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Systematic Review of the Effects of Rural Roads on Expanding Agricultural Markets in Developing Countries

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Systematic Review of the Effects of Rural Roads on Expanding Agricultural Markets in Developing Countries

Authors (in alphabetical order):
Catherine Ludwig, Geetha Nagarajan and Lana Zaman, [1]

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[1] Social Impact, Arlington, VA USA. www.socialimpact.com Please address communication to Lana Zaman at Lzaman@socialimpact.com

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EXECUTIVE SUMMARY

I.I. ABOUT THE REVIEW

In developing countries, the percentage of the workforce dedicated to agriculture is generally than in more developed countries. For example, in sub-Saharan Africa over 60 percent of the entire workforce is involved in agriculture.[2] Most farming activities occur in rural areas where access to reliable transportation is limited. Therefore, for many decades, road interventions have been a popular tool for governments and major donors to address rural poverty. However, according to the World Bank's Rural Access Index (RAI), the average level of access to roads for rural populations in developing countries is still only 57%, and in Sub-Saharan Africa, only 30% of people have access to a road.[3]

The United States Department of Agriculture's (USDA's) Food for Progress (FFPr) Program contracted Social Impact Inc. (SI) to conduct a systematic review on rural road interventions to help inform future FFPr interventions aimed at expanding agricultural markets in developing countries. There exists a large body of qualitative literature on the macro-level benefits of roads as agents of poverty reduction, increased education, and better health; there is also a large body of census data on road length, conditions and populations reached. However, there are decidedly fewer studies that focus specifically on farmer-level outcomes. Recently, many researchers, funded by donor agencies, have begun conducting rigorous impact evaluations on whether rural roads effectively improve farmers' outcomes.

This systematic review consists of a narrative synthesizing the findings of 15 relevant rigorous impact evaluations of the impacts of rural road interventions in developing countries on farmer livelihoods. Specifically, the review examines the impact of roads on farmer incomes, transport costs, production, yields, prices, market access, adoption of modern farming technology, poverty, transportation times, and cropping patterns. SI conducted this review over a period of eight months – from protocol development to drafting and finalizing the report.

I.II. STUDIES INCLUDED IN THIS REVIEW

The review includes impact evaluations of rural and feeder road rehabilitation and construction projects in developing countries that are targeted at farmers and rural communities. Fifteen studies are included, covering eleven countries: Vietnam, Nicaragua, Honduras, Peru, Brazil, India, Bangladesh, Sierra Leone, Ethiopia, Zambia, and Armenia. Eight studies provide evidence on farmer

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[2] http://www.fao.org/docrep/015/i2490e/i2490e01b.pdf

[3] http://www.worldbank.org/transport/transportresults/headline/rural-access/tp-10-final.pdf

income: five studies examine crop production and prices, and four studies explore transport costs and time. Evidence for the remaining outcomes comes from three or fewer studies.

I.III. EFFECTIVENESS OF ROAD INTERVENTIONS

There is evidence that suggests that road interventions affect farmer transport costs, income, and market access positively, but have mixed effects on crop prices. Six out of eight studies found that road interventions significantly increased farmer incomes, and four out of four found significant reductions in transport costs. Three out of three studies found significant increases in market access. Rural road rehabilitation led to a 16% increase in consumption growth (a proxy for income) in Ethiopia. Feeder road rehabilitation led to a 37% decrease in transport costs in Bangladesh during the rainy season, when unpaved roads become impassable. In Brazil, a bridge and culvert construction project led to a 6 km reduction in the distance for farmers to their nearest market. Road interventions were less effective, however, in increasing crop production and prices.

In the immediate aftermath of a road intervention, improved road quality tended to lead to reductions in travel time and the cost to operate vehicles which enhanced farmers' access to markets in the short term. Lower transport costs led to greater access to inputs at cheaper prices as traders could access the markets more cheaply. These benefits enabled farmers to increase their production in the medium term. In addition to increased agricultural production, better road infrastructure led to outside investment in beneficiary communities and employment opportunities, all of which tend to improve household income and consumption and decrease poverty in the long term. There was some evidence for differential impacts based on gender. Men were shown to benefit more than women from increased access to markets due to road interventions, likely as a result of men being more likely than women to produce crops for commercial purposes.

I.IV. FACTORS AFFECTING EFFECTIVENESS OF ROAD INTERVENTIONS

- **Weather Conditions:** Road projects in areas that routinely experience heavy and variable rain will be more effective at reducing transport costs and time than those in more arid climates. During the rainy season, unpaved roads are likely to become impassable, which drastically reduces farmers' ability to get their crops to market.

- **Bundling of Interventions:** Road projects that are coupled with other interventions such as extension services and market infrastructure development will be more effective than standalone road projects. Roads are not a direct source of impact on farmer livelihoods; rather, they connect farmers with services, markets, and opportunities which in turn are impactful.

- **Road Maintenance:** Farmers' expectations of the sustainability of a road project have direct consequences on their actions in response to the project. If farmers do not perceive the road improvement to be permanent (i.e. there are no maintenance plans), they will channel the monetary and other resources gained from the project into savings rather than consumption or production.

I.V. IMPLICATIONS FOR DONORS AND POLICY MAKERS

Road interventions can be an effective tool to improve various measures of farmer welfare including income, market access, and transport costs. Funders wanting to support measures to improve farmer participation in agricultural trade and markets can use road construction and rehabilitation as an effective tool to that end, provided that the above considerations regarding weather conditions, bundling of projects, and road maintenance are taken into account.

1 BACKGROUND

1.1 OVERVIEW

The United States Department of Agriculture's (USDA's) Food for Progress (FFPr) Program contracted Social Impact, Inc. (SI) in 2014 to conduct three systematic reviews, including one on rural road interventions, to help inform future FFPr interventions aimed at expanding agricultural trade and markets in developing countries.[4] This review synthesizes the impacts of rural road construction and rehabilitation interventions on a number of outcomes for farmers in developing countries.[5] These outcomes include farmer incomes, transport costs, crop production/yields, prices, market access, adoption of modern farming technology, poverty, transportation times, and cropping patterns.

1.2 DEFINING RURAL ROAD INTERVENTIONS

For the purposes of this review, rural road interventions are defined as interventions involving the development of new road networks, the rehabilitation of existing roads by improving their grade and quality beyond regular maintenance, and the construction of feeder roads, and carried out for the purpose of improving agricultural outcomes for farming households and rural communities. Our definition of rural road interventions does not, however, include construction or rehabilitation of major road highways and interstate highways, railroads, or water or air transport networks. It also does not include road interventions unrelated to agriculture and rural areas, multi-component interventions in which the impact of the roads could not be separated out from the overall impacts of the combined program, or interventions related to transport vehicles.

