves aggregating benefits and losses across different groups using some form of weights that reflect the priority focus of the intervention. For example, for a poverty or equity-focused evaluation, the social impact of interventions could be measured by changes in poverty outcomes or in equity indicators.

Ex ante analysis is necessarily based on models, as the analysis must predict policy consequences. Conventional CBA tends to rely on partial equilibrium modeling to compute the consequences of interventions as it uses a simple supply-and-demand framework that represents the primary market. While the partial equilibrium framework is valid for small-scale infrastructure, it has limitations for assessing the impacts of large-scale infrastructure interventions, whose effects are likely to spill over beyond their primary markets. General equilibrium modeling provides an appropriate framework in such cases as it accounts for both the direct and indirect effects of large interventions or policy changes that concern private sector participation.

When appraising infrastructure investments with private sector participation, the welfare and distributional impacts must also be analyzed in relation to how they are financed. An FCGE model offers an appropriate framework as it integrates the real and financial sectors of the economy, and can be used to trace the flows of financial and real resources among socioeconomic agents. Regardless of the exact model that is used to measure distributional impacts, it is crucial to conduct the analysis at the household level, or with policy-relevant socioeconomic groups.

Ex post impact analysis is similar to ex ante analysis to the extent that both address the same questions. Thus, CBA can be conducted either ex ante or ex post. The strategies available for coping with the attribution problem also depend on whether the intervention is assigned or not, and the extent of the spillover, or general equilibrium effects.

Even in the case of small-scale infrastructure, the opportunity to undertake random assignment is limited. Policymakers tend to assign small-scale infrastructure on the basis of local conditions, which may lead to endogeneity or selection bias, given that such conditions are also likely to affect potential benefits, which tend to be derived and conditional. Furthermore, benefits may take a long time to materialize. These issues have made using the DD method that uses panel data collected at different points of the intervention cycle, including before and after the intervention, one of the most effective tools for evaluating assigned infrastructure interventions. Depending on the type of endogeneity, the DD method may have to be combined with other methods (e.g. PSM or IV) to obtain unbiased results. The RDD method is useful when there is a discontinuity in the assignment of an intervention. This is usually due to rules about eligibility for the intervention, such as using a threshold based on a town's population for electrification or a threshold based on household income for providing a connection subsidy.

Evaluating the average impact of an intervention is not enough to assess distributional impacts. Regression models that include interaction between the treatment, and household or individual characteristics, provide a framework for the analysis of systematic variation in mean impacts across socioeconomic groups. The distributional impact of an intervention can also be analyzed through quantile treatment effects that capture responses to a treatment across the entire distribution of welfare.

Finally, as in the case of ex ante analysis for large-scale infrastructure interventions, general equilibrium modeling can establish a causal relationship between interventions and outcomes, and also be used to analyze distributional impacts to a limited extent. A detailed distributional analysis would require linking a microsimulation module to a CGE (or FCGE) model, which is the most appropriate framework for analyzing welfare and distributional impacts of non-assignable infrastructure interventions. When such micro-macro modeling is done ex post, the microsimulation uses information from surveys and other relevant data collected after the intervention, as opposed to relying entirely on historic data, as would be the case for ex ante modeling.

Therefore, assessing the welfare and distributional impacts of infrastructure interventions with private sector participation does not require the invention of new approaches or methods; rather it calls for a judicious application of well-known methods of impact evaluation, both ex ante and ex post. In particular, analysts must widen the scope of an infrastructure intervention's evaluation to consider the welfare and distributional implications of the actual or potential financing, and the contractual arrangements for service delivery. The causal relationship between well-being and the intervention are influenced by the modes of funding and financing, the related contractual arrangements with the private sector, and the characteristics of the infrastructure under consideration. This implies that in measuring impacts with a distributional lens, the assessment would identify trade-offs between financial viability and social inclusion associated with different modes of funding and financing.

In infrastructure provision, the tradeoffs between financial viability and equity, or between efficiency or equity, must be taken into account in making decisions about the extent and modalities of private sector participation vis-à-vis the public sector. The decisions themselves are context-specific, where one or more of the considerations are prioritized depending on the context of every situation. Ex ante impact analysis with a distributional lens is essential for informing these decisions with evidence about what these trade-offs are likely to be. To make actual cost-benefit calculations that can, in turn, inform the planning and design (and ex ante analysis) of future projects and policies, ex post evaluations are needed to assess how much of the intended impacts and trade-offs were realized.

Table 1 below presents a list of the available methods for estimating the welfare and distributional impacts of infrastructure interventions that involve the private sector. For each method, the table indicates how the method solves the attribution problem, the type of intervention to which it applies, and whether or not the method can handle distributional issues. These methods apply whether infrastructure is funded entirely by the government, entirely by the private sector, has a combination of both public and private finance, or is funded by the government but managed by the private sector. Some of these methods can be used for both ex ante and ex post evaluations (e.g. CGE, CBA), whereas some are suitable for one and not the other. A few methods also complement each other rather than being mutually exclusive. For example, results obtained using different methods of ex post impact evaluations of assignable interventions, for example, can be used in an ex post CBA analysis.

