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The WEB of Transport Corridors in South Asia

Background Paper

Transport Corridors and Their Wider Economic Benefits

A Critical Review of the Literature

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Abstract

Transport corridors can generate wider economic benefits and costs through their effects on a potentially diverse set of development outcomes, such as economic growth, poverty, jobs, equity, environmental quality, and economic resilience. To advance understanding of how corridors could generate wider economic benefits, this paper undertakes a quantitative review of the literature that estimates the economic benefits of large transport infrastructure projects. It conducts a meta-analysis of 234 estimated impacts found in 78 studies. It focuses on roads, rails, and waterways because transport corridors based on these modes have clearer potential for economic spillovers than, for example, airline routes. The conceptual structure for the review is guided by a simple canonical model describing the policy maker's problem in maximizing the net wider economic benefits of corridors. The meta-analysis confirms that characteristics of individual studies, as well as the placement and design of the transport infrastructures systematically influence the findings of the corridor studies. It also shows that, on average, estimated impacts of corridor interventions on economic welfare and equity tend to be beneficial, while they are often detrimental for environmental quality, and possibly also for social inclusion. Because, around this average, impacts vary widely, policy makers could use complementary policies and institutions to mitigate potential trade-offs and support losers. To clarify the nature and extent of these trade-offs and varied impacts across locales and population groups, much more research is required.

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Produced by the Research Support Team

Transport Corridors and Their Wider Economic Benefits: *A Critical Review of the Literature*[*]

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1. Introduction

Current initiatives and proposals to build transport corridors could demand trillions of dollars in the near future, vastly exceeding the capacity of public finances. By reducing transport costs, such initiatives typically aim to unleash efficiencies in regional and transregional trade. But beyond savings of travel time and vehicle operating costs, these initiatives also strive to generate net benefits for firms and ultimately households stemming from the increased economic opportunities that transport corridors could generate (ADB, DFID, JICA, WB, 2018). However, to help realize these benefits, national governments, the private sector, and the global development community need clear economic thinking on how to prioritize investment proposals for large transport projects and a proper methodology to appraise projects. Without such a methodology, these investments run the risk of uncoordinated efforts resulting in missed opportunities; of squandering limited public resources that could have been used, for instance, to improve education and health; of geopolitical considerations prevailing over economic prospects; and of possible misunderstandings between governments and among international organizations.

In parallel with rising interest among policy makers in appraising and prioritizing transport corridors, there has been a surge of academic interest in empirically evaluating the economic, social, and environmental impacts of large transport infrastructure projects (Redding and Turner 2014; Berg et al. 2015; Laird and Venables 2017). This surge has, at least partly, been driven by improved techniques for rigorously evaluating the economic impacts of these investments, as well as recently completed large-scale investments in transportation networks by countries such as China and India. The academic interest covers both these recent investments as well as historical large-scale investments, such as the investments in the mid-1800s of the United States in its railway network and the British colonial authorities in the late nineteenth and early twentieth centuries in the construction of the colonial Indian railway network. Recent studies also cover investments at a variety of different scales, ranging from the evaluation of the impacts of individual links within either a preexisting or a new system to the evaluation of entire national or even continental systems. Some of these investments may not adhere to what are usually deemed corridor investments. Nevertheless, the large academic literature estimating the impacts of large-scale transport investments could greatly inform policy makers' thinking on corridors and help develop a comprehensive methodology for the appraisal of corridor projects.

This paper provides a rigorous review of the empirical literature estimating the impacts of large transport investments. In doing so, it aims to improve policy makers' understanding of the multiple, and potentially varied, impacts of transport corridor investments. This includes enhancing understanding of the potential trade-offs that the investments can generate both between different development outcomes and between different groups of economic actors. The review also informs policy thinking about the types of complementary policies and institutions that may be needed for wider economic benefits (WEBs) of corridors to materialize. Ultimately, the aim is to inform thinking on what may constitute an optimal "corridor package"— defined as a set of interventions that extends beyond the investment in the trunk transport infrastructure to include reforms and policies that amplify the net economic benefits of that infrastructure. In this light, the optimal package would be the one that a benevolent social planner would choose to maximize overall net benefits.

In reviewing the literature and thinking about the wider economic impacts of transport corridors, our interest is not so much in the immediate outcomes such as savings of travel time and vehicle operating costs (VOC) that remain the focus of most cost-benefit analyses (CBA) for transport projects.[1] Although their importance should not be dismissed and their accurate measurement remains an issue for CBA, these savings are unable to capture the full economic benefits of a transport project in anything other than a hypothetical world of perfectly competitive and complete markets (see, for example, Vickerman 2007 on this point).[2] Rather, our interest is in the wider economic impacts of large transport projects, which include impacts on development outcomes such as *economic welfare* (monetary measures of well-being such as income, wages, and consumption), *social inclusion* (jobs, gender), *equity* (poverty, inequality), *environmental quality* (pollution and deforestation), and *economic resilience* (unexpected losses due to large shocks or protracted trends such as disruptive technologies).[3] Furthermore, we are interested in the potential trade-offs that may occur between these different types of variables—for example, boosting income at the expense of rising pollution or inequality—as well as the heterogeneous impacts of transport projects on a given outcome across different places and economic agents—such as economic impacts that differ across subnational regions, industries, and segments of the population. These heterogeneities are hidden by estimates of average impacts. In some cases, they may involve only relative winners and losers. For instance, when all subnational areas along the route of a transport project gain, some may gain more than others. But, in other cases, the losses for some areas may be absolute.

To achieve greater rigor, this paper adopts a quantitative approach to reviewing the literature. We base our review on a meta-analysis of 78 papers that have been published from 2000 to mid-2017 and that meet a series of qualifying criteria. Taken together, these papers provide 243 individual results, which represent the sample for the quantitative analysis. This includes both simple descriptive analysis and formal econometric meta-regression analysis. The published literature that we consider covers papers published in peer-reviewed academic journals and recognized working paper series, as well as gray literature that has not (yet) been published through a formal outlet and that is only available for download on authors' personal websites.[4] In performing our review, we exclude literature that is solely concerned

[1] Savings in transport costs also form the focus of the social savings approach to assessing the impacts of transport infrastructure investments. This approach was originally pioneered by Fogel (1964) in his assessment of the benefits of the construction of the US railroad system in the nineteenth century.

[2] It is sometimes argued that, even when the assumptions that underpin traditional CBA break down, it remains useful in providing a lower-bound estimate of the net benefits of a transport infrastructure project. However, this line of argument implicitly assumes that all the wider impacts not captured by a traditional CBA are, on net, positive. This may or may not be true.

[3] An attempt was made to consider economic resilience—defined as the resilience of economic agents to various types of large shock (such as commodity price shocks, economic and financial crises, climate change, and natural disasters, among other events)—as a development outcome. However, empirical literature that rigorously examines the impacts of transport infrastructure on economic resilience was found to be, essentially, nonexistent. The only exception is the recent paper by Revoltella et al. (2016), which provides evidence—from periods of both large positive and large negative economic shocks—of the catalytic role played by transport infrastructure in linking local businesses with global growth opportunities. Note that economic resilience is different from the resilience of the transport infrastructure itself to shocks. Literature on this topic exists (see, for example, Rozenberg et al. 2017), but it is not a direct subject of interest for this review.

[4] The inclusion of such literature is important to both assessing and at least partially addressing possible issues of publication bias, whereby the probability of publication in a formal outlet (and, in particular, in a peer-reviewed journal) is increased by the level of reported statistical significance of a result (see, for example, Card, Kluve, and Weber 2009). Even assuming that publication bias can be perfectly addressed, a serious potential issue of "writing-up" bias remains that cannot be addressed. This bias arises from the fact that authors may refrain from writing up results that are economically marginal or statistically insignificant, even in an initial, unpublished, draft version of a paper.

with the evaluation of urban transport infrastructure projects within urban areas.[5] We also exclude literature in which more general transport-related variables appear in the empirical estimation, but these are either not related to evaluating the impacts of a particular large-scale transport infrastructure project and/or they appear as one of several general variables of interest.[6]

A few reviews of literature on the economic impacts of large-scale transport infrastructure projects have been conducted recently. The most notable of these are the reviews by Redding and Turner (2014) and Berg et al. (2015). In both cases, the authors present qualitative reviews of the literature. In contrast, this paper provides a quantitative review of the literature, which includes the use of formal meta-regression analysis techniques. We also consider a broader set of potential economic impacts than is considered in the review by Redding and Turner (2014). Finally, we attempt a more policy-oriented review of the literature in the sense that we ground it in a framework that is designed to reflect the problem faced by the policy maker who is confronted with the challenge of trying to maximize the net wider economic benefits of a proposed transport corridor. This allows us to connect our review paper more directly to the deliberations of policy makers. This framework also helps us highlight important research gaps that remain from the policy perspective.

The remainder of the paper is structured as follows. Section 2 sets out a simple canonical model of the policy maker's problem and an associated simple framework to help frame our analysis of the literature. Section 3 describes the criteria by which papers were selected for inclusion in the review. It also describes the tagging system that was developed to systematically describe the attributes of different papers and their associated results. Section 4 reports results from our descriptive analysis of the literature. Section 5 describes the meta-regression analysis undertaken and discusses its main results. Section 6 concludes.

2. Framework

To provide a conceptual structure for the literature review, we propose the following simple canonical model. The model summarizes the problem that a benevolent policy maker faces when trying to maximize the wider economic benefits (net of costs) of a potential corridor:[7]

$$\max_{R}\{Y'Y - (R - \bar{R})^2\} \tag{1}$$

where R is a column vector of corridor characteristics (such as location, length, and mode of transport) plus "complementary" policies and institutions that might help to amplify the targeted wider economic benefits captured by the vector Y.[8] Note that $(R - \bar{R})^2$ represents the cost of the new transport corridor intervention package including trunk transport infrastructure, transport and trade facilitation measures, as well as complementary market policies and cross-cutting institutions. This cost increases with the distance between

[5] See Redding and Turner (2014) for a discussion of the literature on the impacts of intra-urban infrastructure.

[6] This includes a large empirical New Economic Geography (NEG) literature on the relationship between market access and either wage or GDP per capita outcomes. For a meta-analysis of this literature, see Bosker and Garretsen (2010). It further includes a large empirical literature in macroeconomics, building on the work of Aschauer (1989) that analyzes the relationship between a country's stock of infrastructure, including its stock of transport infrastructure, and its level of development (for a review of this literature, see Straub 2011).

[7] By assuming a benevolent policy maker, we, in effect, assume that the problem that he or she faces is equivalent to that of a social planner.

[8] The vector Y can, in principle, contain a consumption-based utility function, as is commonly used in welfare analysis.

the new set of policies, R, and the preexisting set of policies, $\bar{R}$.[9] For simplicity, we abstract here from time notation because the problem can be readily translated into a maximization problem with a finite or infinite time horizon.[10] We also abstract from the cross-sectional notations because the underlying relationships presented here can hold at different levels of aggregation: local (for instance, subnational units such as districts and counties), national, and transregional (for instance, the population of India and Bangladesh in the neighborhood of a potential corridor spanning the two countries).

The first constraint to this optimization describes how R influences Y, along with other structural factors, X, that can interact with (conditionally increase or decrease) the effect of R on Y:

$$Y = f(R, X) \tag{2}$$

The net wider economic benefits, Y, can be affected by corridors (and their vector of characteristics) directly, conditional on other structural factors, X. These other structural factors may include initial conditions in local product and factor (land, labor, and capital) markets. The function $f(.)$ describes this direct conditional mapping between R and allows for various types of nonlinearities, including simple interactions of variables.[11] Note that the impact of R on Y can vary from beneficial to detrimental across individual outcomes in the vector Y. Essentially, $f(.)$ subsumes a covariance matrix that is lower triangular and captures potential trade-offs and synergic impacts of R on Y. The off-diagonal elements (co-variances) could thus be either negative, close to zero, or positive.[12]

The structural factors, X, can themselves be affected by R. For instance, if the corridor reduces commuting and migration costs, it also reduces frictions in the labor market. This set of constraints to the optimization can be written as:

$$X = g(R, \bar{X}) \tag{3}$$

where $\bar{X}$ is the initial value of X before the corridor intervention and $g(\cdot)$ describes the conditional mapping of R onto X. Again, this mapping can be nonlinear, including the interaction between X and R. Note again that the impact of R on X can vary from beneficial to detrimental across individual variables in the vector X. Basically, $g(\cdot)$ subsumes a covariance matrix that is lower triangular and captures potential trade-offs and synergic impacts of R on X. Solving equation (1)-(3) for R then gives an "optimized policy rule." This "optimized policy rule" specifies the set of corridor characteristics and associated complementary policies (that is, the "corridor intervention package"), $R*$, that the policy maker should adopt in response to any given set of initial conditions to maximize net wider economic benefits:

$$R^* = h(\bar{X},\ \bar{R}) \tag{4}$$

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9 The preexisting set of policies is captured by R. R also captures, for example, if there is preexisting transport infrastructure that the new corridor builds on. For example, the cost of the intervention is likely to be less if it is based on the upgrading of a previous road or railway line.

10 Abstracting from time notation allows us to avoid discussion of discount rates, which ultimately adds the unnecessary complexity of stochastic discount factors based on pricing kernels contingent on the state of the economy (Cochrane, 2009).

11 Nonlinearities can occur when, for example, the impact on real output of a decline in transport costs induced by the construction of a corridor contains threshold effects. The existence of such nonlinearities is predicted by new economic geography models (Krugman 1991a, 1991b; Fujita et al. 1999).

12 Underlying the relationship between R and Y are a set of "immediate outcomes," which consist of direct impacts of R on, for example, travel times and VOCs which, in turn, influence Y. As mentioned in section 1, these immediate outcomes have been the focus of traditional transport CBA, while the focus of this literature review is on the net wider economic benefits of transport projects. As such, for reasons of exposition, we choose not to explicitly emphasize the immediate outcomes in our simple canonical model, although the extension of the model to include them is straightforward.

While some aspects of the optimal "corridor intervention package", R^*, may be needed for net wider economic benefits to materialize regardless of the initial conditions, other features of the package will work best, or only be needed, under certain initial conditions, which include the preexisting transport network, $\bar{R}$. For instance, if a transport corridor is constructed within a setting that is characterized by poorly functioning land markets, then accompanying land market reforms may be needed for the wider economic benefits to be fully realized and distributed equitably. By contrast, such reforms are unlikely to be needed if the corridor is instead constructed in a setting characterized by well-functioning land markets. Similar considerations apply to the need for reforms in other key markets, including product, labor, and capital markets, as well as cross-cutting institutions such as public sector governance.

For concreteness, let us define *R*, *Y,* and *X* using the coverage that will be considered in the presented literature review:

$$R \stackrel{\text{def}}{=} \begin{bmatrix} \text{location} \\ \text{connections} \\ \text{transport mode} \\ \text{good fat} \\ \vdots \\ \text{market policies} \\ \text{institutions} \end{bmatrix};\ X \stackrel{\text{def}}{=} \begin{bmatrix} H-\text{land} \\ L-\text{labor} \\ K-\text{capital} \\ A-\text{product} \end{bmatrix};Y \stackrel{\text{def}}{=} \begin{bmatrix} \text{economic welfare} \\ \text{social inclusion} \\ \text{equity} \\ \text{environmental quality} \\ \text{economic resilience} \end{bmatrix} \tag{5}$$

The corridor intervention package, *R*, describes the location of the trunk transport infrastructure, the nodal areas it will connect and its geographic alignment, the mode of transport it would contain (here either roads, rails, waterways and their combinations), "good fat" meaning strategic redundancies to ensure alternative connections are available when some connection(s) is blocked or damaged, policy reforms for input and product markets (such as labor market policy reforms), and reforms of cross-cutting institutions (such as public governance or property rights). The existing conditions in input (land, labor, capital) and product markets are captured under vector X. Vector Y then summarizes the categories of wider economic benefits (WEBs) considered in this paper: Economic welfare, social inclusion, equity, environmental quality, and economic resilience.

By solving for equation (4), we are interested in knowing which particular characteristics of corridors (mode of transportation, length, location, nodal connections, and so on) and accompanying policies (land market reforms, improved access to finance, regulatory reforms in product markets, and so on) need to receive greater weight under different sets of initial conditions (unclear land titles, labor market frictions, financial markets imperfections, extent and state of any preexisting transport infrastructure and so on). Ideally, we would like to uncover the "true" optimized policy rule, equation (4). This is, of course, a highly ambitious task that cannot be met by a literature review and, indeed, the optimized policy rule is likely to be impossible to ever fully uncover. Less ambitiously, we therefore focus on understanding:

$$\frac{\partial Y}{\partial R} = \beta + \gamma \bar{X} \tag{6}$$

More precisely, we focus on how different corridor intervention packages affect the net wider economic benefits considering both direct effects (equation (2)) and indirect effects (equation (3)). For instance, we may want to consider how changing the types of nodes linked by a corridor or changing the mode of transportation on which the corridor focuses can affect development outcomes—both directly and indirectly, through policies improving access to markets, land use, and migration patterns. Equation (6) captures the overall impact of different aspects of a corridor package on the set of final development outcomes that a policy maker may (potentially) be concerned with (economic welfare, social inclusion, equality, environmental quality, economic resilience). By contrast, $\bar{X}$ captures how aspects of a corridor package might interact with different initial conditions in input and product markets to influence the set of final development outcomes. This can be seen more clearly by integrating equation (6) with respect to R to give:

$$Y = \beta R + \gamma(\bar{X}R) + K \tag{7}$$

where K is the constant of integration. This equation is close to the type of reduced form equation that is often used in the literature to estimate the economic impacts of a large-scale transport infrastructure project, except that typically R is restricted to just the transport intervention, abstracting from complementary policies, and potential interaction effects are typically ignored (that is, the restriction $\gamma = 0$ is imposed).