1.3 THE ISSUE: HOW TO INCREASE ACCESS TO MARKETS AND TRADE FOR FARMERS IN DEVELOPING COUNTRIES?

Studies have shown that farmers in developing countries often struggle to maximize their profits due, in part, to poor road availability and quality, which limits access to domestic, regional, and international markets. According to the Annual Report on the Results and Impact of the International Fund for Agricultural Development (IFAD) Operations, poor roads result in increased transport costs and increased likelihood of damage to crops during transportation (IFAD, 2009). This constraint is especially prevalent in rural areas, where farmers lack access to competitive markets in which to buy inputs and sell outputs. According to the World Bank's Global Infrastructure Facility, more than one billion people living in developing countries live more than two kilometers from an all-weather road

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[4] The other two reviews focus on the roles of Information and Communication Technology (ICT) and Farmers' Cooperatives in improving farmers' outcomes.

[5] For the purpose of this systematic review developing countries include all low-income and lower-middle-income, and upper-middle income countries as classified by the World Bank.

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(The World Bank, 2014).[6] Expanding the rural road network and improving current roads tends to help reduce spatial constraints and facilitate better access to markets for farmers and expansion of trade (World Development Report, 2009).

1.4 FOOD FOR PROGRESS AS A MECHANISM TO ADDRESS EFFECTIVENESS OF RURAL ROADS INTERVENTIONS FOR AGRICULTURE

To date, there are very few systematic reviews of rural roads interventions for agriculture. Most of those available examine macro-level impacts with little explicit focus on farmer-level outcomes (Spratt, 2012; Knox, 2013). Therefore, the purpose of this systematic review is to identify rigorous impact evaluations and synthesize impacts of rural roads interventions on farmer incomes, transport costs, crop production, crop yields, crop prices, market access, adoption of modern farming technology, poverty, transportation times, and cropping patterns. This is accomplished through detailed analysis of rigorous impact evaluations' findings on farmer-related outcomes.

FFPr, originally funded under the Food for Progress Act of 1985 (17 USC 1736), is a program run by the Foreign Agricultural Service (FAS) of USDA. FFPr helps developing countries and emerging democracies modernize and strengthen their agricultural sectors. FFPr has two principal objectives: (1) to improve agricultural productivity and (2) to expand the trade of agricultural products. In order to achieve its objectives, USDA donates agricultural commodities to recipient countries through implementing partners, who are selected by FFPr through a competitive process each year and who sell the goods in local markets to obtain funding for agricultural development programs.

FFPr has funded a wide variety of projects in developing countries over the years, including projects that have trained farmers in improving animal health and the quality of crops, taught farmers effective farming methods, developed infrastructural systems, established and built capacity for producer cooperatives, provided microcredit and agricultural loans, and developed value chains for a variety of agricultural products. Program stakeholders have included private voluntary organizations, universities, foreign governments, and intergovernmental organizations. After 2010, FFPr began to focus its funding on select countries and activities to ensure resources were most effectively allocated to achieve its objectives. However, prior to 2014, FFPr had not conducted country needs assessments nor in-depth research to help inform its agricultural and trade development approach in the countries in which it works. Therefore, in order to better inform its activity selection, FFPr commissioned a series of research activities through a task order with SI that began in September 2014. Under this task order, SI completed an activity mapping of FFPr activities in early 2015 to help FFPr staff better understand the most common types of program activities implemented between 2009 and 2014. The activity mapping also examined variations in activity funding over time and across regions. Additionally, SI prepared an annotated bibliography of rigorous impact evaluations on agricultural interventions with post-production and trade outcomes

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[6] An all-weather road is a road that is passable in all weather conditions. Usually all-weather roads are paved roads that are higher in the center than on the edges to allow for run off and to prevent flooding during heavy rains.

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completed between 2000 and 2014. The activity mapping and annotated bibliography informed the FFPr team's selection of rural roads interventions for systematic review.

FFPr selected roads as a topic for this review because roads have been the focus of many FFPr-funded activities, yet to date there have been no rigorous systematic reviews quantifying their impacts on outcomes for rural farmers. SI's examination of FFPr awards made between 2009 and 2013 showed that 20 percent (30 out of 150) of FFPr activities funded through Cooperative Agreements in that time period focused on infrastructure. In this case "infrastructure" could refer to roads, transportation, market spaces, storage, cold-chain systems, communication structures, etc., all of which facilitate production and marketing activities. Seven of these 30 awards funded road and transportation infrastructure-related activities. FFPr has been working to improve market access for farmers in developing countries for years, but there has been little if any evaluation of the efficacy of its road construction and maintenance activities to that end. This review is intended to provide evidence for this knowledge gap in order to better inform future FFPr activities in this area.

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2 OBJECTIVES

2.1 BACKGROUND ON THE USE OF ROADS FOR AGRICULTURAL INTERVENTIONS

Between 2009 and 2013, FFPr funded seven projects that included components focused on improving or building transportation infrastructure in the form of feeder roads, main roads, and collection hubs. However, FFPr has not conducted any impact evaluations of these interventions. Thus, the FFPr team is unable to definitively determine whether the resources devoted to road improvement projects have made an attributable difference in the lives of farmers and helped to increase agricultural trade and production.

The existing body of literature includes a number of studies on the effect of rural roads on household income, transport costs, and crop prices, among other outcomes. For example, a study of a road rehabilitation project in rural Ethiopia showed that having access to an all-weather road increased farmer consumption growth, a common proxy for income, by 16.3% due to the increased access to local markets (Dercon, 2009). A similar study on a rehabilitation project in Bangladesh showed that farmers' per capita household expenditure, another common proxy for income, increased by 10% mostly as a result of reduced transport costs (Khandker, 2011). Casaburi, in 2013, used a regression discontinuity design to study the effect of feeder road rehabilitation on transport costs in Sierra Leone, and found that travel fares were significantly reduced and travel speeds were significantly increased as a result of the smoother road surface. The same study also found that market prices for crops significantly decreased, except in areas with high cell phone penetration (Casaburi, 2013).

Despite the many helpful one-off studies, there have been no systematic reviews conducted to show which type of agricultural roads interventions, if any, have consistently improved outcomes. Further, no studies have shown which type of intervention works the best to improve outcomes or which target beneficiaries benefit the most from such interventions.

2.2 PURPOSE

The purpose of the systematic review is to help FFPr make evidence-based decisions about program funding for future interventions focused on rural roads. The findings and recommendations will help FFPr staff target interventions based on existing research about the contexts in which such interventions tend to produce positive results. Next, the review will help the FFPr team to gain a better understanding of other actors working on improving rural roads so that FFPr can network with these other actors and, potentially, identify synergies between FFPr interventions and those of other donors or implementing partners. Such networking might result in complementary or partner interventions between FFPr and these other donors or actors, and may position FFPr to become a thought leader in the development and use of rural roads to boost agriculture-led development.

2.3 MAIN OBJECTIVES AND REVIEW QUESTIONS

The objectives of this review are:

(a) To gather, summarize, and integrate rigorous empirical research to help FFPr and other stakeholders understand the evidence regarding impacts of rural road interventions on agricultural outcomes. This will allow FFPr to make practical decisions about interventions and public policy on the use of rural roads to improve agricultural trade and markets in developing countries.