Table 1: Summary of Methods to Estimate the Welfare and Distributional Impacts of Infrastructure Interventions

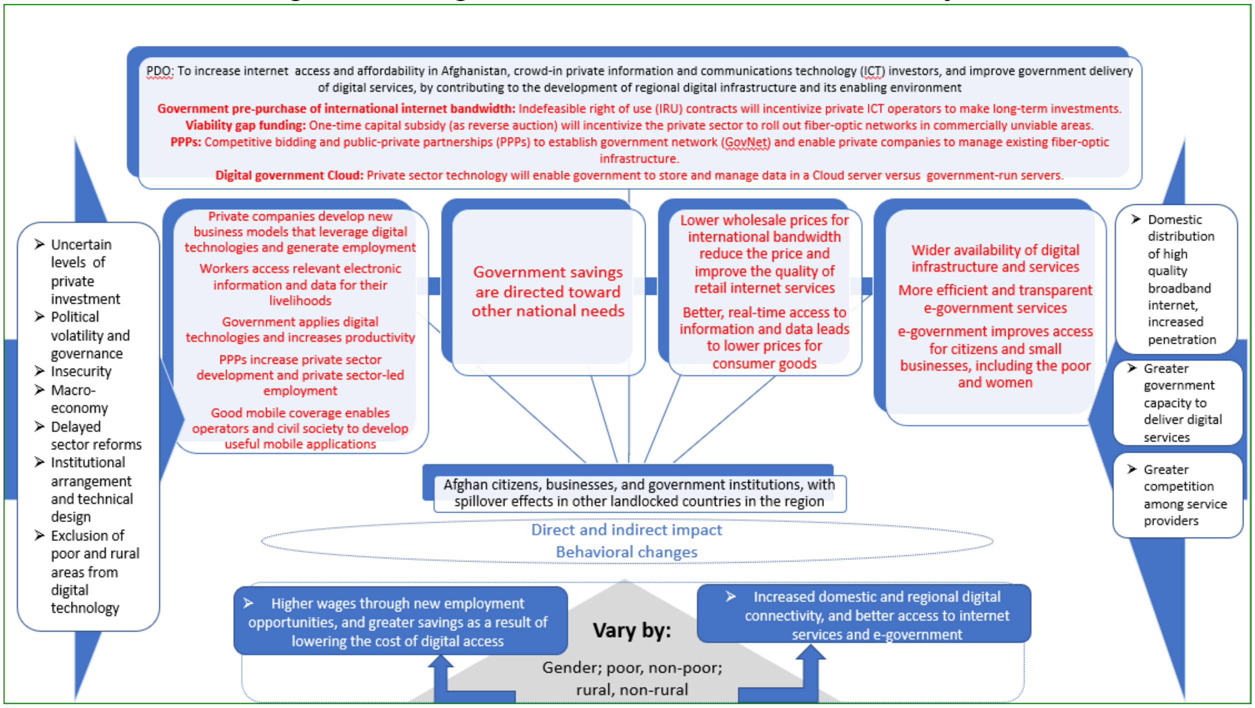
Method	Solves attribution problem	Applicable intervention	Deals with distributional issues	Ex ante or ex post?
Standard CBA (partial equilibrium models)	With-and-without comparison	Assignable, with no significant spillover effects	No	Both
CBA cum Distribution (partial equilibrium models)	With-and-without comparison	Assignable, with no significant spillover effects	Yes	Both
Randomization	With-and-without comparison	Assignable, with no significant spillover effects	Yes, by computing quantile treatment effects.	Ex post
Double Difference (DD)	Before-and-after combined with with-and-without comparison	Assignable, with endogenous placement; where time-invariant initial conditions influence both infrastructure placement and the level of the outcome variable	No	Ex post
DD with IV	Before-and-after combined with with-and-without comparison, and IV	Assignable, with endogenous placement; where time-invariant or time-varying initial conditions affect both infrastructure placement and changes in the outcome variable; initial conditions are assumed unobservable	No	Ex post
DD with PSM	Before-and-after combined with with-and-without comparison, and PSM	Assignable, with endogenous placement; where time-invariant or time-varying initial conditions affect both infrastructure placement and changes in the outcome variable; initial conditions are assumed to be observable	No	Ex post
RDD	With-and-without comparison (may be combined with before-and-after)	Discontinuity in the assignment of an intervention, such as due to rules about eligibility for the intervention	No	Ex post
Standard Quantile Regression	Statistical assumptions	Assignable, with no significant spillover effects	Yes	Ex post
Panel Quantile Regression	Before-and-after combined with with-and-without comparison	Assignable, with endogenous placement	Yes	Ex post
Real CGE	Structural modeling	Non-assignable, with significant spillover effects	Yes (between group inequality)	Both
Real CGE-Microsimulation	Structural modeling	Non-assignable, with significant spillover effects	Yes	Both

FCGE	Structural modeling with financing	Non-assignable, with significant spillover effects	Yes (between group inequality)	Both
FCGE-Microsimulation	Structural modeling with financing	Non-assignable, with significant spillover effects	Yes	Both

***Note*: A**ll ex post evaluation methods for assignable interventions can produce impact estimates that can be used in an ex post CBA.