Underlying the impact of R on the set of final outcomes, Y, are several potential transmission mechanisms and associated intermediate outcomes. These can, in a reduced form manner, be summarized in a chain of expected results (results chain). A stylized version is shown in figure 1. In this results chain, β—describing the reduced form effect of R can be thought of as being a function of α and θ (that is, $\beta = \beta(\alpha, \theta)$), where α captures the strength of the relationship between the transport intervention and a given intermediate outcome, and θ the strength of the relationship between the intermediate outcome and the final outcome.

Given the complexity of the transmission and multiple economic outcomes (wider economic benefits and costs), the multiple impacts could be organized into a hierarchy (figure 2). In this hierarchy, a transport corridor has potential impacts across multiple outcome variables (*economic welfare, social inclusion, equity, environmental quality, resilience*). In some cases, these impacts may be positively correlated—that is, the corridor boosts both incomes and job creation—thereby leading to synergies, producing beneficial effects for both economic welfare and social inclusion. However, in other cases, the impacts may be negatively correlated—for instance, although economic welfare impacts are beneficial, environmental impacts are detrimental—thus leading to trade-offs between different outcomes. In addition to synergies and trade-offs between different outcomes, impacts may be heterogeneous. Hence, for a given outcome, the impacts across different geographic areas, segments of the population, economic sectors, and the like could vary significantly. These heterogeneous impacts may be beneficial for everyone but of varying size (that is, the effects are relative because of greater or smaller predisposition of different population groups and locales to benefit). Or alongside these winners, these effects may create losers in absolute terms. For instance, people may lose jobs, towns may lose population and decay, and certain communities with bleak prospects and poor endowments may get left behind.

3. Methodology

3.1. Selection of Papers

Papers were identified for inclusion in this literature review through a three-step process. In step one, a long list of papers for potential inclusion was identified by performing a series of Google Scholar searches based on different permutations of three categories of keywords:

(a) Transport-related keywords

(b) Keywords relating to outcome variables of interest, including wider economic impact(s) and intermediate outcome(s)
(c) Other keywords designed to capture the focus on empirical or econometric studies (see table 1).

These searches were confined to papers published from 2000 to mid-2017. A distinction was made between final outcomes (wider economic impacts) and intermediate outcomes, where, from a causal perspective, we think of the intermediate outcomes as mediating the relationship between a large-scale transport infrastructure investment and its final impacts, as shown in the results chain in figure 1.[13]

In step two, the papers identified in step one were subjected to two further screening criteria designed to narrow down the list. First, the paper must consider a "*large*" transport infrastructure investment, where "*large*" is defined as an investment that results in either:

(a) A significant improvement in connectivity between at least two major nodes of economic activity; or
(b) Extensive improvements in last-mile connectivity.

With respect to (a), the nodes of economic activity include either cities or ports. The condition that the investment improves connectivity between at least two major nodes was designed to reflect our underlying interest in transport corridors. Meanwhile, with respect to (b), extensive improvements in last-mile connectivity reflect, for example, widespread improvements in a rural road network that connects directly to a national network of highways and primary roads. This allows the search to capture papers that consider transport infrastructure investments that may be complementary to investment more directly in the style of corridors.

The second screening criterion applied was that a paper must meet an "academic standard": namely, that the paper must present the results from original applied research involving statistical or econometric methods. In applying this standard, we were indifferent as to whether a paper was published through a formal academic outlet—such as in a peer-reviewed academic journal, a recognized working paper series, or in an edited book volume—or on an author's personal website. This allows us to capture so-called "gray literature" (unpublished literature). In formal meta-regression analysis, the inclusion of such literature is considered important to detect and avoid publication bias (see, for example, Card, Kluve, and Weber 2009).

In step three, an attempt was made to capture any relevant papers that might have been missed from the list produced by steps one and two. This was done by analyzing the references in the papers from the list, consulting with World Bank experts in areas where we had found little coverage (such as on the subject of economic resilience), and by visiting the personal websites of authors of papers in the list in order to identify additional "works in progress".

[13] Figure 1 depicts a simple linear flow from transport infrastructure investment to final outcomes via intermediate outcomes. However, in some senses, some of the intermediate outcomes shown in the figure may also be considered final outcomes. This is particularly the case with respect to the intermediate outcome variables of population, productivity, and land value.

Following additional cleaning to weed out any obviously irrelevant or only marginally relevant literature, the application of the three steps resulted in a final sample of 78 papers. Figure 3 shows the break-down of papers by mode of publication. Of the 78 papers, 9 percent are unpublished (not published in a formal academic outlet). From these 78 papers, a total of 243 separate results were extracted.[14]

3.2 Tagging of Papers

Having arrived at the list of papers to be included in the review, a tagging system was applied to extract relevant information. An example of the application of this tagging system is provided in table 2. Information was collected from each paper for five basic categories of variables: publication details; intervention details; methodology; results; and additional. To ensure consistency in the collection of information across papers, the value for each variable was restricted to a number of multiple-choice options. Appendix A provides a detailed list of these options, as well as descriptions of the variables. The information collected was compiled into a database. Given that papers frequently report results for more than one outcome variable or sample, the number of rows in this database is equal to the number of results extracted from all papers.

To maximize data collection accuracy, the tagging system was implemented through a double-blind review system. Papers were reviewed and tagged independently by two trained research assistants (RAs) in batches of ten. Following the independent tagging of each batch of papers, a meeting would be convened to compare the results between the two RAs and to reconcile differences. The meetings would also involve occasional over-riding of the tags chosen by both RAs based on the reading of the papers by the authors of this paper.[15] As the papers were tagged, the system for tagging was also refined to reflect our evolving understanding of the literature.[16]

4. Descriptive Statistics

This section describes the overall literature included in the sample based on the data gathered from the application of the tagging system. It starts by briefly documenting the overall time-trend in terms of the number of sampled papers, taking this as representative of the overall trend in terms of the level of academic interest in evaluating the impacts of major transport infrastructure projects. It follows with a characterization of the "typical" (modal) paper in terms of the key details of the type of transport intervention that the paper focuses on, the methodology employed, and the outcome variables that the paper seeks to examine, among other considerations. It then proceeds to a descriptive analysis of the literature in terms of the results reported across both the different categories of final and intermediate outcomes identified in the results chain in figure 1.

The discussion first considers average impacts before moving on to a consideration of heterogeneous impacts, where heterogeneous impacts can occur along different dimensions (such as heterogeneous

[14] This is less than the total number of results reported in the 78 papers. Typically, any given paper will report results from numerous regressions. We only extract results from the most relevant regressions, which typically constitute the authors' self-identified preferred specification(s).

[15] Before the tagging system formally began, an initial dummy run was undertaken using a sample of ten papers. This dummy run was used both to help train the RAs in the system and identify any initial obvious areas for improvement in the system. The results from this dummy run were discarded and the papers subsequently reviewed again.

[16] Table 2 and appendix A present the final tagging system.

impacts across geographic areas versus heterogeneous impacts across different industries or subgroups of the population). Such heterogeneous impacts imply the existence of relative “winners" and “losers." However, in some cases, these relative losses may also reflect *absolute* losses. Thus, the discussion describes the evidence from the literature on the existence of absolute losses as part of the discussion of heterogeneous impacts. Finally, the section describes the extent to which the literature, in its estimation of impacts, considers the effects of complementary policies—defined as policies that are designed to amplify the net benefits associated with the construction of a transport corridor. This amplification may occur either through the enhancement of the beneficial impacts of a transport corridor on a given outcome or the mitigation of trade-offs between different outcomes.

4.1 Publication Time-Trend, Typical Paper, Intervention, and Methodology

4.1.1 Publication Time-Trend

Figure 4 shows the distribution of papers in the sample by year of publication. For unpublished manuscripts, the year of publication corresponds to the date on the manuscript. The trend in terms of number of papers published per year has been strongly upward. While only one paper in the sample was published in 2000, 19 papers were published in 2016.[17] More generally, 71 percent of papers in the sample were published between 2011 and 2016. This strong upward trend reflects the growing academic focus on rigorously evaluating the impacts of major transport infrastructure projects.

4.1.2 Geographical Focus of the Typical Paper

For the purposes of this study, the typical paper is the modal paper. Table A.1 in Appendix A presents a tabulation of the distribution of papers by country—or, in the case where a paper relates to several countries, the region—of study. Of the 78 papers in the sample, 33 papers—or 42 percent of the total—focus on transport infrastructure projects in just three countries: the United States (13 papers), India (11 papers), and China (9 papers). This overwhelming focus on only three countries reflects the extremely large-scale transport infrastructure projects that these countries have undertaken either in recent decades or historically. Over the last two decades, both China and India have constructed major new highway networks—the National Expressway Network (NEN) in the case of China (constructed between 1992 and 2015) and the Golden Quadrilateral (GQ) network in the case of India (constructed between 2001 and 2012). Examples of papers that focus on the evaluation of China’s NEN include Roberts et al. (2012), Faber (2012), and Bosker, Deichmann, and Roberts (2015), while Alder (2015), Ghani, Goswami, and Kerr (2016, 2017) and Khanna (2016) provide examples of papers that focus on India’s GQ.[18] Historically, extensive national railway networks were constructed in both the United States and India in the nineteenth and early twentieth centuries. The evaluation of these networks has been the subject of several papers (Haines and Margo 2006; Donaldson 2010; Atack and Margo 2011; Herrendorf, Schmitz, and Teixeira 2012; Donaldson and Hornbeck 2016). Crucially, these evaluations have been facilitated by the existence of high-quality historical data on both the networks themselves and relevant outcome variables. In the second half of the twentieth century, the United States also constructed its Interstate

[17] We prefer to compare 2016 rather than 2017 with 2000 because we lack a complete year of publications for 2017.
[18] China has also been engaged in the construction of an extensive high-speed railway network that has attracted some attention in the literature (see, for example, Wang 2013).

Highway System, which has been the focus of many papers (for example, Chandra and Thompson 2000; Baum-Snow 2007; Michaels 2008).

Beyond the United States, India, and China, significant numbers of papers focus on either African (18 papers) or Latin American (13 papers) countries. Several of them focus on environmental outcomes, especially on the impacts of roads on deforestation (see, among others, Pfaff et al. 2007; Weinhold and Reis 2008; Damania and Wheeler 2015; Dasgupta and Wheeler 2016). Unlike papers for other regions, several of the papers examining transport investments in Africa focus explicitly on transport networks that cut across national boundaries and therefore cover more than one country (see, for example, Buys, Deichmann, and Wheeler 2006; Jedwab and Storeygard 2016).

4.1.3 Intervention Details

The typical paper focuses on road transport infrastructure. More than three-quarters (78 percent) of 234 reported results evaluate the impacts of some sort of road transport infrastructure, as seen in panel *a* of figure 5. The only other transport mode that receives significant attention in the literature is rail (17 percent of results). The overwhelming focus on road networks reflects, in part, the focus on evaluating the impacts of the NEN in China and the GQ in India, as well as the impacts of the Interstate Highway System in the United States. As mentioned, all these systems were newly constructed networks. Hence, unsurprisingly, panel b reports that 64 percent of results in the sample focus on the evaluation of new network systems. By contrast, a little over one-fifth of results (21 percent) examine the upgrading of a preexisting transport system, while 8 percent of results evaluate the impacts of the upgrading of an individual link within a wider transportation network.

In terms of the type of connection considered, the typical paper focuses on projects that are designed to link urban centers (45 percent), although a significant proportion of the literature (22 percent) looks at the impacts of urban-rural connections. Typically, the focus is on evaluating connections between places that fall within national boundaries, except for several papers on Africa, including Buys, Deichmann, and Wheeler (2006) and Jedwab and Storeygard (2016). However, several studies (8 percent) focus on evaluating the impacts of connection between one or more urban centers and an international gateway (a port or an airport). Examples include Cosar and Demir (2016) and Martincus and Blyde (2013). The preoccupation of the literature with urban-urban connections that fall wholly within national borders is, again, related to the dominance of China, India and the United States as countries of study, as well as the nature of the transport networks that they have constructed.[19]

4.1.4 Methodology

Papers most frequently focus on “economic welfare" as the category of final outcomes (figure 6, panel a) and “population and assets" and "trade and productivity" as intermediate outcomes (figure 6, panel b).

The typical paper uses subnational geographical regions—such as Indian tehsils (Khanna 2016; Alder, Roberts, and Tewari 2017), Chinese counties (Banerjee, Duflo, and Qian 2012), and electoral wards in

[19] Hence, China’s NEN, India’s GQ and the United States’ Interstate Highway System were all explicitly built to link major urban centers.

the United Kingdom (Gibbons et al. 2016)—as the unit of analysis (figure 7, panel a).[20] 80 percent of sampled papers rely on data for such regions, whereas 15 percent of studies utilize micro-data for individual households. By contrast, a mere 2 percent of papers use micro-data for firms (examples include Blyde and Martincus 2013; Gertler et al. 2014; Martincus, Carballo, and Cusolito 2016). Most papers focus on ex post evaluation (panel b).

The typical paper is also explicitly motivated by some underlying theoretical model—quite often an economic geography model of trade (figure 8, panel a)—and relies on reduced-form estimation (figure 8, panel b).[21] Hence, 70 percent of results employ reduced form estimation, while 21 percent evaluate the impacts of transport infrastructure using a structural model. Reduced-form estimation tends to rely on a difference-in-difference (DID) estimator in which the impacts of, for instance, treated subnational regions are evaluated against those of a set of comparison regions before and after the occurrence of the transport infrastructure investment. Such estimation focuses on the identification of impacts in the immediate geographic vicinity of the investment without explicitly seeking to identify the mechanisms through which such impacts occur (see, for example, Ghani, Goswami, and Kerr 2016, 2017). Meanwhile, papers that use a structural model, such as Alder (2015) and Asturias, Garca-Santana, and Magdaleno (2017), focus on a specific mechanism, which is normally related to internal trade. Finally, 9 percent of sample results use a computable general equilibrium (CGE) model. These results are invariably from papers that undertake ex ante impact evaluation analysis (such as Arman and Izady 2015). Structural and CGE-based approaches to evaluation possess the advantage over reduced-form regressions that, in principle, they can separate out the creation of new activity from the redistribution of existing activity. However, the downside of these approaches is that they make the strong assumption that the true underlying structure of the economy is known.[22]

Finally, the typical paper pays strong attention to trying to address the issue of biased estimation of impacts arising from the endogenous placement of transport infrastructure. Indeed, it is fair to say that addressing this issue has become the overwhelming empirical concern in the literature (Berg et al. 2015; Redding and Turner 2014). Endogenous placement concerns arise from the fact that the locations that policy makers chose to link with transport infrastructure are not random. In principle, this can lead ordinary least squares (OLS) estimation to either over- or under-estimate the impacts of the infrastructure. For example, if the outcome variable is a measure of local economic activity, over-estimation could be more likely if policy makers deliberately target the linking of locations that they, in any case, expect to grow quickly. By contrast, under-estimation could be more likely if policy makers deliberately prioritize connections to lagging regions with low underlying economic potential. More than 70 percent of sample results adopt an explicit identification strategy to address endogeneity concerns (figure 9, panel a). Such

[20] A very recent innovation in the literature has been to use subnational "grid cells" of uniform area as units of analysis (Ali et al. 2015; Jedwab and Storeygard 2016).

[21] Economic geography models of trade include both "new economic geography" models (Krugman 1991a, 1991b; Fujita et al. 1999) and Ricardian models of internal trade of the Eaton-Kortum (2002) variety. Examples of papers that are motivated by a neg model include Roberts et al. (2012) and Bosker, Deichmann, and Roberts (2015), while Donaldson (2010), Donaldson and Hornbeck (2016), Alder (2015), and Alder et al. (2017) provide examples of papers motivated by an Eaton-Kortum style Ricardian trade model.

[22] Baum-Snow et al. (2016) provide a comparison of results for the impacts of the construction of China's NEN obtained using reduced-form estimation and a structural—specifically, Eaton-Kortum—model. In doing so, they demonstrate that "technique matters"—that the results obtained depend fundamentally on the approach adopted. They also provide evidence to show that the Eaton-Kortum model misses some quantitatively important features that are evident in the data.

identification strategies most frequently involve a strategy based on instrumental variables (IV),[23] although additional strategies—particularly, following Donaldson (2010), the use of a placebo strategy—have also emerged in recent years (figure 9, panel b). A recent trend in the "strongest" papers has been to employ multiple strategies—for example, both IV and placebo strategies—to convince the reader that estimated impacts are accurately identified (see Ghani, Goswami, and Kerr 2016). The papers that focus on the economic welfare category of final outcomes are most advanced in terms of their attention to endogeneity concerns. By contrast, papers that focus on other outcomes, such as environmental outcomes, tend to pay relatively little attention to employing identification strategies designed to address endogenous placement concerns.

4.2 Descriptive Analysis of Results

4.2.1 Estimated Average Impacts

The 78 papers in the sample cover 234 separate results. Our analysis of these results reveals that the literature provides evidence of statistically significant WEB impacts (at the 5 percent level or greater) on economic welfare, social inclusion, equity, and environmental quality (figure 10, panel a). For a given type of outcome, the amount of confidence that can be attached to this evidence depends on both the number of results reported and the proportion of those results that are significant. In this sense, the evidence of significant impacts on economic welfare outcomes is fairly strong. Almost 100 results relate to this type of outcome, and more than 80 of these results are statistically significant. For social inclusion, equity, and environmental quality outcomes, the proportion of reported impacts that are statistically significant are even greater than for welfare outcomes. However, in each case, the number of results is far fewer (22 for social inclusion, 16 for equity, and 18 for environmental quality outcomes, respectively). The sample contains no results for the WEB of resilience, which highlights a prominent blind-spot in the literature. As for intermediate outcomes, considerable evidence exists that transport infrastructure has significant impacts on both population and assets (such as land values), as well as on levels of trade and productivity (figure 10, panel b). For population and assets, 29 out of 37 reported impacts are statistically significant, while for trade and productivity, 33 out of 37 are significant.