(b) To identify evidence gaps in the literature so that future research can be targeted to address those gaps regarding the effectiveness of agriculture-focused rural road interventions. To that end, the systematic review intends to identify trends and collective impacts of rural road interventions on farmer-level outcomes in the developing world in order to inform future interventions.

The questions addressed through this review include:

2.3.1 Main Questions

1) Do roads-based interventions impact farmers' incomes in developing economies?
2) Do roads-based interventions impact transport costs in developing economies?
3) Do road interventions affect other outcomes including production/yields, crop prices, market access, adoption of modern farming technology, poverty, transportation times, and cropping patterns?

2.3.2 Supplemental Questions

4) What are the common trends and mechanisms for achieving impacts?
5) How do country conditions or crop type affect impacts?
6) What are the current gaps in the literature on roads-based interventions?

3 METHODOLOGY

In conducting this systematic review, the research team searched for, reviewed, coded, and analyzed the results of rigorous impact evaluations. In doing so, SI followed the Campbell Collaboration approach to systematic reviews, described in more detail below. SI developed the methodology for selection of studies to include in the review in close consultation with FFPr; FFPr approved the final protocol in July 2015.[7]

Per the Campbell Collaboration method, the team used a theory-based approach, relying on the theories of change described herein as the framework for the review. The theories of change informed the inclusion criteria, data extraction, and coding. Wherever available, SI extracted information about the causal chains to ensure the theories of change held true. The team focused on higher-level outcomes and impacts but also addressed some of the intermediate outcomes in order to identify and make recommendations to address any breakdowns in the theory of change. The research team conducted an in-depth descriptive review of all main and supplementary outcomes listed in the questions above. The methodology for locating studies; criteria for inclusion in the systematic review; and information on coding and assessing quality are all discussed below.

3.1 SELECTION CRITERIA FOR SYSTEMATIC REVIEW

To be eligible for inclusion in the review, the study had to meet the criteria described below:

3.1.1 Subject Area

All included studies are substantially related to agriculture and agricultural outcomes linked to farm production and agricultural trade or marketing.

3.1.2 Type of Intervention

This systematic review includes studies on road interventions involving the development of new road networks, the rehabilitation of existing roads by improving their grade and quality, and the construction of feeder roads in order to improve agricultural outcomes for farm households and rural communities.

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[7] Discussion of the protocol began in early January 2015 with SI's submission of an annotated bibliography. This was followed with a proposal for systematic review topics in early March 2015. At this time, USDA selected the roads topic as one of the three topics. Based on the preliminary findings from the literature, as well as conversations between SI and USDA on FFPr priorities, SI developed a set of three topic proposals, including details on the protocol and methodology to be used for each. The roads proposal was initially submitted in May and was approved by FFPr in July 2015. SI conducted the systematic reviews between June and September, and wrote the report during October 2015.

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Studies included in this review discuss the following outcomes: income, transport costs, production/ yield, prices, market access, adoption of modern farming technology, poverty, transportation time, and cropping patterns.

3.1.3 Outcomes Defined

In order to be included in the review, studies had to include at least one of the outcomes as defined below[8]:

1) **Transport Costs** are defined as the funding resources necessary to move crops to the market.
2) **Profit** is defined as the amount of money that the household earns from selling a crop, net of input costs such as fertilizers, seeds, transport costs, and loans for financing agricultural work. **Income** includes profit after taxes and return on investments. Income can also be measured using proxy indicators such as consumption, expenditures, and assets, all of which are argued to be better indicators of household income and wealth than income itself in developing countries, as farmers often trade their products for items other than money. **Consumption** is the number, amount, and type of goods and services consumed by a household within a given period of time, and **expenditures** include the amount of money that such households spend on those goods and services.
3) **Prices** refer to input prices, including the price for fertilizers, seeds, and other inputs, as well as product prices, producer prices (for crops, livestock, milk, eggs, etc.), and consumer prices at domestic, regional, and international markets.
4) **Adoption of Inputs and Technology** includes any outcomes that measure uptake of new agricultural technologies. Technology includes pesticide usage, fertilizer usage, improved farming practices, modern and improved seed varieties, and mechanization.
5) **Poverty Count** is determined by counting the number of people with per capita consumption, expenditure, or income that fall above or below a nationally or internationally established benchmark.
6) **Changes in Crop Type/Acreage** includes changes in cropping patterns. Interventions focused in these areas generally work to shift farmers' focus from subsistence crops to higher-value crops, from use of traditional seed varieties to modern and improved seed varieties, and from mono-cropping to mixed- or multiple-cropping. Finally, these changes can result in farmers expanding or reducing the amount of land planted.
7) **Market Access** is defined as participation in, or at least possessing the option to participate in, a local market.
8) **Production** is defined as the volume of produce that is harvested at the end of a growing season and is often measured by weight or size**.**
9) **Yield** is production per unit of land.

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[8] These definitions are commonly applied in rigorous literature.

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3.1.4 Study Type

This review only includes rigorous impact evaluations that used counterfactuals to infer impacts. The impact evaluation designs include: quasi-experimental designs with a well-defined before-and-after timeline and comparison groups, including regression discontinuity designs, studies that use techniques for controlling for selection bias such as statistical matching (for example, propensity score matching or covariate matching), and regression adjustment (for example, difference-in-differences and single-difference regression analysis, instrumental variables estimation, and Heckman selection models). In the realm of road intervention evaluations, it is not possible to use experimental designs where intervention assignment is randomized because roads are public goods, built based on demand and not randomly placed. Furthermore, individuals and households do not randomly settle next to roads after construction (Kingombe, 2012).

3.1.5 Timing and Duration

Only studies published or made available to SI after the year 2000 are included. Additionally, only studies that included an end line at least one full growing season after the baseline are included, as shorter timelines are not expected to yield any measurable results.

3.1.6 Population

The population includes developing countries only. This includes countries classified by the World Bank as low or middle-income countries. Participants include farmers, agricultural households, women and men, agribusinesses, and cooperatives.

3.2 THEORY OF CHANGE FOR OUTCOMES

As shown in the FFPr results framework, increases in agricultural production and expansion of agricultural trade can be achieved through: (1) developing improved infrastructure to support on-farm production and increase availability of inputs, finance, and knowledge (all of which lead to increase in use of improved agricultural technologies and practices and increased production), and (2) improved market and trade infrastructure (resulting in improved marketing of agricultural products and improved linkages between buyers and sellers, leading to improved transaction efficiencies and increased access to markets to sell agricultural products).

While the relationship between road infrastructure and agricultural development is not direct (since roads are not an input into agricultural production activities), new roads and improvements in roads infrastructure can affect both the demand for and supply of agricultural products. Such investments in new roads or improvements of old roads can, therefore, facilitate quicker, cheaper, and more convenient transportation for agricultural service providers, including agricultural extension workers, bankers, and traders. Furthermore, better roads can help farmers access better markets (which often lie some distance from the farms) to obtain inputs and sell outputs. Next, better roads have been shown to drastically reduce the cost of inputs such as fertilizers, seeds, and extension services (Dercon et al, 2009). Finally, better feeder roads that connect rural areas with highways can help link small farmers with urban and international markets to provide quality, fresh agricultural

products at affordable prices to urban consumers.