Annex

Figure A-1: Afghanistan Central Asia South Asia Project



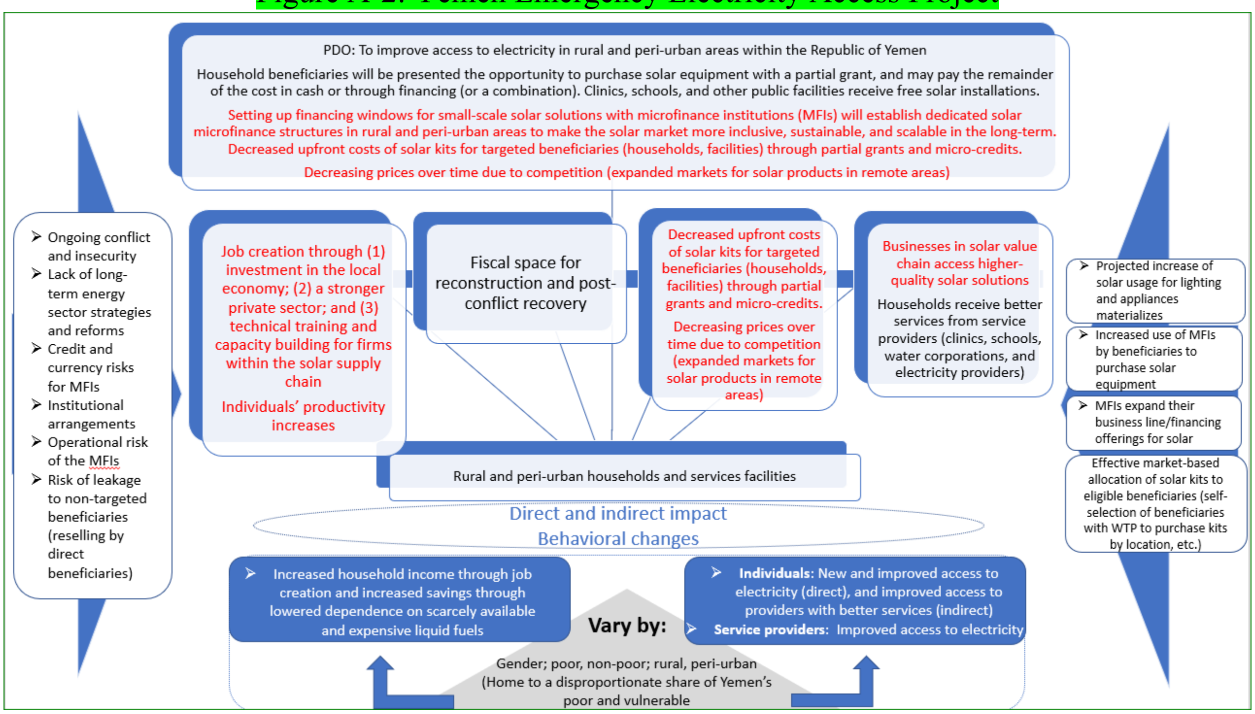
Source: World Bank Group staff

In Afghanistan, digital inclusion is a challenge. Access to internet services remains unattainable for most of the population, and has not trickled down effectively to the poor, and especially to those in rural and remote areas. The Afghanistan Central Asia South Asia (CASA) project (P156894) has adopted a Maximizing for Development (MFD) approach with the intention to crowd-in private sector investment for the information and communications technology (ICT) sector, improve the government's capacity to deliver digital services, and support a competitive market in Afghanistan. There are four specific ways in which this project aims to address binding constraints to increase private participation within the ICT sector: (i) the pre-purchase of international internet bandwidth by the government to incentivize long-term investment by private ICT operators; (ii) viability gap funding to incentivize the private sector to roll out fiber-optic networks in commercially unviable areas; and (iii) PPP mechanisms to establish and manage fiber-optic infrastructure. The key assumptions for the above changes to occur include: the penetration of quality internet will increase due to the government's pre-purchase of internet bandwidth, and the provision of viability gap funding; the government will have greater capacity to deliver digital services to citizens through PPP mechanisms; and through PPP mechanisms, there will be greater competition among internet service providers.

Four types of channels are expected to influence the ultimate well-being of project beneficiaries who, in turn, will be affected by the following behavioral changes: (i) businesses leveraging digital technology to generate employment opportunities, and workers accessing relevant information for their livelihoods (comprising a change in market-income generation capacity); (ii) government directing its savings toward other national needs (comprising a change in non-market income); (iii) lower-cost wholesale internet prices reducing retail internet prices, and increasing the quality of retail internet (resulting in a change in the market prices of consumer goods and services); and, (iv) citizens enjoying greater efficiency and access to e-government services (representing a change in the access, affordability, and quality of non-market goods and services). As noted in Figure A-1, there are also several conditions that may affect the outcomes of private sector interventions. These external factors could negatively impact the proposed timing of the rollout, the envisioned impact of specific components, as well as the overall implementation of the project.

Due to Afghanistan's growing insecurity, the country's political volatility and macroeconomic instability will be key influences on the causal chain. The bottom of Figure A-1 highlights the impact of the project's private sector participation interventions on the welfare of the poor. If the casual chain is realized, increased access to affordable and reliable internet services will lead to changes in poor peoples' monetary well-being such as higher wages (through new employment opportunities) and greater savings, as well as greater consumption resulting from the lower cost of digital access. The causal chain will also lead to changes in non-monetary benefits for the poor such as greater domestic and regional internet connectivity, and better access to internet services and e-government.