The estimated average impacts on the various types of WEBs are mainly found to be beneficial.[24] Hence, most reported impacts on levels of real income, poverty, consumption and jobs are beneficial. However, there are some notable exceptions. Thus, *all* reported results for environmental quality outcomes are detrimental. Likewise, the analysis reveals evidence of transport infrastructure projects having significant detrimental effects on both levels of interpersonal income inequality and, in roughly one-quarter of cases, levels of spatial inequality between subnational regions (figure 11). This implies that major transport infrastructure projects can entail trade-offs between different types of outcomes. While average impacts on economic well-being tend to be positive, this can come at the potential cost of worse outcomes for both environmental quality and social inclusion. The existence of such trade-offs suggests an important potential role for complementary policies.

[23] Redding and Turner (2014) identify three main different types of IV-strategy that are employed in the literature: the "planned route IV," the "historical route IV," and the "inconsequential units approach."
[24] We use the words "beneficial" and "detrimental" here to refer to impacts that we generally expect to enhance or diminish social welfare. Hence, increases in levels of, for example, real income and jobs are considered to be beneficial, while increases in rates of poverty and inequality are considered to be detrimental.

Similarly, in terms of intermediate outcomes, while average impacts are mainly found to beneficial, detrimental results are sometimes reported for some variables. More specifically, the evidence suggests that investment in transport infrastructure tends to reduce prices and boost levels of investment, trade, and productivity, while also promoting industrial diversification and improvements in allocative efficiency. However, in some cases, detrimental impacts on levels of trade, population, and land values are reported (figure 12). Some care is required in interpreting what constitutes a detrimental impact in terms of population and land values from both a welfare and productivity perspective. Hence, for example, Baum-Snow (2007) provides evidence to show that the construction of new limited access highways in the United States between 1950 and 1990 contributed to suburbanization by inducing population deconcentration away from central city areas. However, while we tag this as a "detrimental" impact in terms of the population of a central city, it is not clear that it is detrimental from an overall social welfare perspective.

4.2.2 Evidence of Heterogeneous Impacts

As can be seen from figure 13, there has been a growing trend in the literature to move beyond estimating average impacts of transport infrastructure on the various WEBs and intermediate outcomes to analyzing how these impacts vary across the different units of analysis considered in a study. Given that the majority of papers use subnational regions as their unit of analysis, it will come as no surprise that the dimension along which heterogeneity is most commonly analyzed is geographic (figure 14). The analysis of how impacts vary over time also receives some attention,[25] but the literature provides very little evidence (in terms of number of reported results) on whether, and how, impacts may vary across, for example, different types of firms and differently endowed individuals.

Evidence of heterogeneous impacts implies that, for example, some geographic areas or groups of households or firms gain more relative than others from transport infrastructure improvements. In some cases, however, the losses experienced may not only be relative, but also absolute. Indeed, among the subsample of results that look for evidence of heterogeneous impacts, there is a fair amount of evidence of the existence of absolute losses, even for outcomes where overall average impacts tend to be overwhelmingly positive. A good example of this is provided by the results reported in Roberts et al. (2012). Although this paper reports that the construction of the NEN increased real income across Chinese prefectures by, on average, just less than 4 percent, in quite a number of prefectures, it had a negative impact on real wages in either the urban or rural sector. Hence, in terms of WEBs, evidence of absolute losers alongside absolute winners is reported for both economic welfare and social inclusion outcomes. Relatedly, evidence of absolute losers alongside winners exists for both the intermediate outcomes of population and trade (figure 15).[26] The conclusion to be drawn is that major transport infrastructure

[25] A particularly interesting paper in this regard is Pereira, Hausman, and Pereira (2014). It analyzes the overall impact of railroad investment on economic growth in the Antebellum United States. In doing so, it adopts a bivariate dynamic time series methodological approach, based on the use of a vector autoregressive (VAR) model, which is very different from the more cross-sectional approaches adopted by the majority of the rest of the literature. The use of this approach allows the authors to distinguish short-run demand-side effects associated with railroad construction on economic growth from longer-run supply-side effects.

[26] Again, some care in interpretation is required here. Although a subnational region may experience a decline in population as a result of a transport project that connects it better to other regions, it is not necessarily clear that this makes the region a "loser" from a welfare and productivity perspective. A loss in population may actually stimulate an overall increase in productivity and real wages for the region if, for example, it helps to ease congestion within the region.

projects can entail policy trade-offs not only between different types of WEBs (for example, economic welfare versus environmental quality and social inclusion), but also between different geographic areas and subgroups for a given outcome.

4.2.3 Complementary Policies

Evidence of trade-offs between both different types of WEBs and different subgroups for a given WEB suggests a potentially important role for complementary policies designed to mitigate these trade-offs. Unfortunately, however, out of the 234 results analyzed, only 17 percent seek to investigate how complementary policies may influence a transport infrastructure project's impact on a given outcome (figure 16). This lack of analysis of the role of complementary policies may, in part, reflect the literature's preoccupation with isolating the effects of a transport infrastructure projects from other, potentially "confounding" influences for the purposes of clean identification. When papers do explicitly analyze the role of potentially complementary policies, they tend to focus on labor market policies and adopt a more structural modeling approach. A good example of this is the paper by Bosker, Deichmann, and Roberts (2015), which analyzes both the national and spatial impacts of the NEN in China on levels of real income, while simultaneously considering how these impacts have been influenced by restrictions on migration associated with the country's permanent household registration (Hukou) system. Papers that focus on environmental quality outcomes, especially deforestation, also provide an important exception, as these frequently also consider the role of protected area status in mitigating the impacts of roads on deforestation (Cropper et al. 2001; Damania and Wheeler 2015; Dasgupta and Wheeler 2016).

5. Meta-Regression Analysis

This section presents the results of the formal meta-regression analysis (MRA) of the literature. A MRA is a quantitative tool that helps synthesize findings from diverse empirical studies of a particular phenomenon. It has become a commonly used methodology in the social sciences. By combining the results from multiple papers into a single statistical analysis, it allows primary effects to be distinguished from background variation and contaminating influences (Stanley and Doucouliagos, 2010).

The MRA that we undertake is intended to shed light on several questions. First, can the variations in the estimated impacts of large-scale transport infrastructure projects that are found in the literature be "explained" by variations in the characteristics of the projects themselves and by observed methodological variations across papers? Second, are there policy-relevant insights that emerge from the literature? For example, is there evidence that certain features of projects (such as the mode of transportation or the type of locations they connect) are, on average, associated with better (more beneficial) outcomes?

The major problem that we face in implementing our MRA is that the impacts that we are interested in studying relate to a diverse set of outcomes and are derived using an equally diverse set of treatment variables for different countries based on a nonuniform set of modeling approaches. As such, estimated coefficients on the treatment variable are not comparable across different papers. In some cases, they are not even comparable across different regression results reported within a paper. To overcome this issue and possible problems with heteroscedasticity, we divide (weight) the regression by the estimated standard deviation of the treatment coefficients following Stanley and Jarrell (1989); Stanley and Doucouliagos, 2010; Chen et al. (2012); and Havránek, Iršová, Janda and Zilberman (2015), among others. Specifically, we use the reported *t*-statistic for the coefficient on the treatment variable as our measure of impact rather than the actual treatment coefficient itself. This, in effect, allows us to standardize results across different papers and model specifications. Importantly, a higher reported *t*-statistic can result from either a higher estimated treatment effect of the transport infrastructure or a more precisely estimated—that is, a more certain—treatment effect. We implement our MRA using the sample of results for final outcomes (wider economic impacts) only, leaving MRA of results for intermediate outcomes for future work. In doing so, we also necessarily drop estimates of treatment effects based on CGE models from our sample because these estimates lack accompanying *t*-statistics.

5.1. The Estimated Multivariate Model

We use the ordinary least squares (OLS) model as our baseline regression model and estimate the following specification in which we relate the reported treatment effect to the category of outcome analyzed (economic welfare, equity, social inclusion, and environmental quality), a set of "policy" variables and a set of control variables:

$$Y_{i,j} = \pi + \alpha O_{i,j} + \beta X_{i,j} + \delta Z_{i,j} + \epsilon_{i,j} \tag{8}$$

where Y is the reported *t*-statistic on the treatment variable, O is the category of outcome analyzed, X is the set of policy variables, Z is the set of control variables, and ϵ is the error term. The subscripts i and j stands for papers and estimates. π is the constant term.

The "policy variables" X include variables that can provide useful insights into policy. Most obviously, these include details of the infrastructure intervention itself (type of construction, the transport mode, connection type). They also include dummy variables for whether or not the regression underlying a given result allows for potential heterogeneous effects, whether or not a paper presents evidence of losers as well winners, the markets that a paper highlights as important for the transmission of impacts, and whether or not the paper examines a role for complementary policies. Less obviously, we also include dummies relating to modeling methodology (such as the reduced form and structural models) and identification strategy (most notably, the use of IV estimation) in the set of "policy variables." This is because the comparison of results across different types of modeling methodology can potentially provide insights into whether impacts tend to be confined to the immediate geographic vicinity of a transport infrastructure project or whether they extend beyond this. If, for example, there are wider geographical impacts, then we might expect to obtain more evidence of significant effects when applying a structural model than when applying a reduced-form model. Similarly, the comparison of results from papers that use an IV approach with those that do not can provide indirect insights into the placement decisions that policy makers make when selecting the locations to link with a transport corridor. Meanwhile, the set of control variables includes: dummies for the economic sector of the final outcome (aggregate, manufacturing, urban, rural); dummies for the income classification of the study country (low-income country, lower-middle-income country, upper- middle-income country, high-income country); dummies for World Bank regions;[27] a dummy for whether or not a paper contains an explicit theoretical motivation; and dummies for the unit of analysis (subnational regions, households, firms, countries).

[27] For details of World Bank regions see http://www.worldbank.org/en/where-we-work.

Publication bias has long been a major concern for meta-analysts. Compared to studies that find small and insignificant effects, studies that find statistically significant results are more likely to be published because they are well received by researchers, reviewers, and editors. To control (and test for) publication bias, we use two approaches: First, we include as a control a dummy for whether the paper has been published in a peer-reviewed academic journal.[28] Second, we employ the commonly used Egger test.[29] This test regresses the standard normal deviate of a study effect estimate against its standard error. The null hypothesis is that there are no small-study effects. The estimated bias coefficient is 1.502, with a standard error of 0.612, giving a p-value of 0.015. The test thus provides evidence for the presence of small-study effects: that is, there is a higher level of effect size in studies with smaller sample sizes.

Before turning to our estimations results, it is important to mention that there is a large amount of variance in the estimated impacts of large-scale transport infrastructure projects. Figure 17 presents the kernel densities of the estimated coefficients and the *t*-statistics. The vertical line shows that the distributions are skewed to the right, which is consistent with the fact that the mean paper finds a positive (beneficial) and significant impact.

5.2. Estimation Results

Table 3 presents the results from the estimation of equation (8). In particular, it reports the results from four different variants of this equation. Model 1 includes only dummy variables relating to the category of the outcome (wider economic impacts) variable. Model 2 adds the set of "policy variables," X. Model 3 further includes the set of control variables, Z. Model 4 is a parsimonious model derived by applying backwards stepwise selection to Model 3 to identify the most statistically significant variables.[30] For all four specifications, the dependent variable is transformed so that a positive value always indicates a beneficial outcome and a negative value a detrimental outcome. Standard errors are clustered by paper, thereby allowing for correlation in the error terms for observations extracted from the same paper. The discussion that follows focuses on the results from Models 1 and 4, where Model 4 is the preferred specification.

In Model 1, the estimated (unconditional) mean for the *t*-statistics related to the impacts of large transport infrastructure on economic welfare is 3.547, which is significant at the 1 percent level. Hence, on average, the literature finds that such infrastructure has a significant beneficial effect on economic welfare. The mean *t*-statistic for the transport impact on equity is not significantly different from the estimated mean impact for economic welfare. Therefore, on average, the literature also finds that transport infrastructure has a significant beneficial effect on equity. By contrast, the *t*-statistics for the impacts on social inclusion and environmental quality are found, on average, to be significantly smaller than the average impact on welfare. For social inclusion, the impacts are smaller and/or less certain, but still, on average, beneficial; the net estimated coefficient on social inclusion is 1.711 (= 3.547 − 1.836). The less certain impacts on social inclusion could also be indicative of possible trade-offs between boosting

[28] Appendix B provides a more detailed description of the policy and control variables that are included in the MRA.

[29] The presence of publication bias is usually tested both graphically and formally. The graphical test uses the so-called funnel plot (Egger et al. 1997; Stanley and Doucouliagos 2010), a scatter plot of the estimates (on the horizontal axis) against their precision (the inverse of the standard error; on the vertical axis). See Figure B.3 (Galbraith plot).

[30] In applying backwards stepwise regression, we always force the model to include the three outcome dummy variables: Social Inclusion, Equity, and Environmental Quality.

economic welfare and inclusion through large transport infrastructure. In the case of environmental quality, the net coefficient is −15.023 (= 3.547 − 18.57). Hence, on average, the effect of transport infrastructure on the environment is found to be detrimental. These findings are consistent with those reported in the descriptive analysis of the literature in section 4.3.

For Model 4, several "policy variables" are important. First, the transport mode matters. Compared with roads and waterways, the reported impacts of investments in rail are significantly smaller and/or less certain.

Second, the type of connection also matters. Compared with other types of connection, the literature reports (conditional on the other variables in the model) *t*-statistics that are, on average, significantly smaller for investments that focus on connecting urban centers to international gateways such as ports, land border crossing points, and airports. This result could be, in part, because the ability of such connections to generate beneficial outcomes depends on other factors such as the efficiency of port operations, tariff and nontariff trade barriers, and the functioning of markets, including those to which the gateways connect.

Third, consideration of heterogeneous impacts matters. We find that, relative to studies that do not consider heterogeneous impacts of transport infrastructure, studies that report evidence of heterogeneous effects along several different dimensions (such as across subnational geographic regions or across different sectors) also tend to report significantly smaller *t*-statistics. This finding suggests that a failure to consider heterogeneous impacts is not only a gap in itself, but leads to an over-estimation of either the wider economic impacts of transport infrastructure and/or the level of certainty surrounding these impacts. Furthermore, studies that report evidence of absolute losers (the existence of units of analysis or sectors that incur absolute losses on the outcome variable—that is, detrimental impacts) alongside winners,[31] also report larger *t*-statistics. However, this result is not very robust. In particular, although the estimated coefficient on the winners/losers dummy is positive in Model 4, it is only significant at the 10 percent level and its sign changes between the different models (compare the results for Model 4 with those for Model 2).[32]

Fourth, our results indicate that endogenous placement is a real and important issue. On the whole, the literature seems to target enhanced connectivity between locations that we would, in any case, expect to show more beneficial outcomes. This follows from the finding that, under the identification strategy block of results in table A.1, the estimated coefficient on "none"—which corresponds to the use of OLS estimation by a study—is positive and highly significant. In particular, relative to the case of IV and/or difference-in-difference methods, estimations using OLS yield a *t*-statistic on the treatment variable that is, on average, 3.81 higher.[33]

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[31] For example, Michaels (2008) used the advent of the US Interstate Highway System as an experiment to identify the labor market effects of reduced trade barriers. His results show that by increasing trade, the highways significantly increased the relative demand for nonproduction workers in counties that had a highly skilled labor force and reduced it elsewhere.

[32] The reason could be apparent collinearity with the geographic heterogeneity factor. This collinearity could suggest that losers emerge because of economic impacts on units that are geographically distant from the transport infrastructure that are not only smaller, but, on average, reported to be negative. However, when losers emerge because of other heterogeneity factors, their losses are reported to be much smaller. For instance, lack of skills for a person close to a transport corridor is not as detrimental as if that person is located in a community far away from the new or upgraded transport infrastructure. We will investigate this hypothesis closer in future work.

[33] This could also be attributable to a relatively greater precision of OLS estimates, especially if valid (exogenous) instruments are less relevant (weak).

Although the "policy variables" are of main interest, it is also worth commenting on the results for the control variables in Model 4. Most notably, relative to other regions, reported *t*-statistics are significantly larger for African countries, whereas they are significantly smaller for Western European countries. This suggests that the effects of transport infrastructure investment are larger and/or more certain in Africa than they are in Western Europe. Reported *t*-statistics are, on average, also smaller (larger) when households (firms) are the unit of analysis.[34] Finally, we find no evidence of a bias towards the publication of more favorable results. This follows from the negative and significant estimated coefficient on "Journal article." This means, after controlling for other variables, the reported *t*-statistics in journal paper articles tend to be smaller than those in working papers, book chapters, and unpublished manuscripts. One explanation could be that papers published in peer-reviewed journals tend to exhibit higher levels of rigor when it comes to addressing issues of endogeneity.

Further investigation of the winners and losers led us to look at its correlation with the geographical dimension of the heterogeneity factor.[35] Regarding the correlation with the geographic dimension of the heterogeneity factor, our estimations failed to show any significant and conclusive results when excluding the geographical dimension.

5.3. Robustness Check: Ordered-Probit and Random-Effects Models

This section reports robustness checks along two different estimation methods: the ordered-probit model, and the random-effects model.

Ordered-probit model: To estimate the ordered-probit model, we created a variable that takes a value of 0 for observations (results) that find a statistically significant beneficial impact at the 5 percent level, 1 for those that find an insignificant impact (despite positive or negative estimates), and 2 for those that find a significant detrimental impact. To allow for the comparison of the results, we flip signs of the coefficients and report only results for the model with final outcomes and policy variables.