It should be noted that it is not just availability of roads that impacts key outcomes, but the efficient use of the roads to reduce the spatial disparity between agents, allowing them to obtain inputs and sell outputs at markets that would have otherwise been inaccessible or unavailable to them.

3.3 STUDY SEARCH STRATEGY

The websites, journals, and databases selected for the search are listed in Appendix 1. The research team used specific keywords to search for relevant articles on each of these websites. Keywords followed PICOS (Population, Intervention, Comparison, Outcomes, Study design) format. Each search was conducted by entering a combination containing one word from each PICOS category. A complete list of these search terms is displayed in Appendix 2. Relevant studies were then coded into Database 1.

Since complete PICOS format would have resulted in upwards of 7,000 word combinations to search, and because these searches tend to overlap, returning irrelevant or repetitive hits, SI adjusted searches according to the format of each web site's search engine. Some websites had search filters that allowed for a more targeted search. The World Bank website, for example, had a filter for "Agriculture." Other common filters included "date range," "field," and "study type." Using these filters resulted in much more precision, but less overall retrieval of studies in the search process. As such, many fewer studies were retrieved and coded into the databases, but those that were coded were much more likely to be useful for the systematic review. To ensure that no useful studies (studies that met the systematic review inclusion criteria) would be missed using this technique, the research team also searched without using the filters for a few of the search terms to ensure no relevant studies were missed. The team found that the use of the filters only improved the efficiency of the process and did not eliminate any relevant studies. The filters used and the number of searches conducted for each website are recorded in Appendix 3.

The searches, particularly those in websites that did not have filters, returned a very large number of hits. In order to maximize efficiency and minimize extraneous information, analysts continued coding each consecutive page of hits until they reached a page with no additional hits eligible for the review. Certain word combinations were omitted in cases where similar search patterns were only returning irrelevant and/or repetitive hits. In cases where a particular search returned no relevant hits, based on the above-listed selection criteria, no articles were coded into the database. Many hits were easily excluded because they were not relevant to the proposed review.

Additional searches were conducted through an iterative process of searching through reference lists and bibliographies of relevant studies.

3.3.1 Search for Unpublished Studies

In order to reduce publication bias, SI included both published and unpublished documents. In order to locate unpublished studies, SI contacted lead researchers and organizations in the field of rural

infrastructure, as well as all authors of publications included in the systematic review, asking for recommendations of additional studies, including studies in languages other than English. While there were many non-responses despite repeated requests, some authors responded with recommendations – both published and unpublished – that were then considered for inclusion in the systematic review.

3.3.2 Studies in other Languages

In order to avoid language bias, in addition to English, SI searched for studies in Spanish, French, and Portuguese. The SI research team found that English was the most common language for impact evaluations, particularly for those pertaining to road interventions. Many impact evaluations initially written in English were later translated into other languages, but there were very few evaluations originally written in those other languages. The SI team found only one foreign language paper that was appropriate for inclusion in this systematic review: this paper was originally written in Spanish by Escobal (2002).

3.4 DATABASE CONSTRUCTION

In line with the Campbell Collaboration approach to systematic reviews, the team developed three databases to compile literature searches and analysis, as described below.

3.4.1 Database 1 (Search Database)

Database 1 contained all publications that SI retrieved based on the search strategy above as well as detail on whether the study was included in the systematic review.

In this database, SI analysts recorded basic information on search results, including search terms, search source, study title, year of publication, author information, type of study, study design, topic, type of intervention, population, country, language, and outcomes. Lastly, analysts made recommendations for whether the study should be included or excluded from systematic review based on the above-listed selection criteria. A full 30 percent of all studies were double-coded by two analysts to ensure both agreed on whether the study should be included in the systematic review.

3.4.2 Database 2 (Systematic Review Database)

Analysts read those publications which were determined to meet the criteria for inclusion in the systematic review (based on Database 1) in full and further coded them for additional details pertaining to quantifying the effect sizes, statistical significance, quantitative rigor, and reliability. Specifically, they recorded country information; crop types; unit of assignment to beneficiary and comparison groups; method of assignment to treatment and control groups; method of sampling; whether there was a balance test; effect size, t-statistic, pooled standard deviation for each outcome; numbers of observations in beneficiary and comparison groups; and key moderators. All studies in Database 2 were also double coded to ensure consistency and agreement on key indicators used in the qualitative analysis for the systematic review.

A number of proxies were used in coding study outcomes. Proxies for income included consumption and expenditures, both of which are known indicators of income status. As mentioned previously, both of these proxies are argued to be better indicators of household income and wealth than direct income in the context of developing countries, partly because farmers sometimes trade their products for items other than money, and because there is generally less measurement error with these proxies.

Each of the studies was coded for key moderators, including the percentage of country budgets dedicated to agriculture, the country wealth designation, region, level of international funding, and overall state of fragility. SI used these moderators later in the process to examine whether impacts varied based on country-specific characteristics. The data sources for these moderators are listed below:

1) **Percentage of Country Budgets Dedicated to Agriculture:** FAO's data on agricultural expenditure as a proportion of government expenditure for the year 2011 (United Nations Food and Agriculture Organization). Where data were unavailable for the year 2011, data were drawn from the most recent year available for the particular country.
2) **Country Region and Wealth Designation:** World Bank's List of Economies as of July 2015 (The World Bank).
3) **Level of International Funding:** Official Development Assistance as a proportion of Gross National Income as listed for the year 2013 in the World Bank's World Development Indicators.
4) **State Fragility Index:** The Center for Systemic Peace's 2013 index, which is a composite of states' effectiveness and legitimacy in terms of security and political, economic, and social wellbeing.

3.4.3 Database 3 (Meta-Analysis Database)

The studies selected for the meta-analysis were further screened for quality using a quality checklist. Analysts then coded each of the studies for each of the quality criteria in Database 3, which was used for the meta-analysis only. The quality criteria focused on the different types of biases that might appear in the studies. Analysts scored the potential bias of each study as high, medium, or low and made additional notes on the specific biases in the studies. The types of biases are listed below along with the questions the team considered in rating:

1) **Bias due to baseline confounding:**
   - Did the study design or analysis account for important confounding and modifying variables?
   - Were confounding variables assessed consistently across groups using valid and reliable measures?

2) **Bias due to selection of participants into the study**
   - Did the study design and the start of the intervention coincide?
   - Were the comparison groups appropriate?

- Did the study use randomization correctly and adequately?

3) **Bias due to departure from intended interventions**
- Did the study adjust or control for other interventions that may have resulted in biased results?
- Were baseline study conditions balanced across beneficiary and control or comparison groups?

4) **Bias due to missing data**
- Were outcome data missing or incomplete due to attrition or exclusion from analysis? How was this issue dealt with, if so?