Figure A-2: Yemen Emergency Electricity Access Project



Source: World Bank Group staff

As a result of the ongoing conflict in the Republic of Yemen, the country's electricity supply has collapsed. Before the conflict erupted in 2014, about 66 percent of the population had access to public electricity.[170] By the end of 2017, this number had dwindled to fewer than 10 percent because of extensive damage to the national grid, and fuel shortages across the country. The collapse of public electricity in Yemen has devastated the country. In rural and peri-urban areas, employment and household incomes have been greatly reduced due to people's dependency on the energy-intensive agriculture sector. Households must rely on scarcely available and expensive liquid fuels that have negative health impacts. Due to lack of street lighting, women and children face greater security risks. Electricity is also a binding constraint for critical service facilities that cannot invest in alternative energy sources. These include health facilities and their vaccine cold chains, water supply and sanitation services, food suppliers, and banking services.

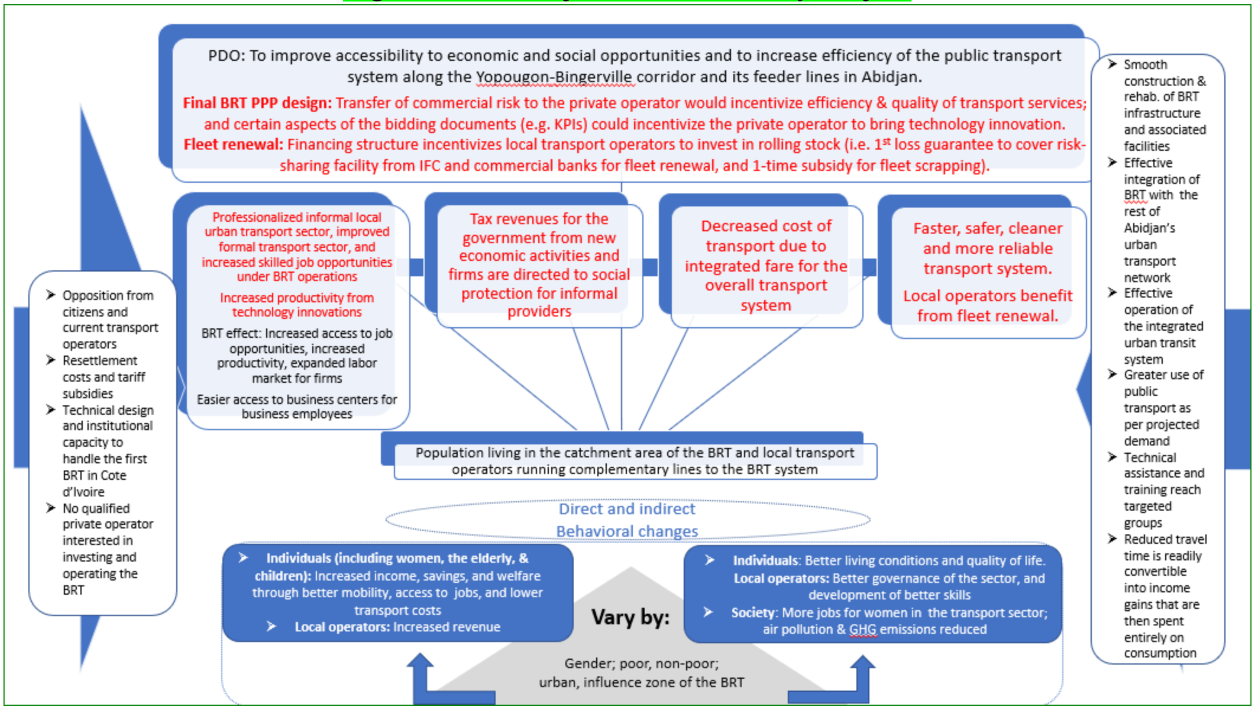
The Yemen Electricity Access Project (P163777) was launched to improve access to electricity in rural and peri-urban areas in Yemen. As an MFD project, the components support grant-financed solar solutions through microfinance institutions (MFIs), while also supporting public facilities with free solar installations. The projected changes from the private sector participation interventions are displayed in the four boxes at the center of Figure A-2. Starting from the far-left, job creation and productivity are expected to increase through investment in the local economy, a stronger private sector, and the strengthening of the solar supply chain market, which will result in a change in market-income generation capacity.

As indicated by the remaining boxes to the right in Figure A-2: the government's savings on power provision will be available for the country's reconstruction and post-conflict recovery, which will result in a change in non-market income; lower upfront costs of solar kits through grants and financing, and lower prices of solar kits through market competition, will result in a change in the market prices of consumer goods and services; and higher quality solar solutions for businesses, and higher quality services from service providers will result in a change in the access, affordability, and quality of non-market goods and services.

In order for these changes to take place, the project makes four key assumptions that are highlighted in the far-right arrow in Figure A-2: the projected increase in solar usage will materialize (as opposed to other forms of energy); there will be market-based allocation of solar kits to poor eligible beneficiaries through self-selection based on their willingness to purchase solar kits; beneficiaries will increase their use of the MFIs that sell the solar equipment; and the MFIs will expand their business lines and financing for solar equipment.

A high risk factor that influences the project's likelihood of success is the country's ongoing conflict and insecurity. Other risk factors that may negatively impact the project include: the country's lack of long-term energy sector strategies; the credit and currency risks faced by the MFIs lending to the households; and the capacity of MFIs to operate smoothly during the country's ongoing crisis. There are also risks associated with the implementation arrangements led by the United Nations Office for Project Services (in collaboration with local entities), and the risks associated with beneficiaries selling their subsidized solar systems, which would benefit higher-income households. If project risks are mitigated and the causal assumptions materialize, beneficiary households should experience higher incomes through job creation, and greater savings through less dependence on expensive and scarcely available liquid fuels; individuals should experience better access to electricity, and greater access to better-quality services; and service providers should experience improved access to electricity.