Random-effects model: Following Jeppensen, List, and Folmer (2002), we estimate a random effects panel model. There are four main reasons to possibly favor the random effects model over the fixed effects model. First, the fixed effects model assumes that all papers have been conducted under similar conditions and the only difference between them is their power to detect a beneficial or detrimental impact. This is less likely to be the case with our data since the Higgins statistic (I^2=98%) provides evidence of clear heterogeneity. Second, the random-effects meta-regression can be considered as an extension to fixed-effects meta-regression that allows for residual heterogeneity. Third, the random effects model will reflect the fact that all studies included in the analysis are assumed to be a random sample of all possible studies that meet the inclusion criteria for our literature review. Fourth, the random effects model assumes that the estimated coefficient is randomly, normally distributed across studies.[36] Specifically, this model is expressed as follows:

[34] This result could arise because studies that use micro-data are better able to control for sorting effects.

[35] We also explored this with a different estimation method (the ordered-probit estimation model). The results are presented in the robustness check section.

[36] Recall that the fixed-effect model assumes that the true effect size for all studies is identical, and the only reason the effect size varies across studies is the sampling error (error in estimating the effect size). However, the random-effects model goal is not to estimate one true effect size, but to estimate the mean of a distribution of effects of possibly varying sizes. Since each study provides information about a specific effect size, we want to be sure that all these effect sizes are represented in the summary estimate.

$$\widehat{\beta_{i,j}} = u_i + \alpha X_{i,j} + \gamma C_{i,j} + \epsilon_{i,j} \tag{9}$$

where $\widehat{\beta_{i,j}}$ is the j estimated coefficient reported in paper i; $X_{i,j}$ is the matrix of our meta-policy variables; and $C_{i,j}$ is the matrix of our meta-control variables. The policy and control variables are included to explain the variation of transport elasticities. They measure relevant characteristics of an empirical study and explain its systematic variation from other results in the literature. α and γ are vectors of coefficients. Since we have adopted a multiple-estimate-per-study approach, u_i is the random paper effects. This is a slightly different approach to the Jeppensen, List, and Folmer (2002) framework, where u_i corresponds to the random author effect.

Equation (9) is rarely estimated because of heteroskedasticity (Stanley and Doucouliagos, 2010). To obtain efficient estimates we estimate its weighted least squares (WLS) version, which divides equation (9) by the standard deviation. The corresponding meta-regression model is expressed as follows:

$$\widehat{t_{i,j}} = u_i \frac{1}{se_j} + \alpha X_{i,j} \frac{1}{se_j} + \gamma C_{i,j} \frac{1}{se_j} + \epsilon_{i,j} \tag{10}$$

where $t_{i,j}$ is the standardized impact estimate, and se_j the standard error of estimate j. The robustness of our random-effect results will be tested by reporting the OLS results. The main difference between the two models is that the OLS regression gives the same weight to the between- and within-paper variation. To deal with the correlation between coefficients in the same paper, we clustered standard errors at the paper level for the OLS estimation.

Evidence of publication bias, and how we deal with extreme coefficient values and potential sampling error, are presented in appendix B. The full results from the estimated ordered-probit and random effects models are presented in appendix table B.1. Estimates for all models (1 to 4) are qualitatively comparable. To save space we only report results of Model 2 (outcome plus policy variables) using all three estimation methods. Several results emerge from this robustness analysis.

First, most of our results are consistent with the OLS regression of the *t*-statistics (that is, with the results reported in table 3). The only exception concerns the heterogeneity factor, where the signs and significance levels change for the four heterogeneity dimensions (land, labor, temporal, and inclusion).

Second, columns 2 and 3 of table B.1 show that the probability of finding a beneficial and detrimental impact on "environmental quality" in circumstances when the average impact on welfare is significantly positive. This probability decreases by −2.9 percentage points for finding a beneficial impact and increases by 1.5 percentage points for finding a detrimental impact on "environmental quality"—confirming a prevailing significant trade-off in boosting economic welfare and protecting the environment. Similarly, the results indicate estimated trade-offs between "welfare" and "equity" as well as "welfare" and "social inclusion"—that is, a decreased probability of finding a significantly beneficial impact on "equity" and "inclusion" in circumstances of increasing welfare, on average. However, both the marginal effects are statistically insignificant at common levels.

Third, columns 2 and 3 of table B.1 further show that the probability of finding a significantly beneficial (detrimental) impact of a "new construction link" relative to a "new construction system" (the omitted category) significantly increases (decreases) by 1.4 (0.7) percentage points. Similar results apply to the "other" (residual) category of connection type. Furthermore, switching from a road infrastructure to a waterway transportation mode is associated with a significant 1.7 percentage point reduction in the probability of finding a beneficial impact, and a significant 0.09 percentage point increase in finding a detrimental impact.

Fourth, the change in the probability of finding a beneficial (detrimental) impact in studies that report absolute losers alongside winners significantly decreases (increases) by 34.7 (18.3) percentage points.

6. Conclusion

This paper conducted a quantitative-based review and formal meta-regression analysis of studies estimating the wider economic impacts of large-scale transport infrastructure projects. The primary objective was to help policy makers better solve the problem of optimally designing the intervention package for a transport corridor. While anchored in the trunk transport infrastructure, such an intervention package also includes a set of complementary policies and institutional reforms that help amplify the net wider economic benefits of the trunk infrastructure by boosting average impacts and mitigating trade-offs. With this objective, the paper yields several important insights.

First, policy makers must account for potential trade-offs in different development outcomes and across different (sub) sets of economic actors when designing a transport corridor package. This follows from two key findings of the literature review:

- While for the wider economic outcomes of economic welfare and equity, average estimated impacts tend to be beneficial, for environmental quality and possibly social inclusion, they are often detrimental.
- Even for economic welfare and equity, while the average impacts may be beneficial, considerable heterogeneity in these impacts can exist. In some cases, this heterogeneity may involve subnational locations or segments of the population that lose in absolute terms.

The existence and nature of these trade-offs should drive the choice of complementary interventions that accompany the construction of the trunk transport infrastructure itself—such as compensation policies for the identified losers from trunk infrastructure investments.

Second, the set of complementary policies and institutions that form part of the optimal transport corridor package could depend on the nature of the transport infrastructure intervention that forms the backbone of that package. This follows, for example, from our meta-regression finding that estimated impacts depend on the type of locations that are being connected. In particular, transport projects that target enhancing connectivity between urban centers and international gateways (such as ports, land border crossing points, and airports) yield significantly smaller or less certain impacts than projects that target purely internal enhancements of connectivity (such as enhancements between two domestic cities). This is consistent with the hypothesis that realizing the full benefits of better connectivity to international gateways requires tackling impediments imposed by other factors, such as inefficient port operations or the existence of prohibitively high tariff and nontariff barriers to trade. Although not necessarily considered by the surveyed empirical literature, our canonical model of the policy maker's problem suggests that the set of complementary policies and institutions that enter into the optimal corridor package will depend on two aspects: preintervention conditions (imperfections) in product, capital, labor, and land markets; and the initial endowments of different locations and economic agents that are affected by the transport intervention.

Third, the placement and design of the transport infrastructure itself matters for the net wider economic benefits a transport corridor package can achieve. Not only does this follow from the finding that the size and certainty of estimated impacts depend on the type of locations being connected, but our meta-regressions also reveal that the mode of transportation matters. Within our sample, the estimated wider economic benefits of rail projects are smaller/less certain than those of road projects. However, care is required in interpreting this finding, given that the literature mainly studies historical rail projects—such as the colonial railway network in India or the Antebellum railway network in the United States. It is possible that the impacts of modern freight and passenger railway networks, including modern high-speed railway networks that have not been extensively studied, differ considerably from those of the historical networks.

In addition to these three main policy insights, our review of the literature highlights many important areas where further research is needed to better inform the optimal design of transport corridor packages. The five most pressing areas are as follows.

First, much more research is required to clarify the nature and extent of trade-offs. In particular, the impacts of large transport projects on measures of economic welfare has been studied extensively. However, the evidence of impacts on other types of outcome is more limited and less rigorous. A prime example is the impact on economic resilience—defined as the resilience of economic agents to various types of shock, rather than the resilience of the transport infrastructure itself. For this impact, we were unable to find a single paper that met the criteria for inclusion in our sample. Although environmental impacts are better studied, the literature is not as advanced in its consideration of endogeneity problems as the literature focusing on economic welfare. Research to study the impact of a single transport project on the outcomes of economic welfare, social inclusion, equity, and environmental quality simultaneously would be particularly useful. This would provide more direct insight into the nature of the trade-offs between these outcomes, rather than the more indirect inference that we make by looking across papers. Likewise, more research is required to explore trade-offs across different segments of the population for each development outcome. Although the analysis of heterogeneous impacts and winners/losers has become more common in the literature in recent years, it is still relatively rare for papers to consider heterogeneity along any dimension other than geography.

Second, the importance of trade-offs points to the importance of complementary policies. The literature has done little to analyze the role of other policies in shaping the impacts of transport infrastructure. Hence, we find virtually no evidence on the appropriate design of complementary policies in different circumstances. An important technical reason for this neglect of complementary policies may be that the literature has been striving to cleanly identify the impacts of the transport infrastructure itself. This, of course, requires isolating infrastructure impacts from the impacts of other factors, including other policy changes and reforms. While this is desirable from the perspective of academic rigor, the cost of this rigor may be policy relevance.

Third, in principle, a promising way to study trade-offs and the interaction of transport infrastructure investments with other policies could be through structural general equilibrium modeling. Such modeling also lends itself to the potential ex ante evaluation of proposed transport corridor packages. Our review shows that the literature is dominated by reduced-form estimations. Perhaps there is some skepticism about structural general equilibrium modeling because it assumes that the model structure is correct at capturing the factual transmission mechanisms and functional forms when linking policy interventions to outcomes, as well as when drawing conclusions about the multiple and second-round impacts. If the model structure is correct, structural general equilibrium models could be the best tool to use. But if incorrect, it could be an inferior tool to use for policy decision making. By contrast, standard reduced-form, difference-in-difference estimation is purely empirical and requires little knowledge of the underlying mechanisms. As such, reduced-form estimation is generally seen as being more flexible and reliable. But the flexibility comes at the cost of weak identification and partial equilibrium estimates, with little consideration of second-round effects. Further research is required to improve the quality and accuracy of structural general equilibrium models, and the identification and comprehensiveness of reduced- form regressions.

Fourth, the literature has been mainly concerned with estimating the impacts of road projects. When it has focused on the evaluation of rail projects, it has mainly been on historical projects. Hence, more research is required on the evaluation of more modern rail projects, including both high-speed rail and freight railway corridors such as those that India is currently constructing. More research is also required on the impacts of multi-modal transport projects, especially because multi-modal freight movements are likely to be key to the design of many transport corridor projects in the future.

Fifth and finally, the literature that we surveyed covers a wide variety of countries. Nevertheless, much of the research (42 percent of papers in our sample) has focused on just three countries: China, India, and the United States. Therefore, the literature would benefit from research on other countries to gain insights into impacts in different country contexts.

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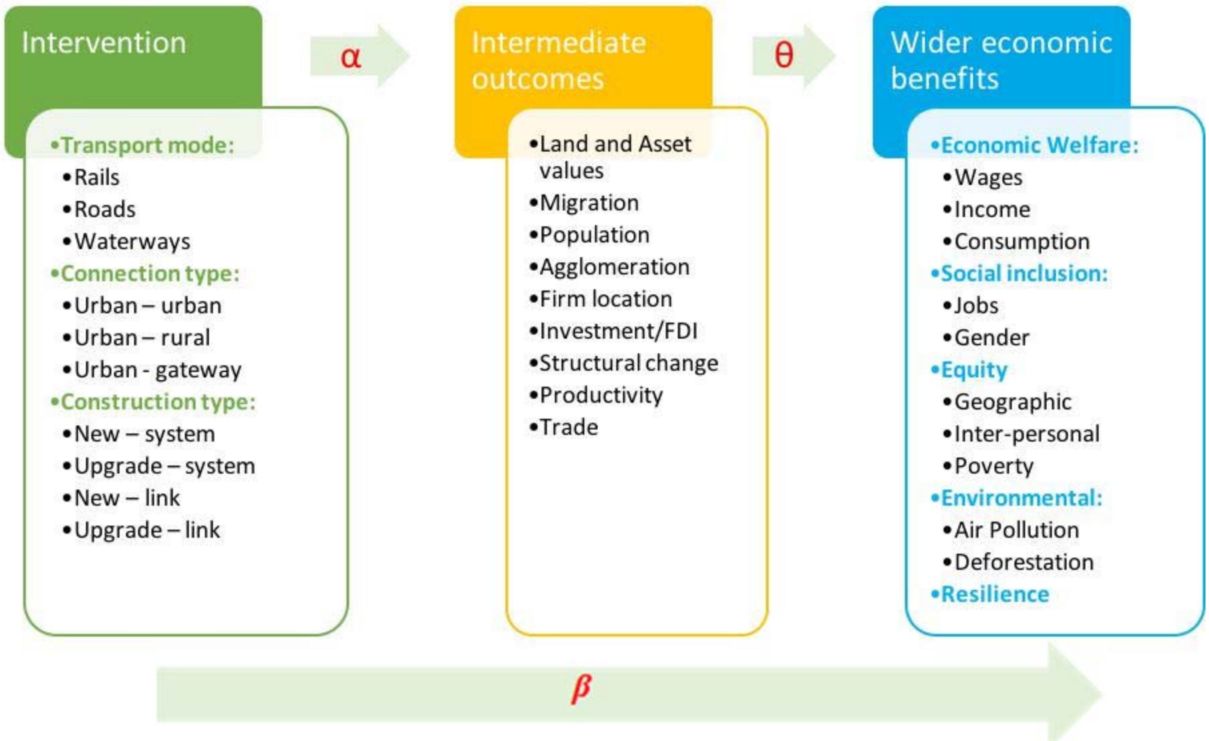
Figures in the Main Text

Figure 1. The Chain of Expected Results



Note: FDI = foreign direct investment.

Figure 2. The Hierarchy of Multiple Impacts

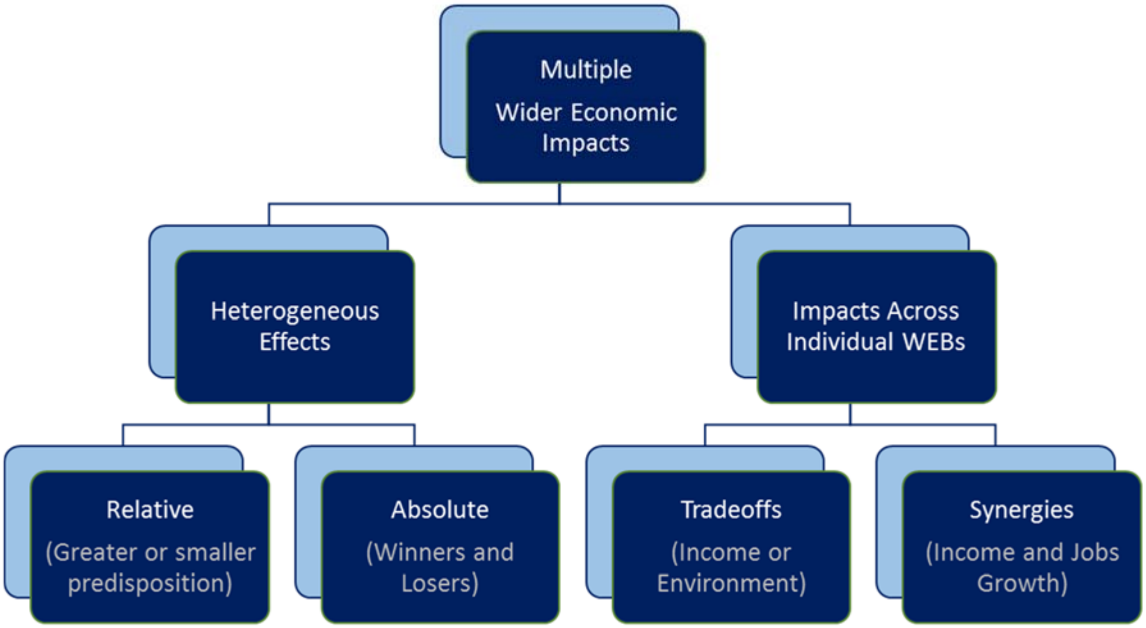
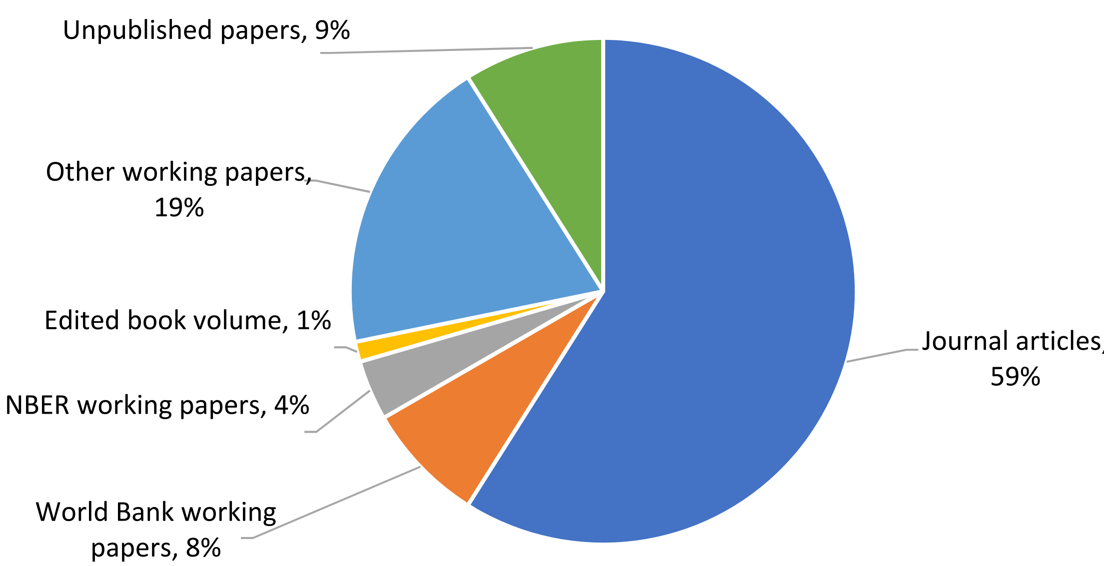
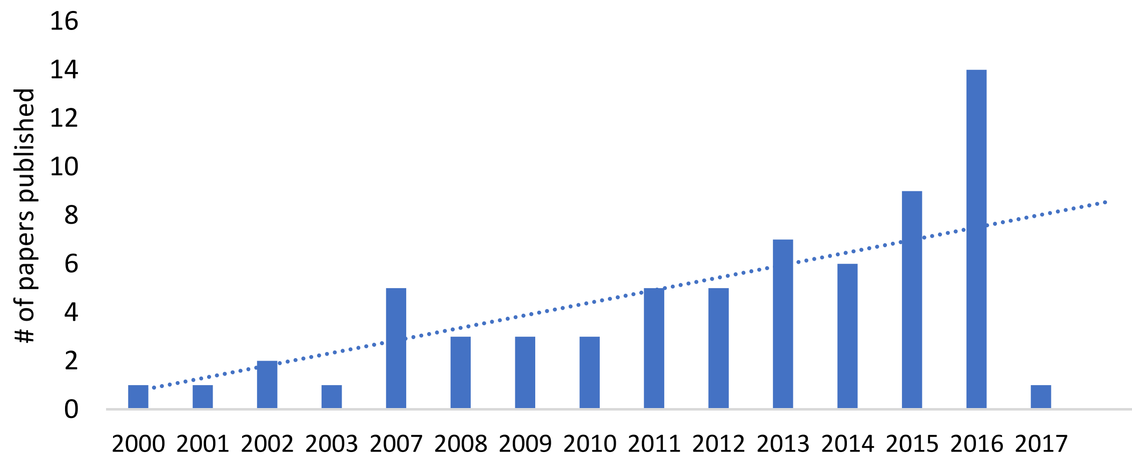


Figure 3. Mode of publication of sample papers



Note: NBER = National Bureau of Economic Research.