5) **Bias due to measurement of outcomes**
- Can readers be confident in the assessment of the outcome?
- Were the methods of outcome assessment comparable across intervention groups?

6) **Bias due to selection of results**
- Was there missing and incomplete information? Was this handled well?
- Were there any other potential threats to internal validity (e.g., inappropriate statistical methods)?

3.5 CODING RELIABILITY

As described above, to ensure that the decisions made for inclusion/exclusion in the systematic review were unbiased and consistent for Database 1, the research team used double coding. Two primary coders first coded all the documents, and a third coder randomly selected and reviewed a sample of 30 percent of the above. Any discrepancies in coding were closely examined and reconciled. In all cases, the decision to include or exclude the study in the systematic review was consistent.

All studies (100 percent) selected for inclusion in the systematic review (Database 2) were double-coded using the same method to ensure accurate effect sizes. Coders discussed and reconciled discrepancies to ensure reliability. All decisions on whether to include studies in the systematic review were consistent, and coders were in agreement.

The above search and coding strategies resulted in the following number of studies in each database as displayed in Figure 1.

Figure 1. Databases Used to Develop the Systematic Review

1: Data Collection

(150 + Studies)

2: Systematic Review

(15 Studies)

3: Meta Analysis

(3 Studies)

Systematic Review of the Effects of Rural Roads Interventions on Agricultural Outcomes
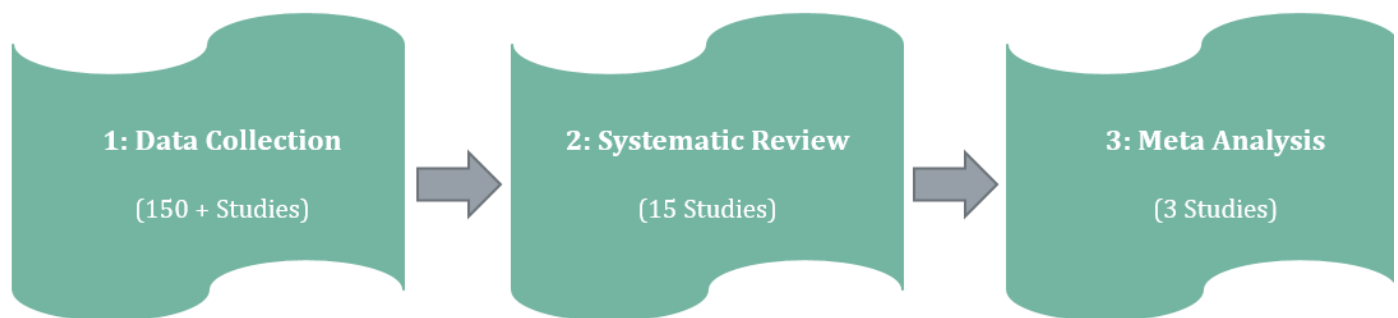
3.6 EXAMPLES OF STUDIES INCLUDED IN THE SYSTEMATIC REVIEW

In order to be included in the systematic review, studies had to meet all six of the PICOS-based criteria discussed earlier in this review: subject area, type of intervention, outcome, study type, time/duration of the study, and study population. As such, all studies included in this systematic review include a discussion of the impacts of road interventions on rural populations in developing countries for at least one of the listed outcomes (income, transport costs, crop production, crop yield, prices, market access, adoption of modern farming technology, poverty, transportation time, and cropping patterns). Further, the studies needed to be rigorous in design and analysis, include a counterfactual to attribute effects to the intervention, use an adequate sample size and length of study, analyze data using appropriate statistical methods, and have been published or made available after the year 2000.

SI came across many qualitative studies, including a small number of qualitative systematic reviews of the effect of roads on agriculture (Knox, 2013 and Spratt, 2012). However, USDA asked SI to exclude studies that were qualitative in nature from the systematic review, which eliminated the vast majority of papers found during the search. Nonetheless, SI reviewed these papers in search of references to quantitative studies and to examine commentaries on such studies. These papers helped to inform recommendations and gaps in the existing literature.

3.7 EXAMPLES OF STUDIES EXCLUDED FROM THE SYSTEMATIC REVIEW

Studies that failed to meet SI's established inclusion protocol discussed above were excluded from the systematic review. Examples of papers that were excluded include non-agriculture-related interventions, qualitative studies, quantitative studies lacking counterfactuals, and studies that did not seek to identify attribution of outcomes.

The requirement that all studies recommended for inclusion in this review be rigorous quantitative evaluations with a clear attribution severely limited the number of studies and eliminated many studies that are often quoted in the literature on agricultural roads interventions. Due to the challenges road interventions present (endogeneity of road placement), and the high cost of road projects and their evaluation, the majority of studies that met the inclusion criteria were official evaluations conducted by researchers funded by major donors under roads projects, rather than unsolicited work of independent researchers.

Often, the studies published in journals and university sites were not evaluations of a particular road intervention, but rather correlations of various measures of road density or access and a range of outcome variables, particularly poverty and welfare. For example, Gibson's 2003 study in Papua New Guinea is often cited in roads literature as support for the positive impact of infrastructure on poverty, but was not included in this review because it used a rough measure for road access and had no counterfactual to infer attribution to roads. Gibson measured road access by asking village leaders how long it took to walk to various locations, and did not identify a control or comparison group to infer impacts.

SI also came across a number of studies that looked at population-level outcomes of road interventions such as national poverty, health, and education rates rather than outcomes focused on agriculture or farmers. Because these studies were not sufficiently related to agriculture, they did not meet the criteria and were also excluded.

3.8 DETERMINATION OF INDEPENDENCE OF FINDINGS

Some studies included the same outcome measured using various definitions or techniques. In other cases, studies included multiple measures of profit for different crops or at different points in time. Khandker (2011), for example, included price statistics for three different output crops as well as input price statistics. SI used the following protocol, approved by USDA, to determine which outcome to use in such instances, as discussed below.

When there were multiple points in time for measurements of the same outcome in the same study, the team selected the latest measurement using the most rigorous methodology. When there were multiple measures of the same outcome, the more rigorous measure was used. If none was clearly more rigorous, the factor identified by the study authors as more rigorous was selected.

To illustrate the application of the selection criteria to assure independence of findings, we provide examples here. While Casaburi (2013) reported changes in transport costs measured both in terms of the travel fare (per km) and the average speed (km/hour), only travel fare was included because it was the most similar to our definition of transport costs and was the most consistent with outcomes from other papers. In another case, NORC (2013) provided many different measurements of income including income from labor-market employment in the agricultural and non-agricultural sectors, as well as both common proxies: consumption and expenditure. In this case, SI included agricultural income because it was the primary intended outcome to measure as opposed to a proxy.