Figure A-3: Abidjan Urban Mobility Project



Source: World Bank Group staff

Urban mobility has become a major challenge in Abidjan, in Côte d'Ivoire, as population growth and economic development have significantly increased the demand for transport. The weaknesses of the current public transport supply, which is dominated by informality, lack of coordination, obsolescence, inadequacy, and a shortage of system management personnel, place additional pressure on the system. As a result, the population suffers from inadequate mobility and high transport costs due to an expensive and poor-quality public transport system.

The Abidjan Urban Mobility Project (P167401) supports the government's efforts to implement a holistic strategy for sustainable mobility. Through the MFD approach, the project seeks to improve access to economic and social opportunities, and increase efficiency of the public transport system along the Yopougon-Bingerville corridor, and its feeder lines in Abidjan. This is achieved through establishing and integrating a new BRT system; strengthening Abidjan's Public Transport Company; restructuring the feeder bus system; and supporting the artisanal transport sector, and last-mile accessibility.

In order to leverage private sector finance and expertise, the project includes a PPP to generate efficiency gains, and increase quality and innovation. Additionally, the project supports a financing scheme in partnership with IFC that incentivizes local transport operators to invest in rolling stock renewal. These specific private sector interventions are intended to lead to: a professionalized and improved informal and formal transport sector; increased opportunities for skilled jobs with the BRT; increased productivity from technology innovations (representing a change in market-income generation capacity); increased tax revenue for social protection for informal transport providers (representing a change in non-market income); lower transportation costs as a result of an integrated fare system (representing a change in the market prices of consumer goods and services); and a faster, safer, cleaner, and more reliable transport system, and associated fleet (resulting in a change in the access, affordability, and quality of non-market goods and services).

The key assumptions linked to the private sector participation elements associated with implementing the BRT are as follows. The first one is that targeted transport operators will receive technical assistance provided by the project, and that the new transit system will be created as a result of successful construction, effective integration, and efficient operations. From the users' perspective, the key assumptions include greater use of public transport as per projected demand, and greater consumption resulting from income gains derived from less time spent on travel, and more time to earn income.

The overall risk factors that could impact the implementation of the project include: opposition from citizens who are forced to move by the BRT's construction; opposition from the current transport operators due to their lost tariff subsidies; poor technical quality of the BRT's design; lack of institutional capacity in Côte d'Ivoire to manage the BRT; and no qualified bidders willing invest in, and operate, the BRT.

Successful implementation of an efficient public transport system along the Yopougon-Bingerville corridor and its feeder lines should result in a number of improvements in the well-being of populations living in the catchment area, and of the local transport operators running complementary lines. Monetary changes for individuals will stem from better mobility through lower transport costs and better access to jobs, higher incomes, and greater savings. Local operators will benefit from increased revenue. Changes in non-monetary well-being will be realized through better living conditions and quality of life for individuals, better governance, and local operators and construction workers developing better skills and, hence, improving their marketability. The health of local residents will improve too as a result of less polluting transport systems.

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[1] Welfare impacts refer to the impacts of a project on well-being – monetary as well as non-monetary dimensions, as relevant – of individuals and/or households or of specific groups (such as the poor or the bottom 40% of the income distribution). Distributional impact refers to how the welfare impacts of a project, which are often measured in terms of net benefits (economic benefits minus costs) are distributed among different segments of the population, such as those differentiated by income or wealth levels, age, gender, location, and even education and occupation.
[2] The African Development Bank, Asian Development Bank, European Bank for Reconstruction and Development, European Investment Bank, Inter-American Development Bank, International Monetary Fund, and World Bank Group jointly prepared the Discussion Note "From Billions to Trillions: Transforming Development Finance, Post-2015 Financing for Development: Multilateral Development Finance" for the April 18, 2015, Development Committee meeting. The Note outlines the MDBs' joint commitment to mobilize greater investment from the private sector and institutional investors, as well as a methodology for private capital mobilization that uses a reference guide to calculate and jointly report on the extent of private investment mobilized for their projects.
[3] The importance of considering underserved groups in private sector operations is highlighted in IFC's Anticipated Impact Measurement and Monitoring (AIMM) System (IFC 2019). AIMM comprises principles for inclusion, and an associated methodology for scoring the extent to which an IFC investment provides unserved/underserved groups (e.g. by gender, income level, age, geographic location, citizenship/refugee status) goods and services, or income generation opportunities. By scoring IFC projects on the extent to which they focus on providing goods, services or income opportunities to vulnerable groups, the AIMM system supports IFC's efforts to be more inclusive and reach traditionally unserved/underserved segments of the population that "lack access to basic goods, services, jobs, and/or assets that are important aspects of well-being." As each investment's context differs, the AIMM system helps project teams to determine who may be unserved/underserved in a particular context and address the specific barriers they face.
[4] World Bank 1994.
[5] Calderón and Servén 2010.
[6] Calderon and Servén 2014.
[7] Khandker and Koolwal 2009.
[8] Khandker and Koolwal 2010.
[9] Agénor and Moreno-Dodson 2006.
[10] Freeman et al. 2012.
[11] Energy infrastructure includes electricity generation, transmission, and distribution, as well as oil and gas pipelines. Water and sanitation infrastructure includes water supply and distribution, and sewage treatment. Telecommunications infrastructure includes cable and fiber-optic transmission, towers, base stations, fixed lines, and satellites.
[12] Infrastructure benefits vary between countries, with those lacking basic hard infrastructure differing from those that focus on improving the quality of services, or spending efficiently on the infrastructure—all of which are crucial for the delivery of human capital outcomes.
[13] Jalan and Ravallion 2003. Also see Pruss-Ustun et al. 2014.
[14] SDG9 on infrastructure, industrialization, and innovation commits to "significantly increase access to ICTs [information and communications technologies] and strive to provide universal and affordable access to the internet in least developed countries by 2020." (World Bank 2016 p. 309).
[15] According to the World Development Report 2016, the "real significance of the internet for the SDGs is likely to lie in helping to achieve other targets, such as target 3.9 on achieving universal health coverage, target 5b on promoting women's empowerment, or target 10c on reducing the transmission costs of migrant remittances to below 3 percent." (World Bank 2016 p. 309).
[16] Henderson et al. 2001 and World Bank 2009.
[17] Density indicates the intensity of socioeconomic activity on a unit of land, distance reflects the costs of access to socioeconomic opportunities, and division stems from any barrier to socioeconomic interaction.
[18] World Development Report 2009.
[19] World Bank, ASEAN, and Australian Aid 2018.
[20] For more details, including a review of the current literature on distributional impacts of digital infrastructure, see "The Distributional Impact of Digitization: A Framework Paper" (currently in draft), which is being prepared by the Poverty & Equity GP in the World Bank.
[21] Aker (2008); Aker and Fafchamps (2015)