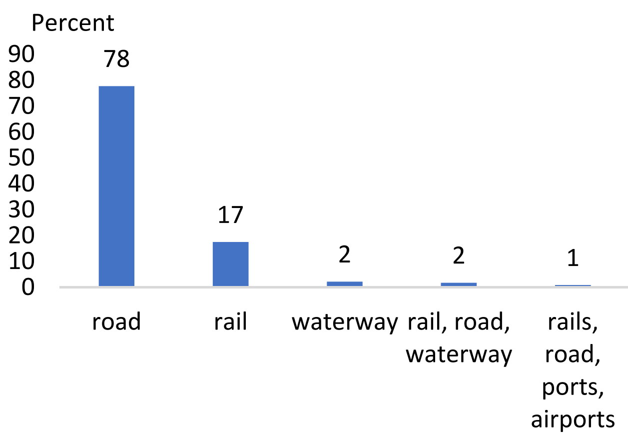
Figure 4. Number of papers in sample by year of publication



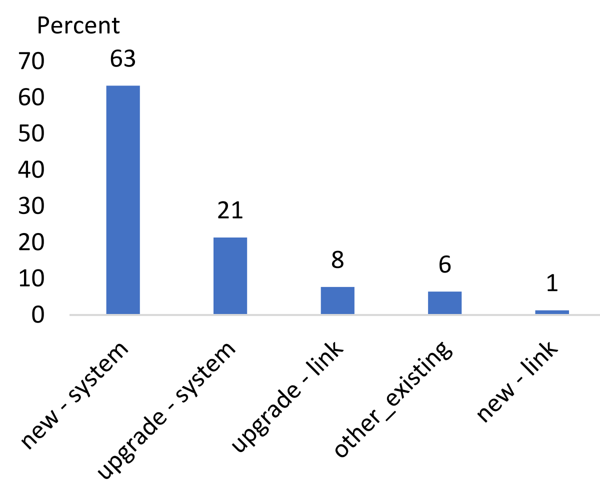
Note: 78 papers with 234 results (analyzed outcomes) tagged by April, 2017.

Figure 5. Distribution of results by

a. transportation mode



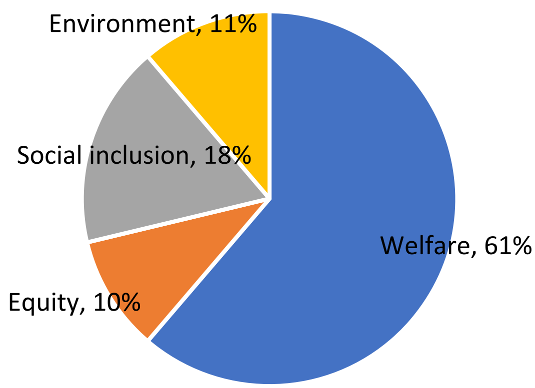
b. construction type



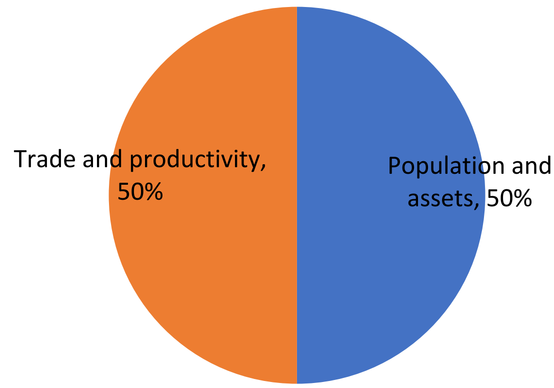
Note: 78 papers with 234 results (analyzed outcomes) tagged by April, 2017.

Figure 6. Distribution of Reported Results by Type of Outcome

a. Final outcome



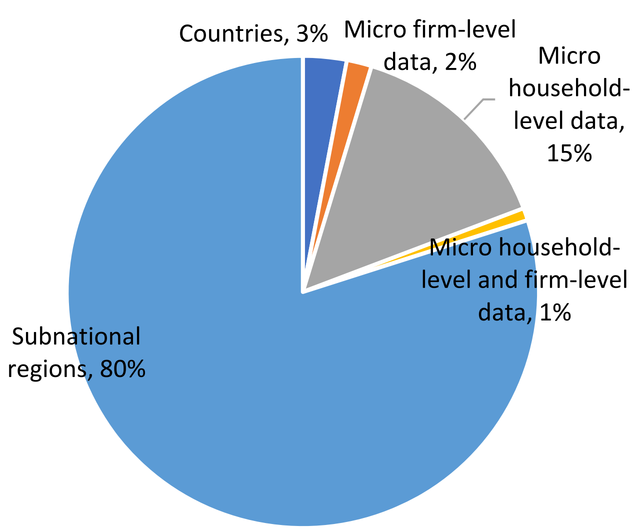
b. Intermediate outcome



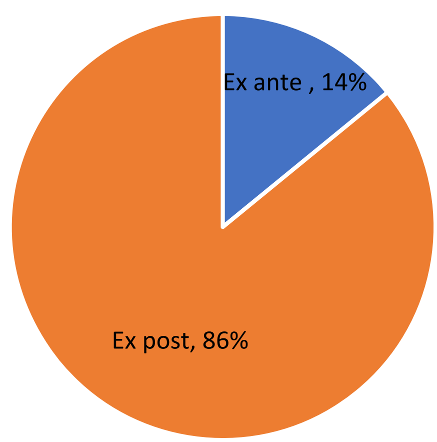
Note: 78 papers with 234 results (analyzed outcomes) tagged by April, 2017.

Figure 7. Distribution of Reported Results by Unit of Analysis and By Type of Analysis

a. Unit of an analysis



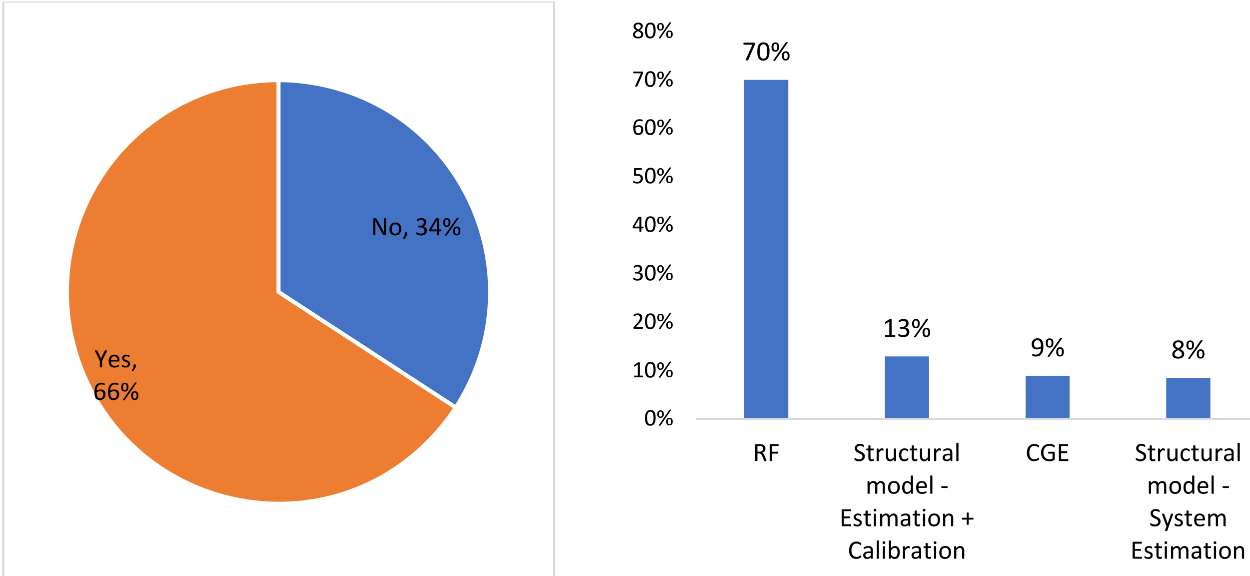
b. Type of analysis



Note: 78 papers with 234 results (analyzed outcomes) tagged by April, 2017.

Figure 8. Share of Reported Results that Are Motivated by Some Underlying Theoretical Model, and the Methodologies Used

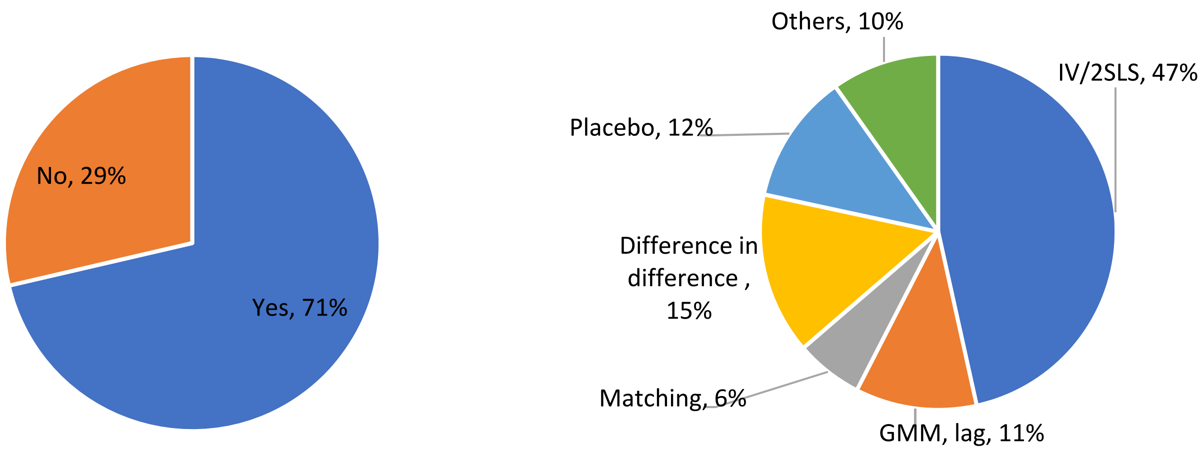
a. Motivating theory? **b. Estimation methodology used**



Note: 78 papers with 234 results (analyzed outcomes) tagged by April, 2017.

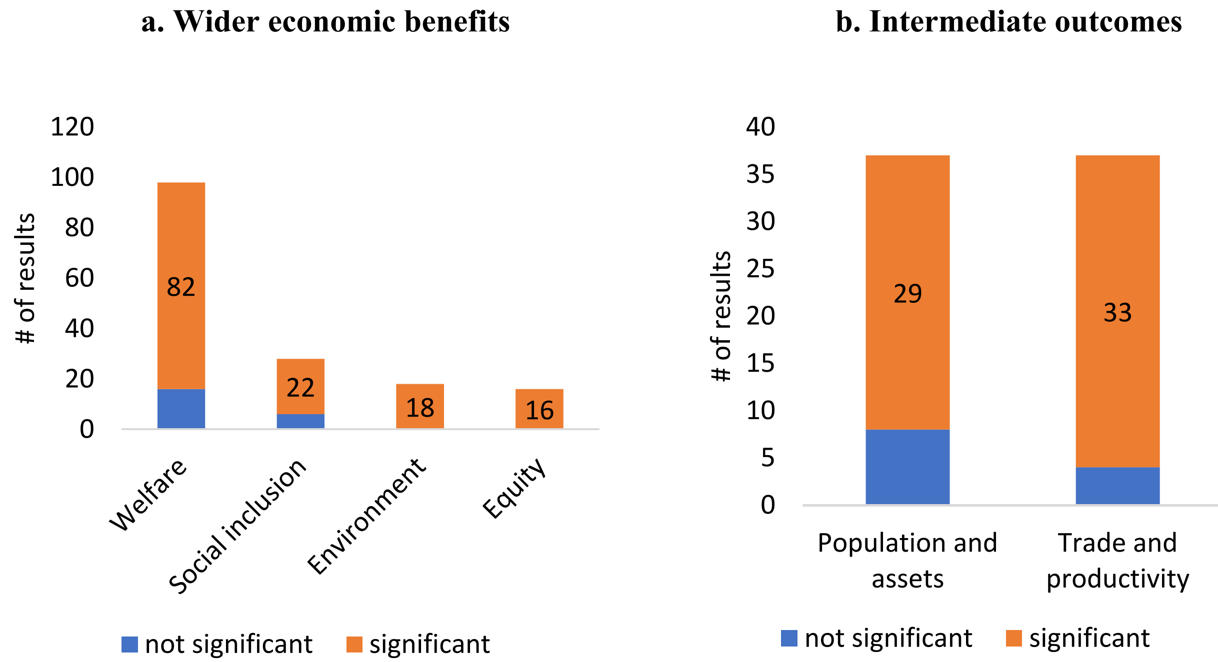
Figure 9. Share of Reported Results that Employ an Identification Strategy to Address Endogeneity Concerns and Identification Strategies Employed

a. Identification strategy? **b. IV strategies employed**



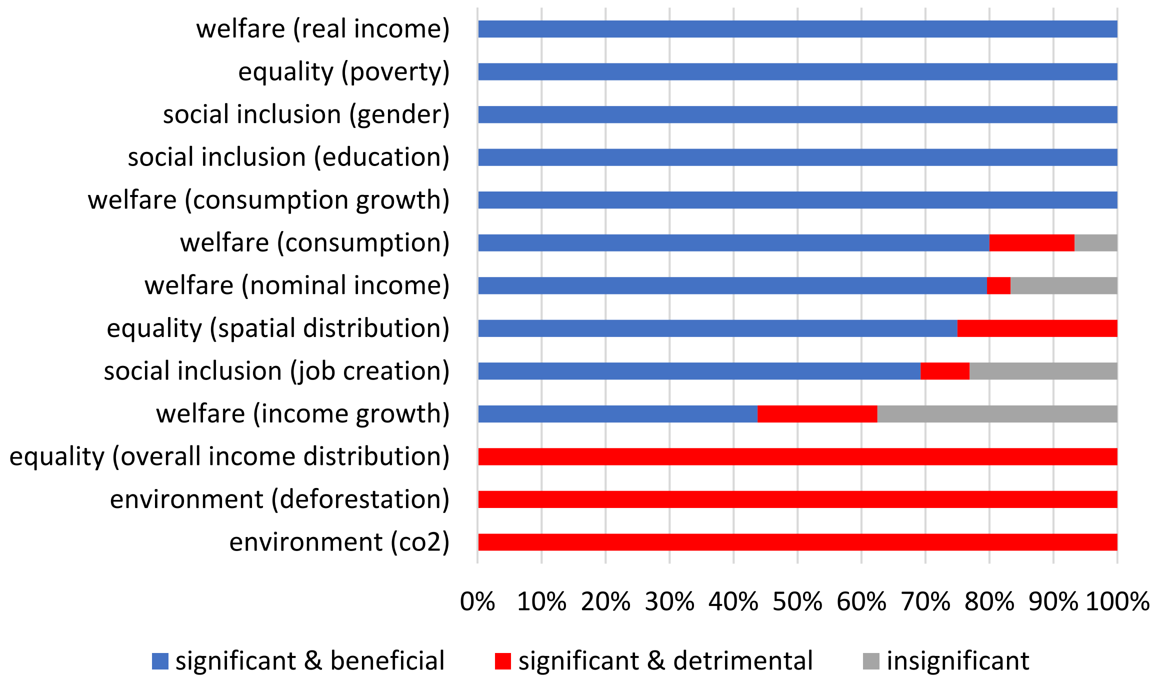
Note: 78 papers with 234 results (analyzed outcomes) tagged by April, 2017.