Khandker conducted a study that included both midterm (2009) and endline (2011) evaluations of the RRMIMP project in Bangladesh. Both evaluations included the outcomes of incomes and transport costs. SI chose to report the income variable from the 2011 study because it was more recent and provided a better indication of long-term outcomes. For transport costs, however, the outcome variable was measured differently in the midterm and endline reports. The midterm report examined year-round average transport costs, while the endline reported these costs for the rainy season only. Both of these measures are included in the discussions below.[9]

Additionally, in cases where the same author has written multiple papers, the following criteria was used to avoid redundancy or misrepresentation: If an author wrote multiple papers on the same region and outcome, only the latest paper with the most rigorous methodology was included. Escobal,

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[9] Although both results are discussed in the narrative, only the results from the midterm were included in the meta-analysis, since it was the most comparable across other studies.

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for example, wrote several papers on Peru, but only the latest one with rigorous methodology was selected for the review.

3.9 ANALYSIS METHODS

Using the 15 studies identified for the review, we summarize the findings on effects of roads on several farmer outcomes and present the results with summary discussions supported by relevant data shown in tabular and graphical formats. Some systematic reviews additionally include quantitative analysis, called meta-analysis. For each of the farmer outcomes examined, we found that only a few studies met the criteria for inclusion in meta-analysis[10]. Meta-analysis requires at least five studies under each category such that data can be summarized into a single statistic to represent effect sizes, and many more studies to run regressions to quantitatively examine differences in effects due to moderators such as regional/country context, income status, etc. Therefore, we present illustrative meta-analysis results in Section 6 on the two outcomes that are discussed most extensively in the reviewed papers and for which relevant data are available. Due to the limited number of studies, the meta-analysis results in this review should be interpreted with caution. In the future, as more rigorous studies are conducted on effects of roads interventions, such meta-analysis could be conducted to better understand effect sizes of roads interventions.

3.10 METHODOLOGICAL LIMITATIONS

3.10.1 Selection Bias

Due to the endogenous nature of roads, program placement bias was common in the studies reviewed. Therefore, SI carefully reviewed all the papers (with a checklist developed by SI) for the design and statistical analysis methods used by the authors to minimize the bias, and only included those that were found to be rigorous. This, however, reduced the number of studies included in this review.

3.10.2 Multiple-Treatment Bias

A few of the studies included in the systematic review may have been biased due to confounding variables otherwise known as multiple-treatment bias. In these studies, there was an additional component to treatment, other than roads, that confounded findings. For example, in Dercon's 2009 study in Ethiopia, he looked not only at the effect of road rehabilitation, but also at whether a household had received a visit from an extension officer.

3.10.3 Missing Data Bias

In terms of missing data, there were two main issues that may have led to a small amount of bias. The first is that many authors listed the overall number of observations but did not report on the breakdown between the treatment or comparison groups. SI contacted the authors for such missing data. While several authors responded, others did not. In cases in which no response was received,

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[10] Most studies did not include data on overall standard deviations, which are needed to conduct a meta-analysis.

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SI assumed that the total number of observations was split equally between beneficiary and comparison groups, as this is the most commonly used sampling strategy. Any bias arising from this issue would be small and not likely to substantially alter outcomes. The second issue is that a number of studies did not provide sufficient information to calculate the pooled standard deviation. Again, SI contacted the authors and got responses from a few, but not many. Therefore, SI used the overall standard deviation, which is a very close proxy of pooled standard deviation. Despite SI's adjustments, there were only a few studies with the required quantitative data on key outcomes such as income and transport costs that could be aggregated using meta-analysis. This limited SI from conducting a meaningful meta-analysis.

3.10.4 Missing Studies

SI conducted a wide search of all relevant websites and contacted several authors who have conducted research on roads to locate relevant published and unpublished studies in four major languages (English, Spanish, Portuguese and French) to include in the review. However, it is possible that the team missed studies that are yet to be completed and in languages other than the four noted which may have influenced the findings reported in the review. Additionally, many studies that have not yet been conducted are "missing" in the sense that they represent gaps in the literature. However, the research team is confident that its search was as comprehensive as possible.

4 FINDINGS: TYPES OF INTERVENTIONS AND EVALUATIONS

A total of 15 studies were included to arrive at the findings presented below. All 15 studies used non-experimental designs (experimental designs (randomized controlled trials) do not exist to date in the literature on rural road interventions). The study designs included difference-in-differences, propensity score matching, regression discontinuity, and instrumental variables.

The regional breakdown of studies in this systematic review was nearly evenly distributed between South Asia (five), Sub-Saharan Africa (four), and Latin America (four), with additional studies located in East Asia (one) and Eastern Europe (one). The systematic review also includes studies of interventions in low-income, lower-middle-income, and upper-middle-income economies, as classified by the World Bank, with the majority of studies being conducted in lower-middle-income countries. The most commonly studied countries included Bangladesh, Ethiopia, and India, all of which had at least two published studies on interventions in their countries. The clustering of papers in a few countries suggests that there may be gaps in the literature.

4.1   INTERVENTION TYPES

In terms of types of interventions, the majority of the papers examined for this review included interventions related to rehabilitation of existing roads. There were also studies that focused specifically on feeder road rehabilitation and the construction of new roads. It is worth noting that often, interventions were a combination of rehabilitation and reconstruction, depending on the condition of roads in the area under treatment. The road interventions included in this systematic review generally fall into three categories as described below. Details about the number of interventions that fall into each category are also included in Table 1.

4.1.1   Rehabilitation of Existing Roads

Road rehabilitation interventions focus on improving the quality of rural roads through upgrading existing gravel or dirt roads to bitumen surfaced roads that can be classified as all-weather roads. These interventions are usually targeted at specified segments of road near productive village clusters and take several years to complete.

This systematic review included more studies that focused on the rehabilitation of existing roads than any other category, with nine of the fifteen studies falling into this group. Although rural road rehabilitation is a long-term investment that affects populations beyond farm households, the papers SI reviewed that fell into this category focus on areas or communities in which farming was the primary livelihood. These studies also recommended a number of pathways through which rehabilitation of rural roads could reasonably be expected to affect agricultural outcomes, including reductions in vehicle operating costs and reduced travel time and cost, all of which serve to enhance farmers' access to markets.

4.1.2   Rehabilitation / Construction of Feeder Roads

Feeder road rehabilitation and construction interventions focus on "last mile" challenges[11] to market access by improving or constructing roads that connect rural areas to local markets. As Casaburi (2013) noted, rural markets in many economies in Sub-Saharan Africa are not well integrated, and both farmers and traders have to travel long distances to engage in trade. A World Bank Background Paper on African Infrastructure noted that since 2000, major feeder roads rehabilitation programs have been implemented in Cameroon, the DRC, Ghana, Mozambique, Sierra Leone, and South Sudan, among other countries in Sub-Saharan Africa (Carruthers et al., 2010).

Five of the fifteen papers included in the systematic review focused specifically on feeder road rehabilitation and construction and its effect on farmers' outcomes. Kingombe (2012), for example, examined the effects of a large feeder road rehabilitation and maintenance program on the productivity of cash crops in Eastern Zambia.