[22] Hjort and Poulson 2019.
[23] Poliquin 2018.
[24] Hjort and Poulson 2019.
[25] Asian Development Bank 2012.
[26] Stiglitz 1997.
[27] World Bank 1994.
[28] World Bank 2019b.
[29] World Bank 2017.
[30] World Bank 2017.
[31] The Cascade algorithm is a policy and a project-level decision-making framework to determine whether sustainable private sector solutions can be leveraged to optimize the use of scarce public resources. WBG teams ask first whether a project can be delivered through sustainable private sector solutions while limiting public liabilities, and, if not, whether WBG support (the public finance option) to improve the investment environment or risk mitigation can help achieve such solutions, while maintaining environmental, social, fiscal, and governance standards (World Bank 2017a).
[32] Gassner et al. 2009.
[33] The study assessed the impact of private sector participation, based on a panel dataset that comprised 301 utilities with private sector participation, and 926 state-owned enterprises (SOEs). To ensure a causal interpretation of the results, the study compared the changes over time in the outcomes associated with private sector firms, with those of sufficiently similar SOEs. It used propensity score matching to identify the best comparator SOEs, and applied the Difference-In-Differences method to estimate the causal effect of private sector participation (see Section 4 for more on these methods).
[34] Andrés et al. 2008.
[35] Gassner et al. 2009.
[36] This is partly the reason why Andrés et al. (2008) found the impact of privatization on prices to be very mixed, particularly for the water sector (see Box 8).
[37] McKenzie and Mookherjee 2003.
[38] Freije and Rivas 2002.
[39] World Bank. 2015. "Poverty and Social Impact Analysis Brief."
https://www.worldbank.org/en/topic/poverty/brief/poverty-and-social-impact-analysis-psia
[40] See the recent publications featured on the PSIA website. More resources, including specific analytics and research, are available on the webpages for PSIA events, such as the "Prosperity, Equality And Sustainability Conference" (2016), and "From Evidence to Policy: Innovations in Shaping Reforms in Africa" (2015). Also see the website of the Poverty and Social Impact Analysis Multi-Donor Trust Fund, which includes links to all the learning events and annual reports supported by the trust fund. To advance the overall objectives of the PSIA approach, the internal WBG-only website—the Equity Policy Lab (EPL)—provides WBG staff with advanced tools for data analysis, and simulations to conduct distributional analysis of policy changes, with particular emphasis on fiscal policy. To increase the likelihood that the WBG's analytical and operational work considers the distributional impact of interventions, the EPL provides task teams and analysts with appropriate, just-in-time expertise.
[41] Essama-Nssah (2013a) discusses the types of questions that evaluations are supposed to answer and points out that an evaluation question is answerable only if there is a logical and feasible pathway from known information to a meaningful answer.
[42] Gertler et al. 2016.
[43] Hansen, Anderson, and White. 2011.
[44] Weber, Staub-Bisang, and Alfen 2016.
[45] Markard 2011.
[46] Given that CGE models are costly to build, econometric methods can still be used to estimate the first-order impact of an infrastructure intervention on direct beneficiaries. This is the approach taken by a couple of papers cited in this Guidance Note: Dinkelman (2011) on the national electrification program in South Africa, and Hjort and Poilsen (2019) on the arrival of fast internet in Africa. The reader may also consult Fabrizio, Rose, and Wolfram (2007) on the impact of regulatory restructuring of the electricity market in the US.
[47] McDavid and Hawthorn 2006.
[48] Gertler et al. 2016.
[49] Mayne 2015.
[50] Gertler et al. 2016
[51] See Raitzer et al. (2019) for a more elaborate version of this example.
[52] Heckman 2005.