Figure 10: Distribution of Reported Results in Terms of Statistical Significance of WEBs and Intermediate Outcomes



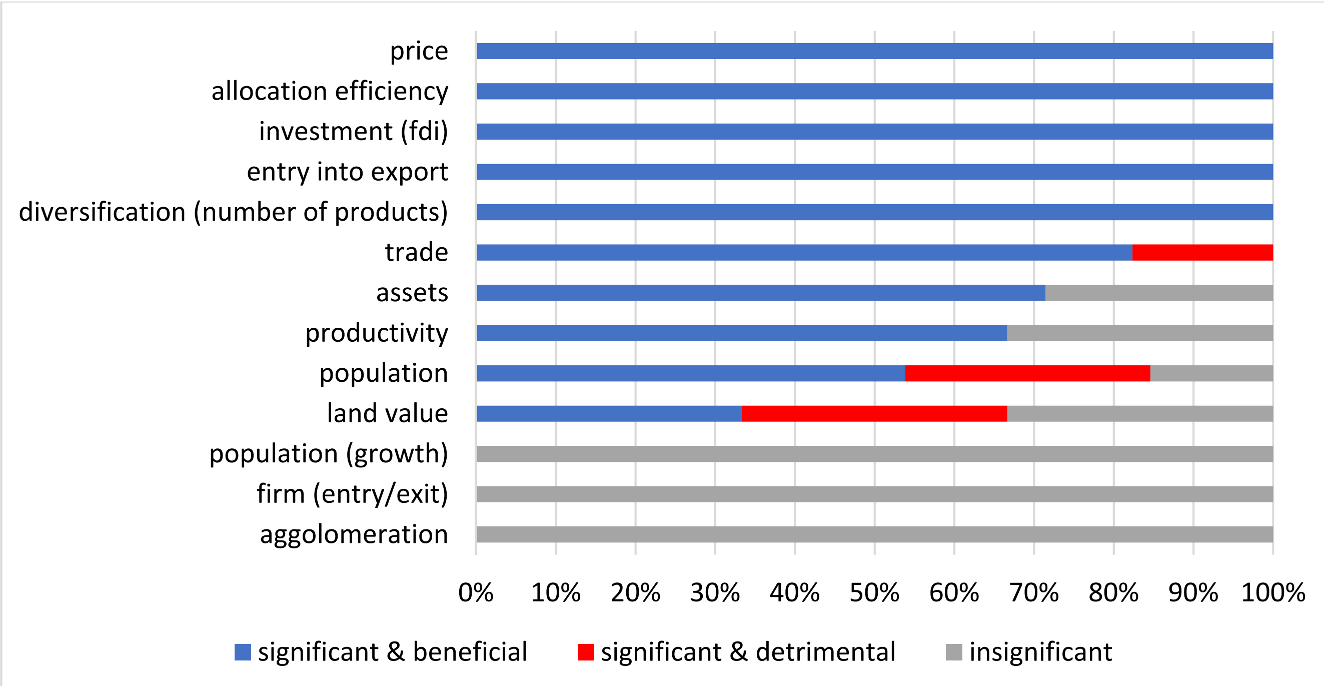
Note: 78 papers with 234 results (analyzed outcomes) tagged by April, 2017.

Figure 11. Distribution of Reported Results for WEBs According to Whether They Are Significantly Beneficial or Detrimental



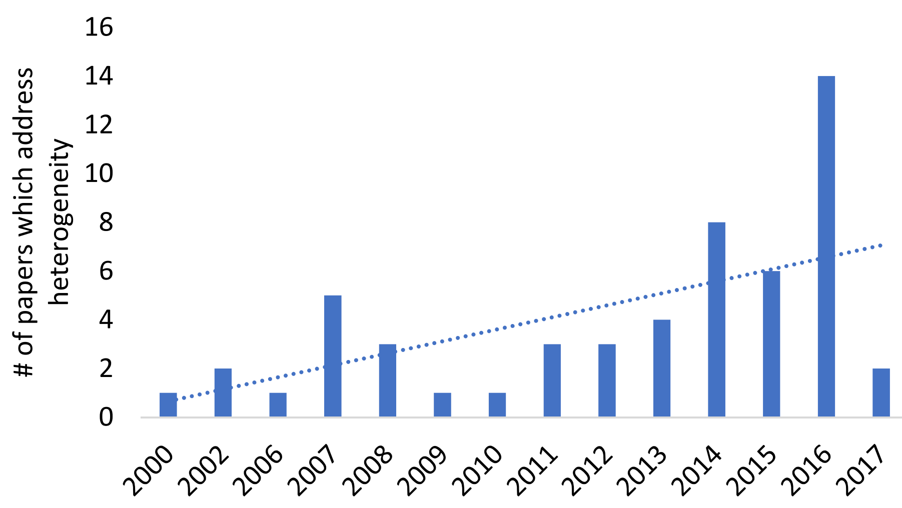
Note: 78 papers with 234 results (analyzed outcomes) tagged by April, 2017.

Figure 12. Distribution of Reported Results for Intermediate Outcomes According to Whether They Are Significantly Beneficial or Detrimental



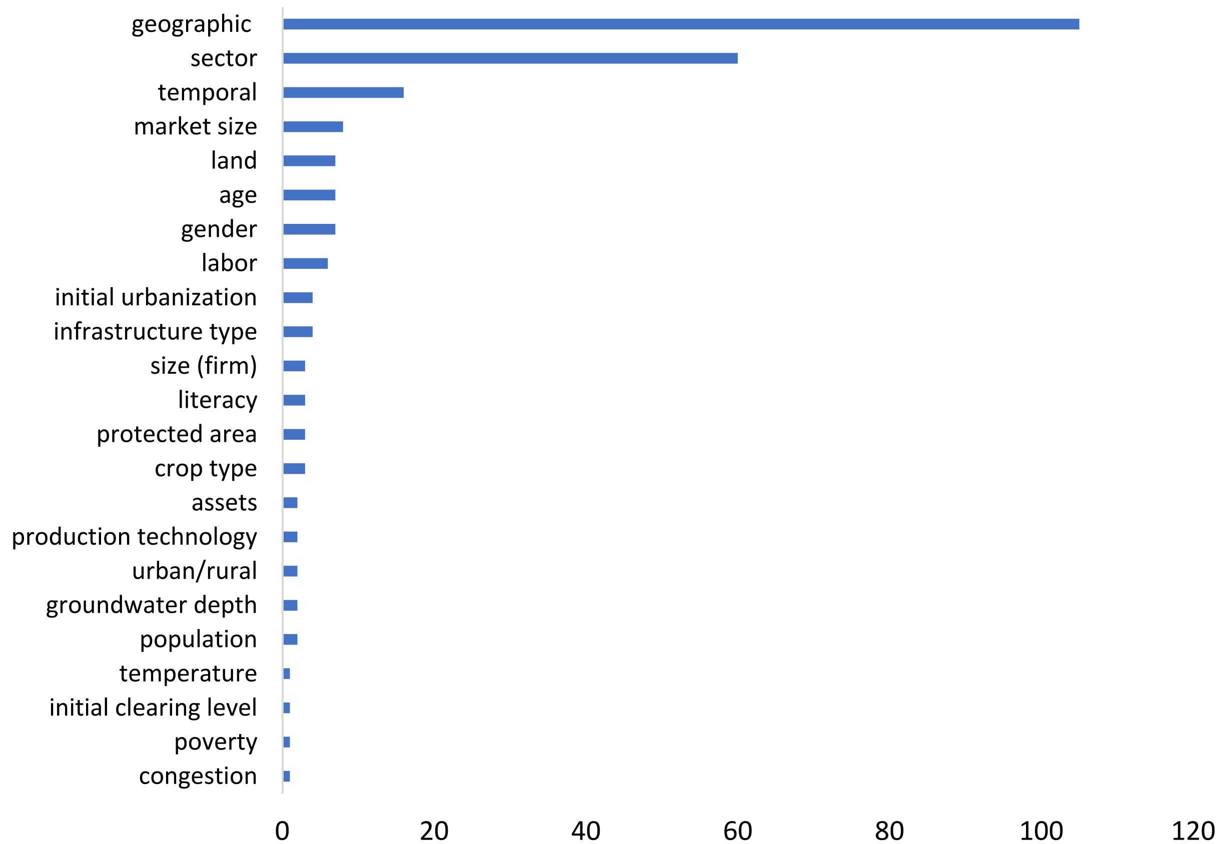
Note: 78 papers with 234 results (analyzed outcomes) tagged by April, 2017.

Figure 13. The Growing Trend to Analyze Heterogeneous Impacts



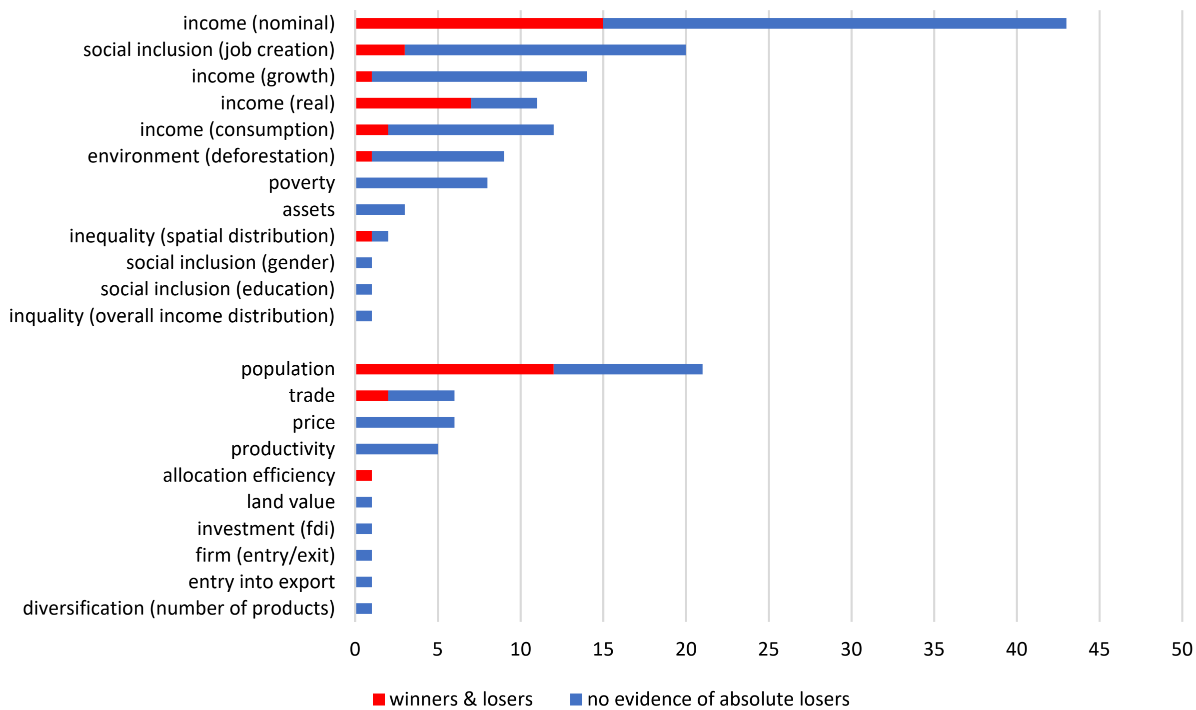
Note: 78 papers with 234 results (analyzed outcomes) tagged by April, 2017.

Figure 14. Number of Reported Results by Heterogeneity Factor



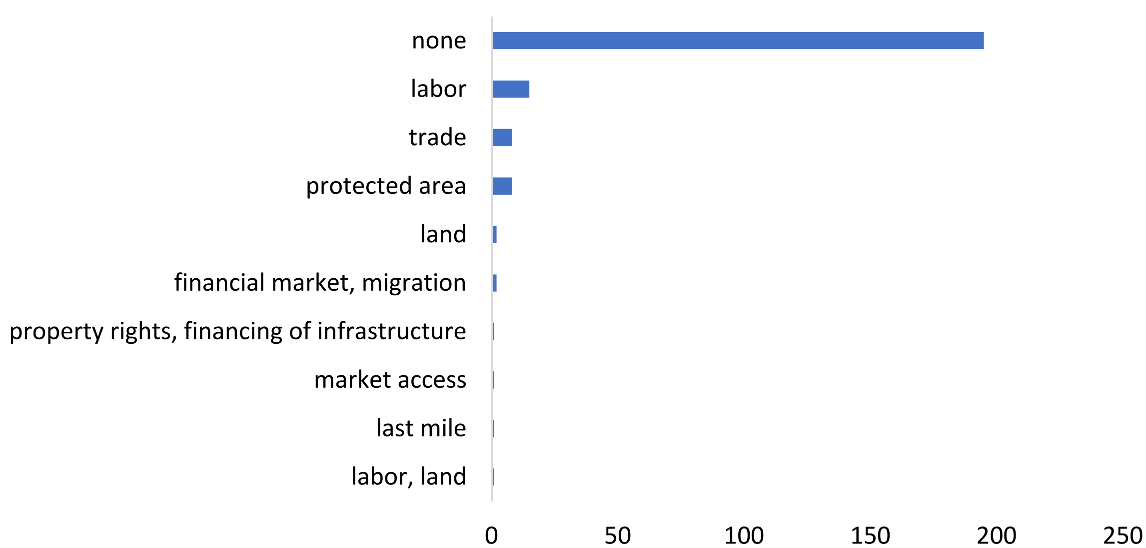
Note: 78 papers with 234 results (analyzed outcomes) tagged by April, 2017. Initial clearing level refers to initial level of deforestation, where the land is thereafter converted to a non-forest use.

Figure 15. Distribution of Reported Results that Analyze Heterogeneity According to Whether They Report Evidence of Absolute Losers



Note: 78 papers with 234 results (analyzed outcomes) tagged by April, 2017.

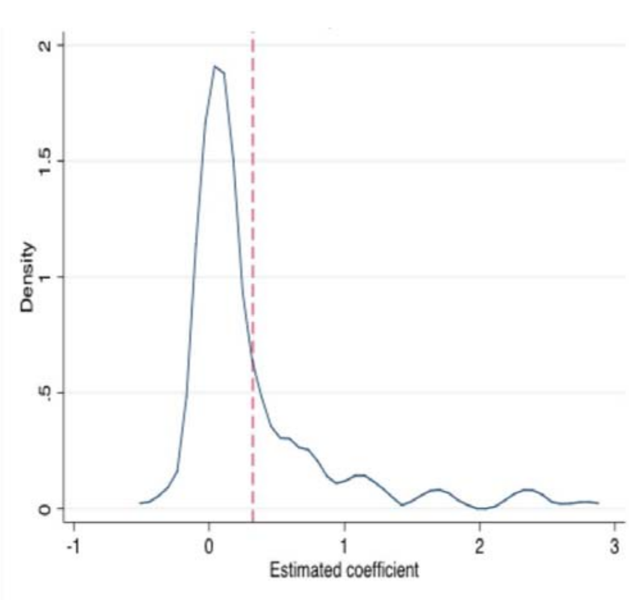
Figure 16. Number of Reported Results that Estimate Impacts of Complementary Policies



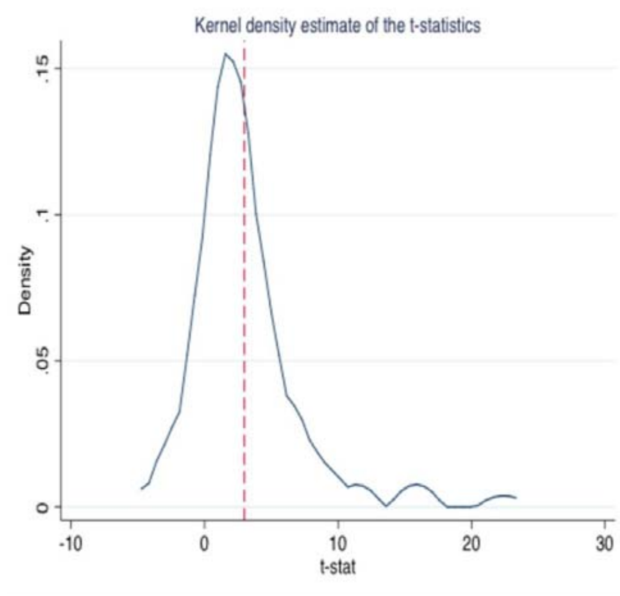
Note: 78 papers with 234 results (analyzed outcomes) tagged by April, 2017.

Figure 17. Estimated Kernel Densities of the Estimated Coefficients and t-Statistics

a. Coefficients



b. t-stats



Tables in the Main Text

Table 1. Keywords Used in Google Scholar Searches

	Outcomes		
Transport Related	**Final**	**Intermediate**	**Additional**
Road(s)	Income	Trade	Evaluation
Expressway(s)	GDP	Firm location	Impact evaluation
Highway(s)	Income per capita	Investment	Empirical
Rail	GDP per capita	FDI	Econometric
Railway(s)	Consumption	Productivity	Econometric analysis
Railroad(s)	Growth	Population	
Waterway(s)	Employment	Land value	
Transport	Jobs	Agglomeration	
Corridor(s)	Gender	Urbanization	
Transport corridor(s)	Inequality	Structural change	
Economic corridor(s)	Pollution		
	Deforestation		
	Resilience		

Note: FDI = foreign direct investment.

Table 2: System for Gathering of Information from Papers.