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[11] "Last Mile" challenges refer to the difficulty of selling inputs to or sourcing commodities from smallholder farmers, who are geographically-dispersed and poorly connected by low quality roads.
https://www.microlinks.org/sites/default/files/resource/files/Scaling_Impact_Output_Markets_Report.pdf

4.1.3   Construction of New Road Networks

Construction of new road networks is, understandably, an intervention less common than rehabilitation due to the enormous cost and government support needed for construction. Only one study included the construction of new road networks as its primary focus. Bell's 2012 study of the Government of India's *Pradhan Mantri Gram Sadak Yojana* (PMGSY) project examined the extensive road construction project, which had as its goal an all-weather road connection for all of India's habitations with populations exceeding 500 persons (250 in hilly and desert areas) by 2015. The study examined how construction of new roads and the resulting improvement in market access affected rural farmers' outcomes.

As mentioned previously, some studies included a combination of construction and rehabilitation due to the unique needs of the roads under consideration. Ali (2011) examined a feeder road paving program in Bangladesh that upgraded 47 feeder roads that connected growth center markets to bitumen surfaces. The project also involved the construction of culverts and small bridges to connect existing road networks. Ali found that the improved roads enhanced farmers' access to input and output markets and led them to increase production of high yield variety rice, which signifies an adoption of improved farming technology.

The number of studies under each type of intervention is listed below in Table 1.

Table 1. Number of Studies by Type of Intervention

4.2   STUDY DESIGN TYPES

Type of Intervention	Number of Studies	Percentage of Studies
Rehabilitation of Existing Roads	9	60%
Feeder Road Rehabilitation / Construction	5	33.3%
Construction of New Road Networks	1	6.6%
Total:	**15**	**100%**

All 15 studies used quasi-experimental designs. As discussed earlier, due to the endogenous nature of road rehabilitation and construction projects, there are no experimental design studies in roads literature to date. Among the 15 studies, the most popular method was difference-in-differences (DiD), sometimes combined with matching techniques such as propensity score matching (PSM). DiD focuses on differences in outcomes over time between project and non-project groups, but assumes equal trends in underlying characteristics in those groups, which is why matching techniques such as PSM are also applied. DiD in combination with PSM has become an increasingly common method for evaluating roads projects because it takes into account endogeneity concerns. As Kingombe (2012) noted, DiD controls for time-invariant observable and unobservable variables and addresses time invariant selection bias, but initial conditions can still influence subsequent changes in the outcome variable of interest, which is why PSM is also used to select the best possible comparison communities.

Six of the fifteen studies included in this systematic review used a simple difference-in-differences design to determine the impact of rural road interventions on farmers' outcomes, while another two used a combination of difference-in-differences with propensity score matching. One study used simple propensity score matching, one used regression discontinuity, one used a before-and-after design, and one used a time series design. Two studies, an original and its replication, used instrumental variable design, and one study used an innovative continuous treatment variable design which allowed villages to be classified not strictly as treatment and control, but rather in varying degrees of treatment relative to their location to improved roads, to allow for spillover effects from the roads.

4.3 GEOGRAPHIC COVERAGE

As displayed in Table 2, the geographic distribution of studies was almost evenly split between South Asia, Sub-Saharan Africa, and Latin America. There was some clustering of studies in a handful of specific countries, including Bangladesh, Ethiopia, and India.

Table 2. Studies by Country and Region

Region/Country	Number of Systematic Review Studies	Percentage of Studies
East Asia & Pacific	**1**	6%
Vietnam	1	6%
Latin America & Caribbean	**4**	26%
Nicaragua	1	6%
Honduras	1	6%
Peru	1	6%
Brazil	1	6%
South Asia	**5**	33%
India	2	13%
Bangladesh	3	20%
Sub-Saharan Africa	**4**	26%
Sierra Leone	1	6%
Ethiopia	2	13%
Zambia	1	6%
Europe & Central Asia	**1**	6%
Armenia	**1**	6%
Total	**15**	100%

4.4 COUNTRY WEALTH

Table 3, below, displays the studies according to country wealth. Two thirds of all the studies discussed in the systematic review examined lower-middle-income countries. Twenty percent of the

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studies examined low-income countries and the remaining thirteen percent looked at upper-middle-income countries.

Table 3: **Studies by Country Wealth Designation**

Country Wealth Designation	Number of Systematic Review Studies	Percentage
Low income	3	20%
Lower middle income	10	67%
Upper middle income	2	13%
Total	15	100%

4.5 TIMING OF PUBLICATION OF STUDIES

Figure 2 depicts the number of systematic review studies published or made available during the search period (2000 – present). Although the timeframe began in 2000, the SI research team did not find any relevant studies published earlier than 2002. The number of studies steadily increased, peaking in the year 2011, but remains high up to the present, with three studies published in 2015. Also worth noting is that while all the studies were published after 2000, some of the projects which they were evaluating understandably took place before 2000. The SI team also found pre-study announcements of studies on multiple donor websites[12] that appear to be highly relevant and which will likely be released in 2016; in short, there seems to be a continued research interest in this field.

Figure 2. Number of Studies included in the Systematic Review by Year Published

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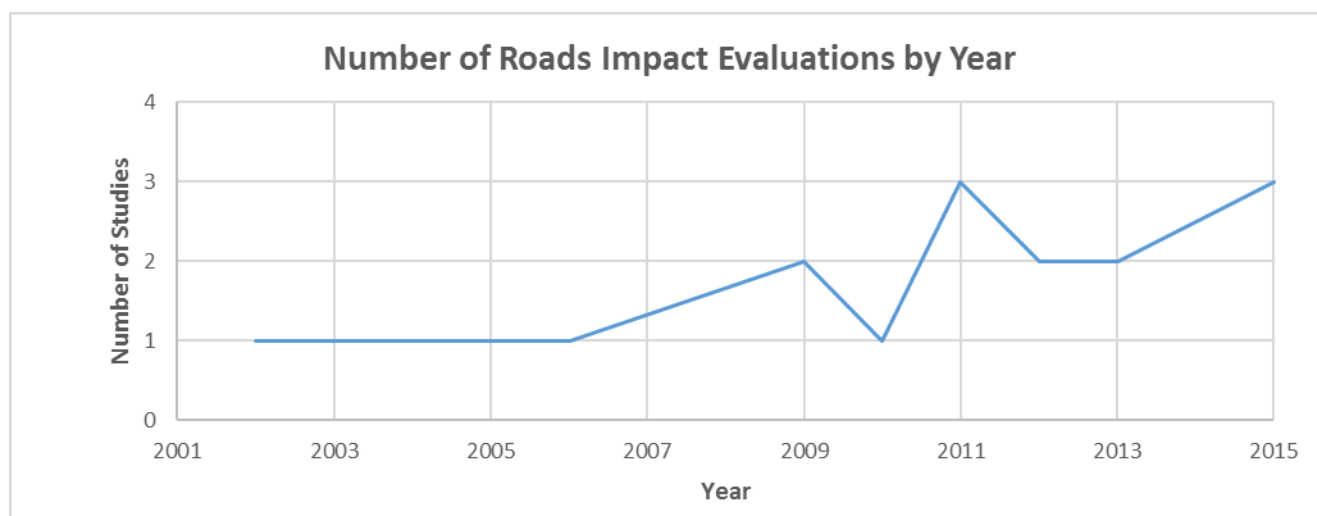
[12] The World Bank approved the Rwanda Feeder Roads Development Project in March 2014 with the objective of linking productive agricultural areas with marketing centers. It is too early in the project for an evaluation to have taken place, but the project objectives specifically include supporting monitoring and evaluation of the project. http://www.worldbank.org/projects/P126498/rwanda-feeder-roads-development-project?lang=en