[53] These projects were approved by the World Bank Board of Directors in fiscal years 2018 and 2019.
[54] Lindblom 2001.
[55] Bussolo and Lopez-Calva 2009.
[56] With respect to labor market outcomes, it is important to consider both the formal and informal sectors. In many developing countries, unskilled labor, which is supplied mostly by the poor, is predominantly employed in the informal sector of the economy. It may also be useful to distinguish among sources of labor supply: local labor versus labor from outside the catchment area.
[57] Ravallion 2009.
[58] World Bank 2009 and Hansen, Anderson, and White 2011.
[59] BenYishay and Tunstall 2011.
[60] Mayne 2015.
[61] World Bank 2008b.
[62] While these channels are listed separately, interactions among them may occur.
[63] Ibid.
[64] Input from IFC.
[65] Mayne 2001.
[66] Funnell and Rogers 2011.
[67] World Bank 2012.
[68] Funnell and Rogers 2011.
[69] Schacter 2002.
[70] Schacter 2011.
[71] Knowlton and Phillips 2009.
[72] The words used for the acronym SMART vary. For example, Gertler et al. (2016) use the words: Specific, Measurable, Attributable (i.e. can be linked to the intervention), Realistic, and Targeted; while Kusek and Rist (2004) use the words: Specific, Measurable, Attainable, Relevant, and Trackable. In both versions of the acronym, the common words are Specific and Measurable.
[73] Kusek and Rist (2004) also use the acronym CREAM, which stands for Clear, Relevant, Economical, Adequate, and Monitorable. The word Clear requires countering ambiguity in definition; Relevant means that the indicator is appropriate for the matter under consideration; Economical assumes that the indicator can be implemented at a reasonable cost; Adequate requires providing a sufficient basis for understanding and assessing performance; and Monitorable means that the indicator can be validated independently.
[74] World Bank 2012.
[75] Robinson 2013.
[76] World Bank 2013.
[77] Quade 1982.
[78] Both valuation and evaluation constructs connote a comparison, but the former refers to the comparison of things, while the latter is an assessment of the relative merits of actions (Dasgupta 2001).
[79] Sen 2000.
[80] Sen (2000) argues that CBA should be interpreted broadly as a social choice approach rather than as a specific method. This interpretation makes it possible for CBA to use other evaluation criteria beyond efficiency. The framework reduces all interventions to a common metric, regardless of their characteristics and variations in the sources of their costs or benefits (Vickerman 2007).
[81] Squire and van der Tak (1975) emphasize that the situation without the intervention should never be considered simply as a continuation of the status quo. It is the situation that is expected to prevail in the absence of the intervention, when changes in the outcome variables and the contextual factors that would occur anyway, have been taken into consideration.
[82] Freeman 2003.
[83] As Holland (1986) points out, the effect of a cause can be understood only in relation to another cause.
[84] Squire and van der Tak 1975.
[85] The EU (2015) recommends the use of multi-criteria analysis for shortlisting the alternatives, and then applying CBA to the shortlisted options to identify the most socially desirable one.
[86] World Bank 2017e.
[87] EU 2015.
[88] Belli et al. 2001.
[89] World Bank 2018a.
[90] Boardman et al. 2018.

[91] Market failure creates a divergence between the market price and the marginal social cost. The solution is to use a shadow price, which is an estimate of what the market price would be if the good was traded in an efficient market (Boardman et al. 2018).
[92] Belli et al. 2001.
[93] Accurately estimating demand for transport projects is particularly challenging because transport infrastructure lasts for a long time, and long-term forecasts are prone to errors. These errors can be costly for society, given that transport projects require large investments, over a long period, and pose a risk of burdening society with underused, costly investments.
[94] Shahraki and Bachmann 2018.
[95] Vickerman 2007.
[96] Kim, Hewings, and Amir 2017; Kim, Hewings, and Bae 2015.
[97] Ibid.
[98] The highway links Busan and Daegu, the second- and third-largest cities in the Republic of Korea..

[99] Sen 2000.
[100] As will be discussed later, the social value of policy outcomes is based on an aggregation of individual valuations.
[101] While CBA and valuation methods are discussed here in the context of ex-ante evaluation, it is important to note that these methods can also be applied ex-post.
[102] Bronsteen, Buccafusco, and Masur 2013.
[103]ADB 2012.
[104] More detailed discussions on both revealed preference, and stated preference valuation methods for nonmarket goods, can be found in Freeman et al. (2014) and Champ et al. (2017). In addition, the emergence of happiness-based policy analysis has led to a new evaluation approach that uses the concept of subjective well-being to produce metrics for valuing policy outcomes in CBA. Regarding the latter, see Fujiwara and Dolan (2016) and Essama-Nssah (2015).
[105] Belli et al. 2001.
[106] Robinson 2007.
[107] According to Robinson (2007), the "statistical life" method can be used to aggregate small changes in mortality risk across a large population. For instance, if an intervention brings about a reduction in mortality risk of about 1 in 20,000, in a population of 20,000, this is considered to have saved one statistical life.
[108] Different wages based on high- and low-risk occupational choices.
[109] Belli et al. 2001.
[110] Loomis 2011.
[111] World Bank (2017e) also recommends distributional analysis for CBA that focuses on identifying winners and losers, and on quantifying the magnitude of the gains and losses accruing to them—even in cases where the project's net benefit is positive.
[112] World Bank 2015.
[113] Spillover effects, which can be positive or negative, refer to the impacts of an intervention on socioeconomic agents, groups, or sectors, other than those that are directly affected or targeted by the intervention.
[114] See "Bringing a Poverty and Equity Lens to Country Private Sector Diagnostics: Resource Note for Poverty & Equity GP Teams (World Bank. 2018d. Internal document, available on request).
[115] Lokshin et al. 2013.
[116] Araar et al. 2018.
[117] IFC (2018)
[118] Haddad et al. 2019.
[119] Belli et al. 2001.
[120] Segerson 2017.
[121] The Lorenz curve is an indicator of inequality with regard to how some outcome variable such as income is distributed across a population. In the case of an income distribution, the Lorenz curve is a graph in which the cumulative percentage of total income measured on the vertical axis is plotted against the cumulative percentage of the corresponding population (ranked in increasing values of income) on the horizontal axis. The degree of inequality in the distribution is indicated by the extent to which the curve sags below a straight diagonal line.
[122] Carrigan et al. 2013.
[123] For a detailed discussion of issues related to discounting, see Boardman (2018).
[124] Exposure to a policy intervention or an investment project is usually called a treatment. Thus, policy impacts are also referred to as treatment effects.
[125] Input from IFC.
[126] Essama-Nssah 2013b.