Publication Details	Intervention Details	Methodology	Results	Additional
Authors**: Ghani, Goswami, Kerr (2016)**	Transport mode: **Road**	Motivating theory? **No**	Significant impact (5 %)? **Yes**	Markets: **Labor**
Publication year: **2016**	Type of construction: **Upgrade system**	Type of analysis (*ex ante* / *ex post*)? **Ex post**	Sign of estimated impact: **Beneficial**	Complementary policies: **None**
Journal: **World Bank Economic Review**	Connection type: **Urban-urban**	Methodology: **Reduced-form**	Look for heterogeneity? **Yes**	
Journal quality (impact factor): **1.488**	Time of intervention: **1994-2009**	Unit of analysis: **Sub-national regions**	Heterogeneity factor? **Geographic**	
		Sector: **Urban**	Winners & losers? **Yes**	
		Sample-period: **1994-2009**		
		Outcome variable: **Income (nominal), Social inclusion (job creation)**		
		Treatment variable: **Continuous**		
		Identification strategy: **None**		

Table 3. Meta-Regression Analysis (MRA): Dependent Variable = t-stat (OLS Estimation)

Variables	Model 1	Model 2	Model 3	Model4
	Outcomes only	(2) + policy	Full model	Parsimonious
Constant	3.547***	11.21***	4.429	8.074***
	(0.654)	(2.326)	(11.890)	(1.308)
Outcome (omitted = economic welfare)				
Equity	2.934	-2.916	-3.138	-1.914
	(2.839)	(2.384)	(2.611)	(1.708)
Social inclusion	-1.836*	-1.579	-2.318	-2.035**
	(0.940)	(1.137)	(1.638)	(0.933)
Environment	-18.57***	-23.81***	-16.29*	-24.28***
	(2.360)	(2.486)	(9.546)	(1.395)
Type of construction (omitted = new system)				
Upgrade of system		-1.004	-2.806	
		(1.624)	(3.122)	
New link		8.549**	4.618	
		(3.614)	(5.728)	
Upgrade of link		0.494	5.56	
		(2.473)	(6.330)	
Other		6.243**	-6.215	
		(2.479)	(8.955)	
Transport mode (omitted = road)				
Rail		-4.371**	-4.944	-4.992***
		(1.985)	(4.603)	(1.641)
Waterway		-0.125	1.694	
		(1.722)	(4.840)	
Connection type (omitted = urban—urban)				
Urban–rural		-2.415	-0.88	
		(1.847)	(2.888)	
Urban–gateway		-0.667	-2.817	-3.846***
		(1.861)	(4.207)	(0.904)
Heterogeneity factor (omitted = does not look for heterogeneity)				
Geographic		-8.173***	-9.221***	-7.580***
		(2.333)	(2.936)	(1.419)
Sectoral		-7.844**	-7.326	-3.797*
		(3.212)	(4.836)	(1.977)
Geo-sectoral		-6.372***	-8.549*	-5.681***
		(2.077)	(4.323)	(1.249)
Land		-4.015	-5.265	-6.170**
		(2.456)	(4.362)	(2.373)
Labor		-5.624***	-3.982	-4.029***
		(1.802)	(5.144)	(1.136)
Temporal		-4.004	0.374	
		(2.693)	(4.793)	
Inclusion		-4.546**	-1.114	
		(1.990)	(6.037)	

Winners/losers	-1.132	0.607	1.964*
	(1.606)	(3.001)	(1.021)
Methodology (omitted = reduced form)			
Structural	-0.171	-2.744	
	(1.101)	(4.477)	
Identification strategy (omitted = IV)			
Diff-in-diff	-1.351	-0.865	
	(1.525)	(4.361)	
Matching	-4.234	-2.682	-2.343**
	(2.537)	(4.931)	(1.096)
Other (RE/VAR/Fuzzy)	-4.005*	-7.368	-3.882***
	(2.216)	(4.684)	(1.175)
None	0.154	2.801	3.808***
	(1.272)	(2.932)	(0.911)
Motivating theory			
Yes		-1.301	
		(3.195)	
Treatment variable (omitted = discrete)			
Travel-time		1.743	6.253***
		(6.868)	(2.018)
Continuous		-1.414	
		(5.190)	
Transport cost		2.724	3.068**
		(4.644)	(1.484)
Size of investment		3.56	11.92***
		(10.700)	(2.608)
Market access		1.852	
		(3.923)	
Others (road/upgrade quality)		-8.183	-6.161***
		(4.850)	(1.722)
Sector (omitted = aggregate)			
Manufacturing		-1.448	
		(3.084)	
Rural		0.333	
		(2.825)	
Urban		1.244	
		(3.042)	
Unit of analysis (omitted = sub-national regions)			
Households		-4.492	-3.532**
		(4.935)	(1.609)
Firms		6.119	1.739
		(9.216)	(1.130)
Countries		16.04	
		(14.500)	
Income class of study country (omitted = Upper MIC)			
LIC		-3.327	
		(3.893)	

Lower MIC			-2.084	
			(4.803)	
HIC			8.227	
			(13.690)	
Region of study country (omitted = North America)				
Africa			8.513	4.946***
			(7.575)	(1.557)
EAP			10.44	
			(11.050)	
Western Europe			1.073	-5.475**
			(7.991)	(2.060)
LAC			5.299	
			(7.612)	
SAR			11.75	
			(15.470)	
Other controls				
Journal article			-1.917	-1.855**
			(2.956)	(0.690)
Precision (1/sd)	-0.0037	0.0053	0.000834	
	(0.008)	(0.007)	(0.010)	
Observations	102	88	88	88
Adjusted R2	0.578	0.771	0.854	0.835

Note: Robust standard errors are in parentheses and clustered at study level. EAP = East Asia and Pacific; HIC = high-income countries; LAC = Latin America and Caribbean; LIC = lower-income countries; MIC = middle-income countries; MRA = meta-regression analysis; OLS = ordinary least squares; SAR = South Asia Region; sd = standard deviation. *** p<0.01, ** p<0.05, * p<0.1

Appendix A. Tagging System and Data

Detailed Description of the Tagging System

A tagging system was developed to facilitate the systematic collection of data from papers selected for inclusion in the literature review. This system covers 29 variables grouped into five categories: publication details; intervention details; methodology; results; and additional. The variables under each category are listed below:

- Publication details: Title of paper, author(s), year of publication, journal, journal quality, country, key words, key findings.
- Intervention details: Transport mode, type of construction, time of intervention, sample period, type of analysis, unit of analysis, connection type.
- Methodology: Motivating theory, methodology, treatment variable, identification strategy.
- Results: Final outcome, significant impact at 5% level, estimated impact on the outcome, sector, whether a paper looks for heterogeneity or not, heterogeneity factor, whether there are winners and losers.
- Additional: Complementary policy, markets, and any additional notes that might be relevant to the analysis.

To help ensure the consistency and comparability of the data extracted from papers, the values of many variables were restricted to a set of options, which are discussed in detail next. Data were collected for each result of interest reported in a paper. Hence, if a paper presents results for two different outcome variables of interest, data were collected for both results. As a consequence, the final data set that results from the application of the tagging system contains $N = \sum_{i=1}^{P} r_i$ observations, where r_i indexes the number of results extracted from paper i and there are P papers in total.

Publication Details

- Author(s): All listed authors of the paper.
- Year of publication: For journal papers, the year of publication of the issue of the journal in which the paper appears. For working papers, the year of publication for the version from which information was extracted. This is typically the latest version available online, but does not rule out subsequently updated versions that have been published. For unpublished manuscripts that were downloaded from the personal websites of authors and other sources, the year of publication was taken from the date on the manuscript.
- Journal quality: RePEc simple impact factor (only recorded for papers published in peer-reviewed journals).
- Country: Country or countries studied in the paper. Where the paper presents analysis for an entire region (such as Africa), the name of the region is recorded.
- Key words: Key words stated by the author(s). In cases in which no key words were available, the team determined based on the study.
- Key findings: Summary of main findings based on the abstract of the paper.

Intervention Details

- Transport mode: Describes the mode of transportation to which the intervention relates. Values of the variable were restricted to four options: *road, rail, waterway, and intermodal*. Intermodal refers to transport infrastructure investments that combine more than one mode as part of an integrated package. In cases where the paper evaluates the impacts of transport infrastructure the covers more than one mode but these modes are not necessarily part of an integrated system, all relevant modes were tagged.[37]

- Type of construction: Indicates whether the infrastructure investment represents new construction or an upgrade of preexisting infrastructure, as well as its coverage as an individual link or an entire system. Values of the variable were restricted to four options: *new construction - system, new construction - individual link, upgrade—system, upgrade—individual link*. One or more options were allowed to be selected.

- Time of intervention: Refers to the years during which the infrastructure was constructed. When it is unclear from the study, the value is recorded as missing.

- Sample-period: Sample-period used in estimation of impacts and/or model calibration.

- Type of analysis: Restricted to two options: *ex ante* and *ex post*. Ex ante refers to the evaluation of a transport infrastructure project before it has been undertaken, while ex post refers to the evaluation of a project after it has been implemented based on observed outcomes.

- Unit of analysis: The type of data used in the empirical analysis to generate a result. Values are restricted to five options: *country, countries, subnational regions, micro-data−households, micro-data– firms*. One or more options were allowed to be selected.

- Connection type: The types of location that the transport infrastructure connects. Values are restricted to four options: *urban-urban, urban-rural, urban-gateway, rural-rural*. One or more options were allowed to be selected. Gateway refers to an international port, land border, or airport that provides a gateway to international markets.

Methodology

- Motivating theory: Whether the paper includes an explicit theoretical model or discussion to motivate and/or support the design of the empirical analysis. Values are restricted to two options: *yes* and *no*.

- Methodology: The empirical methodology employed in the estimation of the impacts of the transport infrastructure investment. Values are restricted to four options: *reduced form (RF), structural model − estimation + calibration; structural model − system estimation; computable general equilibrium*. "Structural model − estimation + calibration" refers to the estimation of impacts based on a fully specified structural model where values of the parameters of the model are assigned based on a mixture of estimation and calibration techniques.[38] If the methodology is none of the available options, it is marked in variable "note."

[37] This is the case, for example, for papers that consider the impacts of a general measure of the stock of transportation infrastructure (e.g. Cantos et al. 2005) or that consider the impacts of proximity to corridors that have historically been the target of multiple types of transport infrastructure investment (e.g. Banerjee, Duflo, and Qian 2012).

[38] Roberts et al. (2012) is an example of a paper that was tagged as "structural model − estimation + calibration."

- Treatment variable: Refers to how the transport infrastructure investment is incorporated into the empirical model. For example, when the model includes a dummy variable with 1 for exposure to the transport infrastructure and 0 for otherwise, the value is recorded as discrete. When the investment is incorporated as an independent variable using the distance to the location of the infrastructure, the value is recorded as continuous. Values are restricted to seven options: *discrete, continuous, investment size in $, change in travel time, change in transport cost, quality upgrade, market access*. In cases where the available options do not describe how the investment is incorporated into the model, the closest option was selected.

- Identification strategy: Refers to the type of strategy used in the estimation to address potential issues of endogeneity (most notably, issues of endogenous placement of the transport infrastructure). Values restricted to the following options: *difference-in-difference, double difference-in-difference, IV/2SLS, matching, placebo, heteroskedasticity-based identification, other*, or *none*.

Results

- Outcome variable: Records the outcome variable that the analysis estimates the impacts of the transport infrastructure on. This outcome variable can be either a *final outcome*—in which case, it refers to a wider economic benefits (WEB) variable—or an *intermediate outcome*. Values for an intermediate outcome are restricted to the following options: *trade, migration, population, land value, investment (foreign direct investment, FDI), productivity, agglomeration, market access, firm location, structural change, congestion*. Values for a final outcome are restricted to the following options: *welfare (assets), welfare (consumption growth), welfare (consumption), welfare (income growth), welfare (nominal income), welfare (real income), welfare (income volatility), environment (deforestation), environment (CO_2 emissions), environment (others), equity (overall income distribution), equity (spatial distribution), poverty, social inclusion (education), social inclusion (gender), social inclusion (job), social inclusion (others), resilience (marginal loss), resilience (food security), resilience (access)*. When impacts on several outcomes are reported in a study, each outcome as a separate observation.

- Sector: Records whether, for the given unit of analysis, the estimated impact refers to an aggregate-level or sectoral level outcome. Values restricted to five options: *aggregate, agriculture, manufacturing, services, urban, rural*.

- Significant impact: Whether the estimated impact of treatment variable on outcome variable is statistically significant at the 5 percent level. Values restricted to two options: *yes* and *no*. Where an estimate of impact is based on counterfactual simulation using either a CGE or structural model and statistical significance is therefore not reported, the variable is coded *yes* if the author(s) refer to it as being, for example, "large," "important," "significant." Otherwise, it is coded as *no*.

- Estimated impact sign: Refers to whether the estimated impact of *treatment variable* on *outcome variable* is "beneficial" or "detrimental," where beneficial (detrimental) indicates that the impact is positive (negative) from a broader social welfare perspective. Note that "beneficial" does not necessarily indicate that the estimated coefficient on treatment variable is positive. For example, if the outcome variable is a measure of deforestation and the treatment variable is discrete, then a positive estimated coefficient would represent a detrimental impact. Values are restricted to two options: *beneficial* and *detrimental*.

- Look for heterogeneity: Whether the analysis tests for variations in the impact of the infrastructure across any dimension. Values are restricted to two options: *yes* (tests for heterogeneity) and *no*.

- Heterogeneity factor: Refers to the dimension across which the impact varies. Values restricted to the following options: *geographic, sector, geo-sector, land, labor, temporal, gender*. One or more options were allowed to be selected. When the dimension was found not to match with any of the options available, the closest option was selected. Observations for which *look for heterogeneity* = *no* were coded as missing.

- Winners and losers: Whether the infrastructure is estimated to result in *absolute* losses for certain geographic regions or groups of economic actors alongside the presence of winners. Values restricted to two options: *yes* (evidence of losers is presented) and *no*.

Additional

- Complementary policy: Records whether or not the paper contains any explicit analysis of the role of complementary policies in influencing the impact of *treatment variable(s) on outcome variable(s).* Values restricted to two options: *yes* and *no*.

- Markets: Records whether or not the paper discusses imperfections or features of the operation of particular market(s) as potentially influencing the estimated impacts obtained. If the paper does contain such a discussion, the market is recorded. Values are restricted to the following options: *land, labor, capital, finance, goods and services, none,* or *not discussed*. Selection or more than one market was allowed.

- Note: Any additional information that might be relevant for the quantitative analysis performed for the literature review.

- The distribution of papers by country is presented in table A.1

Table A.1. Distribution of Papers by Country

Country	Count of Study
Australia	1
Bangladesh	2
Brazil	6
Cameroon	1
Chile	1
China	9
Colombia	1
Congo, Dem. Rep.	1
Egypt, Arab Rep.	1
Ethiopia	2
France	1
India	11
Indonesia	2
Iran, Islamic Rep.	1
Mexico	3
Netherlands	1
Nigeria	2
Papua New Guinea	1
Peru	1
Spain	3
Tanzania	1
Thailand	1
Turkey	1
United Kingdom	2
United States	13
Uganda	1
Vietnam	1
Region	**Count of Study**
Africa	3
Cameroon, Central Africa Republic, Ethiopia	1
East-Africa	0
Mexico/Belize/Guatemala	1
Sub-Saharan Africa	1
West-Africa	1

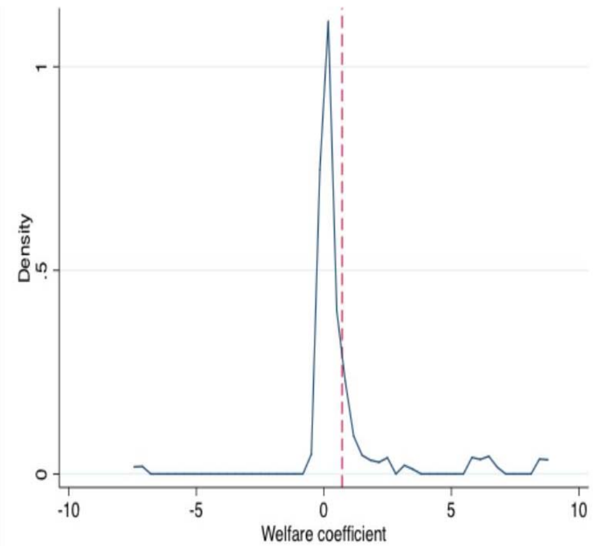
Note: Several papers have studied more than one country, so the sum of counts in the table exceeds the total number of papers. Africa refers to cross-countries studies that investigate the effects in many African countries.

Appendix B. Additional Meta-Analysis Results and Robustness Estimations

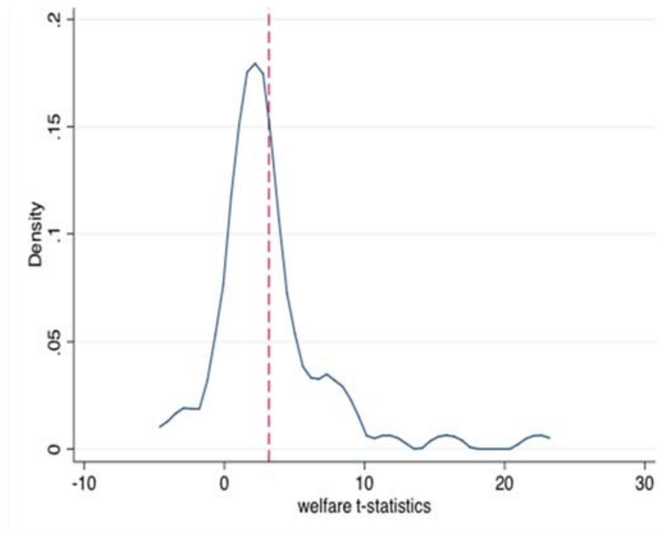
B.1. K-densities of Outcome Estimates Coefficients and t-Statistics

Figure B.1. Estimated Kernel Densities of the Estimated Coefficients and t-Statistics

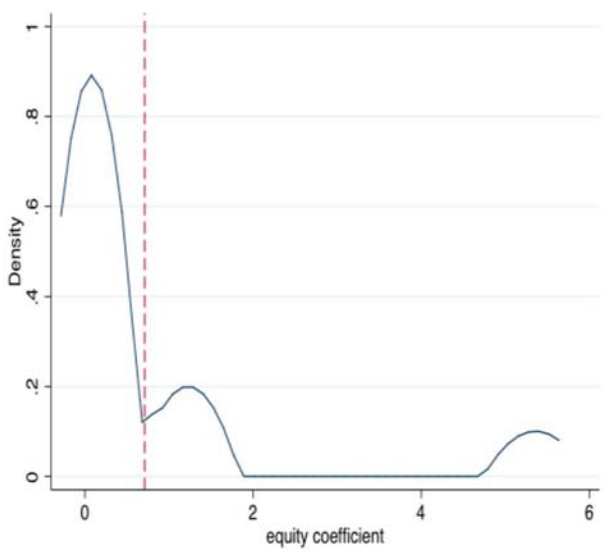
a. Estimated coefficients for welfare



b. t- Statistics for welfare



c. Estimated coefficients for equity



d. t- Statistics for equity

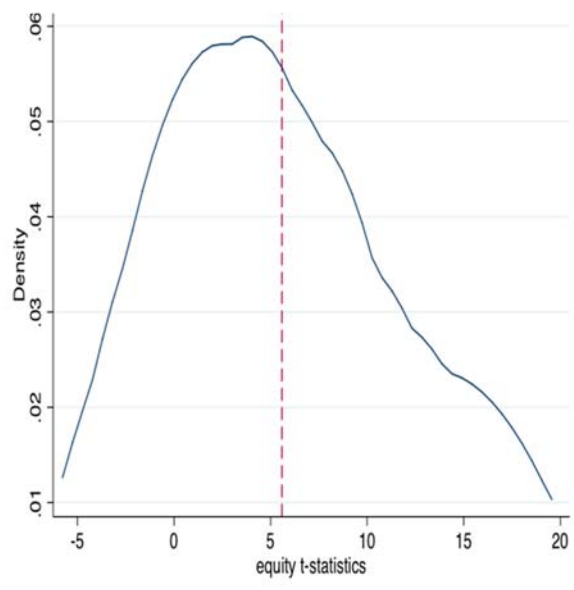
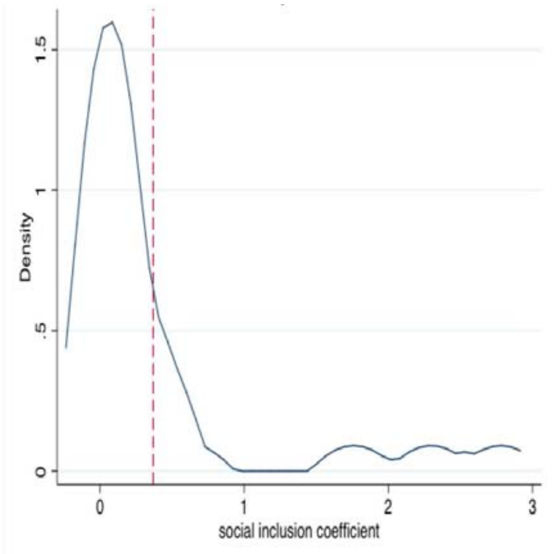
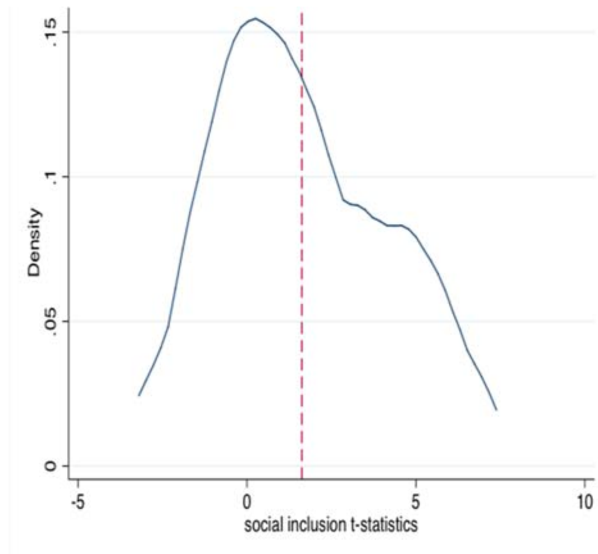


Figure B.2. Estimated Kernel Densities of the Estimated Coefficients

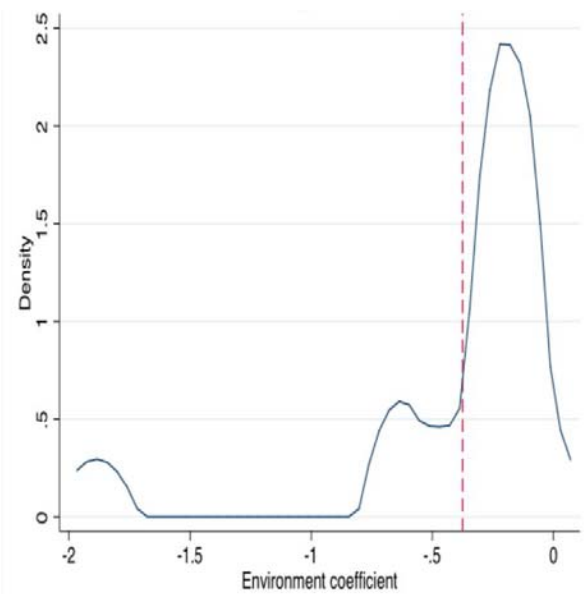
a. Estimated coefficients for social inclusion



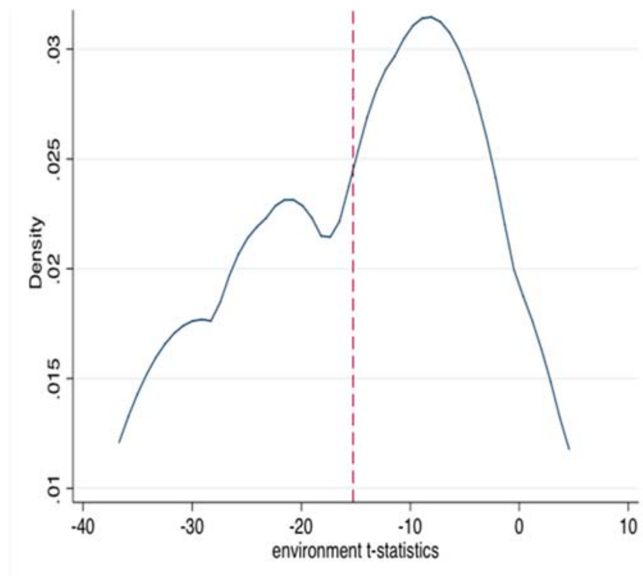
b. t- Statistics for social inclusion



c. Estimated coefficients for environment



d. t- Statistics for environment



B.2. Ordered-Probit Estimation and Marginal Effects Results

Table B.1. Meta-Regression Analysis: Results of the Random-Effect and Ordered-Probit Estimations

Variables	Estimate models			Marginal effects from the Ordered-Probit		
	OLS t-stat	Random-Effect t-stats	Ordered-Probit	Beneficial	Detrimental	Insignificant
Outcome (omitted = economic welfare)						
Equity	-2.916	-0.087	-0.710	-0.129	0.068	0.061
	(2.384)	(0.202)	(0.826)	(0.146)	(0.081)	(0.067)
Social inclusion	-1.579	-0.087	-0.845	-0.153	0.081	0.072
	(1.137)	(0.202)	(0.616)	(0.106)	(0.060)	(0.048)
Environment	-23.81***	-0.826***	-16.02***	-2.901***	1.530***	1.372***
	(2.486)	(0.242)	(1.533)	(0.263)	(0.269)	(0.272)
Type of construction (omitted = new system)						
Upgrade of system	-1.004	-0.083	-0.360	-0.065	0.034	0.031
	(1.624)	(0.219)	(0.557)	(0.100)	(0.054)	(0.047)
New link	8.549**	0.671	7.601***	1.377***	-0.726***	-0.651***
	(3.614)	(0.579)	(1.464)	(0.280)	(0.171)	(0.187)
Upgrade of link	0.494	-0.273	0.930	0.168	-0.089	-0.080
	(2.473)	(0.204)	(0.905)	(0.161)	(0.082)	(0.081)
Other	6.243**	0.360*	6.467***	1.171***	-0.617***	-0.554***
	(2.479)	(0.216)	(1.029)	(0.188)	(0.136)	(0.132)
Transport mode (omitted = road)						
Rail	4.371**	0.051	-0.506	-0.092	0.048	0.043
	(1.985)	(0.196)	(0.398)	(0.069)	(0.035)	(0.035)
Waterway	-0.125	-0.128	-0.957*	-0.173**	0.0914**	0.0819*
	(1.722)	(0.256)	(0.501)	(0.085)	(0.046)	(0.043)
Connection type (omitted = urban-urban)						
Urban-rural	2.415	-0.021	-0.281	-0.051	0.027	0.024
	(1.847)	(0.167)	(0.477)	(0.085)	(0.046)	(0.039)
Urban-gateway	1.748	-0.002	0.705	0.128	-0.067	-0.060
	(1.430)	(0.253)	(0.559)	(0.102)	(0.053)	(0.051)
Heterogeneity factor (omitted = does not look for heterogeneity)						
Geographic	-8.173***	-0.483*	-1.033*	-0.187*	0.099	0.0884*
	(2.333)	(0.276)	(0.627)	(0.107)	(0.064)	(0.046)
Sectoral	-7.844**	-0.208	-0.836	-0.151	0.080	0.072
	(3.212)	(0.323)	(1.127)	(0.203)	(0.109)	(0.096)
Geo-sectoral	-6.372***	-0.406**	-1.245**	-0.226**	0.119*	0.107**
	(2.077)	(0.195)	(0.595)	(0.104)	(0.065)	(0.044)
Land	-4.015	0.018	4.980***	0.902***	-0.476***	-0.426***
	(2.456)	(0.312)	(0.853)	(0.192)	(0.098)	(0.138)
Labor	-5.624***	0.194	0.291	0.053	-0.028	-0.025
	(1.802)	(0.284)	(0.852)	(0.154)	(0.082)	(0.073)
Temporal	-4.004	0.201	1.690*	0.306*	-0.161*	-0.145*
	(2.693)	(0.318)	(0.907)	(0.161)	(0.086)	(0.083)

Inclusion	-4.546**		0.815	0.148	-0.078	-0.070
	(1.990)		(0.847)	(0.153)	(0.080)	(0.074)
Winners/losers	-1.132	-0.352*	-1.915***	-0.347***	0.183***	0.164***
	(1.606)	(0.201)	(0.525)	(0.082)	(0.050)	(0.050)
Methodology (omitted = reduced form)						
Structural	-0.171	-0.086	0.256	0.046	-0.025	-0.022
	(1.101)	(0.177)	(0.526)	(0.096)	(0.050)	(0.046)
Identification strategy (omitted = IV)						
Diff-in-diff	-1.351	-0.363*	-0.882	-0.160	0.084	0.076
	(1.525)	(0.183)	(0.635)	(0.114)	(0.065)	(0.052)
Matching	-4.234	-0.462	-0.988*	-0.179**	0.0943*	0.0846*
	(2.537)	(0.350)	(0.509)	(0.090)	(0.049)	(0.046)
Other (RE/VAR/Fuzzy)	-4.005*	-0.039	-2.455**	-0.445***	0.234**	0.210**
	(2.216)	(0.177)	(0.954)	(0.164)	(0.095)	(0.084)
None	0.154	-0.007	1.554**	0.282**	-0.148**	-0.133**
	(1.272)	(0.232)	(0.625)	(0.110)	(0.062)	(0.058)
Observations	88	121	120	120	120	120
Adjusted R^2	0.771	0.642	0.492			

Note: Robust standard errors are in parentheses and clustered at study level. The estimated model is an ordered-probit model with outcomes and policy variables. Beneficial or detrimental results are reported significant results. The OLS t-stat estimation is reported for comparison. *** p<0.01, ** p<0.05, * p<0.1.

B.3. Random Effect Model Estimation Results

Dealing with Extreme Coefficients

Extreme deviations from the main sample of estimates are problematic for statistical analyses. They usually compress the variation of the rest of the sample. To deal with this issue, we use the Grubbs test (NIST/SEMATECH 2004) as our criterion to exclude from our estimation extreme outliers. This test calculates, G, the maximum deviation from the sample mean, divided by the standard deviation (SD), calculated including that observation. If $G = \max\left(\frac{X_i - \bar{X}}{SD}\right) > G^*$, the observation is deleted. G^* is the critical value for G at a confidence level α and is computed by $G^* = (N-1)\sqrt{\frac{T^2}{N(N-2+T^2)}}$, where T is the critical value of a t-distribution with $(N-2)$ degrees of freedom and a confidence interval of $\frac{\alpha}{2N}$. We start with $N = 149$ observations (estimated coefficients) and set $\alpha = 0.001$, which yields $G^* = 5.086$. The Grubbs procedure eliminates one outlier at a time, recalculating $\bar{X}$ and SD with each iteration. We apply this procedure and this led to the removal of the coefficients of eight outliers. As a result, the mean and standard deviation changed drastically from 0.18 to 0.54 and from 111.3 to 1.7, respectively.

Table B.2. The Grubbs Procedure to Eliminate Extreme Coefficients

Coefficient	N	Mean	SD	IQR	P5	P95	Min	Max
Before	149	0.18	111.27	0.44	-0.42	6.49	-917.3	854
After	141	0.54	1.7	0.42	-0.23	3.22	-7.27	8.61

Note: SD = standard deviation; IQR = Q_3-Q_1; p5 = 5^{th} percentile; p95 = 95^{th} percentile min= minimum; max = maximum.

As can be seen from table B.2, there is a large amount of variance in the estimated reduction in transportation effects. The fifth percentile is −0.23 and the 95^{th} percentile is 3.22. The standard deviation is 0.54 and the interquartile range is 0.42. The vertical line show that the mean is skew to the right, which is consistent with the descriptive section where the mean paper finds a positive (beneficial) and significant impact.

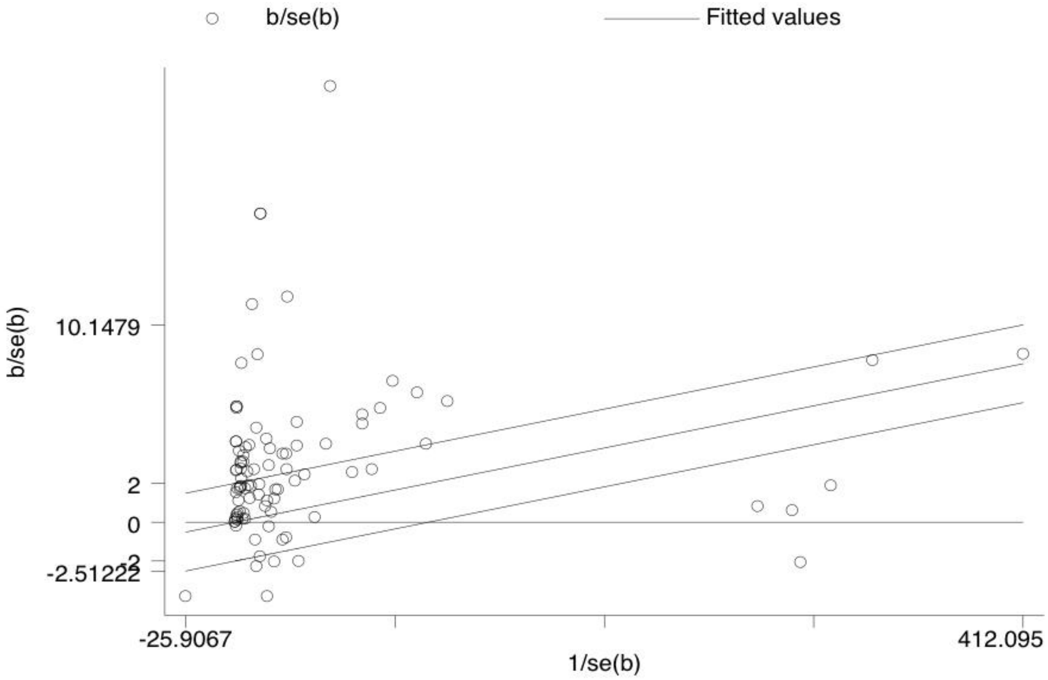
Testing for Sampling Error

Our coefficients of transportation effect are based on a sample of countries and years studies. It is therefore important to investigate the role of sampling error. To do so, we estimate the I^2 statistic provided by Higgins et al. (2003). The I^2 tests for the variation in the transportation coefficient attributable to heterogeneity. Specifically, let β_i represent an individual estimate of the transportation effect and $\bar{\beta}$ represent an estimate of the population mean. Define Z_i by:

$$Z_i = \frac{\beta_i - \bar{\beta}}{\sigma(\beta_i)} \tag{11}$$

Under the null of a single population mean, Z_i should follow a t distribution with $n_i - k_i$ degrees of freedom (153 in our case). The estimate I^2 statistic is 98 percent and represents the percentage of between-paper variability due to heterogeneity. This statistic point toward a strong indication of heterogeneity (98 percent of the total variation across our studies is due to heterogeneity rather than chance). Based on this statistically significant heterogeneity result, we investigate the causes of between-paper variation (heterogeneity) in the transportation effects estimation. This result is also confirmed by the Galbraith funnel plot of the transport estimates with the precision of their estimation. In the absence of heterogeneity, much of the within area is above +/− 2.

Figure B.3. Assessing Heterogeneity Using the Galbraith Plot



Source: Authors computation based on Galbraith plot.

Testing for Publication Bias and Small-Study Effect

Publication bias has long been a major concern for meta-analysts. Compare to study that find small and insignificant effects, studies that find statistically and significant results are more likely to be published because they are well received by researchers, reviewers, and editors. To perform a test of publication effects, we employ the commonly used Egger test. This test regresses the standard normal deviate of a study effect estimate against its standard error. The test null is that there are no small-study effects. The estimated bias coefficient is 1.502 with a standard error of 0.612, giving a p-value of 0.015. The acceptation of the null hypothesis suggests that there are no small-study effects. These results suggest that those values that are published in journals tend to emphasize small effects.