[127] van de Walle 2009.
[128] Binswanger et al. 1993.
[129] van de Walle 2009.
[130] Claveau 2011.
[131] Heckman and Smith 1995.
[132] White (2011) makes a distinction between large and small n interventions, where n indicates the number of possible observations at the level of treatment assignment.
[133] Gonzalez-Navarro and Quintana-Domeque 2016.
[134] Raitzer et al. 2019. These authors further explain that interrupted time series can be interpreted as an RDD when the threshold is a particular point in time when an intervention came into effect. This approach requires that the intervention's effectiveness is sudden, rather than gradual. A good example is the completion of a bridge.
[135] White and Raitzer 2017.
[136] Pomeranz 2017.
[137] Burlig and Preonas 2016.
[138] Casaburi, Glennerster, and Suriy 2013.
[139] This condition, it is important to note, is met by randomization. Assuming full compliance (i.e. units comply with their assignment to the treatment or control group), randomization creates variation in the treatment received by those who are eligible, and this variation is independent of the potential outcomes (Heckman and Smith 1995).
[140] Gertler et al. 2016.
[141] This estimation is commonly implemented as a two-stage least squares: The first stage involves regressing the endogenous indicator of participation on the instruments and computing the fitted values; stage two runs a regression of the outcome variable on the fitted values from stage one and other relevant variables. The treatment effect is the coefficient of the fitted values in the outcome equation (Raitzer, Blondal, and Sibal 2019).
[142] Dinkelman 2011.
[143] Andrés et al. 2008.
[144] Dinkelman (2011) ruled out this possibility in the case of rural KZN, noting that the land's gradient has a limited impact on agricultural productivity, and that agricultural employment growth is limited, as few people are engaged in farming.
[145] Barron and Torero 2014.
[146] Pomeranz 2017.
[147] Bernajee, et al. 2011.
[148] Meenakshi et al. 2013.
[149] Van de Walle 2009.
[150] If baseline data are not available, Ravallion (2008) advocates the use of the triple-difference estimator (DDD) to identify impacts by observing the outcomes of participants after, rather than before, the program. The DDD is defined as the difference between the double difference for those who stayed, and those who left the program. The validity of the approach hinges on two basic conditions: (1) dropping out of the program is as good as random, and (2) there are no current gains for the non-participants.
[151] Lokshin and Yemtsov 2005.
[152] van de Walle and Mu 2007.
[153] Cuong 2011.
[154] van de Walle 2009.
[155] van de Walle et al. 2017.
[156] White 2011.
[157] Broegaard et al. 2011.
[158] van de Walle 2009.
[159] van de Walle 2003.
[160] Examples of the CGE model approach include Boccanfuso, Estache, and Savard (2009) and Chisari, Estache, and Romero (1999).
[161] Khandker et al. 2013.
[162] World Bank 2008a.
[163] Modification of the double difference method used in the Vietnam study stemmed from the observation that communes and households received electricity at different times. This implied that commune and household characteristics respond to electrification in a dynamic way, which invalidates the standard assumption of time-invariant confounders that are usually relied on for identification of the ex post impact of infrastructure interventions. Khandker et al. (2013) assumed that time-variant factors depended on the initial conditions that characterized

communes and households. This assumption, combined with the panel structure of the data, allowed the authors to implement a modified household-level, fixed-effects regression to deal with the endogeneity bias.

[164] The panel quantile regression model was inspired by the one used by Gamper-Rabindran et al. (2010) in evaluating the impact that piped water had on infant mortality in Brazil. The framework used in the Vietnam study entailed the specification of a quantile regression for each year of the panel, and it assumed that unobserved confounders were driven by the observed characteristics of communes and households. To account for endogeneity bias, quantile treatment effects were estimated through a two-step procedure meant to mimic fixed-effect estimation.

[165] Bensch et al. 2016.

[166] Chisari, Estache, and Romero 1999.

[167] For more recent research on the quality of infrastructure regulation see Ghossein and Ruiz Nunez (2018).

[168] Boccanfuso, Estache, and Savard 2009.

[169] Hansen, Andersen, and White 2011.

[170] Another 12 percent had access to private electricity solutions.