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4.6 TABLE OF STUDIES BY OUTCOME

Table 4, below, displays the number of studies in this review that reported on each type of outcome. The table also lists the authors' names and years of publication for each of these papers, in addition to the study period, type of treatment, statistical design, and sign and significance of outcomes. The largest number of papers reported on income, followed closely by production/yield and prices. Fewer papers reported on transport costs, market access, transport time, and poverty rates and very few reported on the remaining outcomes, including cropping patterns and adoption of modern farming technology.

Table 4: Number of Studies by Outcome

Study Name	Location	Treatment	Income	Transport Costs	Production / Yield	Prices	Market Access	Modern Farming Tech	Poverty	Transport Times	Cropping Patterns	Statistical Design
Ali 2011 (Program Occurred 1995-1996)	Bangladesh	Feeder Road Rehab						Increase ** ⬆ Acreage dedicated to HYV rice 156.5				DiD
Khandker 2009 (Program Occurred 1995-1996)	Bangladesh	Feeder Road Rehab	Increase *** ⬆ % change in per capita expenditure (taka) 0.108	Decrease * ⬇ % change in transport cost (taka one way) -0.222	Increase *** ⬆ Laspeyres output quantity index 0.078	Increase *** ⬆ Price index of ag. output 0.031				Decrease *** ⬇ Time to nearest village market (minutes, one way) -0.357		DiD
Khandker 2011 (Program Occurred 1995-1996)	Bangladesh	Feeder Road Rehab	Increase *** ⬆ % change in per cap expenditure (taka)	Decrease *** ⬇ % change in transport cost (taka one way)	NS	NS						DiD

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Study Name	Location	Treatment	Income	Transport Costs	Production / Yield	Prices	Market Access	Modern Farming Tech	Poverty	Transport Times	Cropping Patterns	Statistical Design
			0.1	Rainy season -0.377								
Casaburi 2013 (Program Occurred 2009-2011)	Sierra Leone	Feeder Road Rehab		Decrease ** ⬇ Fare (Sierra Leonean Leones) per km -0.594		Decrease *** ⬇ Sierra Leonean Leones per cup Rice -.105 Cassava -.141				Decrease ** ⬇ Average speed in kph (speed increased so transport time decreased) 12.769		RD
Bell 2012 (Program started 2000 still ongoing, 2020 completion target)	India	Rural Road Construction		Decrease *** ⬇ Cost in rupees to transport 100 kg of rice 1 km 12.32		Increase ** ⬆ Paddy price (rupees per quintal) 7.95						Before/ After
Dercon 2009 (Surveys done in 1994, 95, 97,	Ethiopia	Rural Road Rehab	Increase *** ⬆ % change in consumption						Decrease** ⬇			IV

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Study Name	Location	Treatment	Income	Transport Costs	Production / Yield	Prices	Market Access	Modern Farming Tech	Poverty	Transport Times	Cropping Patterns	Statistical Design
99, and 2004)			growth 0.163						% change in poverty rate -0.069			

Study Name	Location	Treatment	Income	Transport Costs	Production / Yield	Prices	Market Access	Modern Farming Tech	Poverty	Transport Times	Cropping Patterns	Statistical Design
Mu 2011 (Program occurred 1997-2001)	Vietnam	Rural Road Rehab					Increase ** ⬆ probability of market being accessible (percent) 0.09					DiD/ PSM
Narayanamoorthy 2006 (Panel data 1970/71, 1980/81, & 1990/91)	India	Aggregate level of road improvement			Increase *** ⬆ Value of change in ag. output (Rupees per hectare) for a 1% increase in road coverage 46							Time Series

Study Name	Location	Treatment	Income	Transport Costs	Production / Yield	Prices	Market Access	Modern Farming Tech	Poverty	Transport Times	Cropping Patterns	Statistical Design
Mathematica 2015 (Program occurred 2007-2013)	Armenia	Rural Road Rehab	NS		NS	NS	Increase *** ⬆ Likelihood of household reporting no access problems (%) .20 overall		Increase * ⬆ Likelihood of household being poor (%) .10			DiD
Kingombe 2012 (Program occurred 1996-2001)	Zambia	Feeder Road Rehab			Decrease * ⬇ Cotton production (kilograms) -0.1629							DiD
NORC 2013 (Program occurred 2007-2012)	Honduras	Rural Road Rehab	Increase *** ⬆ Income (Honduran Lempiras per year) 71.9							NS		CTV

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Study Name	Location	Treatment	Income	Transport Costs	Production / Yield	Prices	Market Access	Modern Farming Tech	Poverty	Transport Times	Cropping Patterns	Statistical Design
Bowser 2015 (surveys done in 1994, 95, 97, 99, and 2004)	Ethiopia	Rural Road Rehab	Increase *** % change in consumption growth rate in short term 0.455						Decrease ** poverty headcount rate -0.0686			IV
Iimi 2015 (Program occurred 2006-2011)	Brazil	Rural Road Rehab and Bridge/ Culvert Construction	Increase *** Change in Household Income (Brazilian Real in the last month) 100.40 Real				Increase *** Distance to nearest populated place (km) 6.07 km			Decrease ** Travel time to nearest populated place (min) 12.93 mins		DiD/ PSM
Danida 2010 (Program Phase I occurred 1999-2004 and Phase II 2004-2009)	Nicaragua	Rural Road Rehab									NS	DiD

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Escobal 2002 (Program occurred 1996-1999)	Peru	Rural Road Rehab	NS									PSM
Total Number of Studies			8	4	5	5	3	1	3	4	1	

Note: ***, ** and * represent statistical significance of the results at 1, 5 and 10% levels, respectively. NS represents that results were not statistically significant at the 10% level.

PSM = Propensity Score Matching; DiD = Difference-in-Difference; IV = Instrumental Variable; CTV= Continuous Treatment Variable; RD= Regression Discontinuity Design

5 FINDINGS: EFFECTS OF ROADS ON FARMER OUTCOMES

The research team synthesizes the findings from the 15 studies included in this systematic review below by farmer-level outcome. In discussing effects, the research team categorizes study findings as statistically significant if the study author stated that results were significant at a 90 percent confidence interval level or higher.

5.1 TRANSPORT COSTS

Overall the studies showed that road interventions tend to reduce transport costs for farmers.

As shown in Figure 3, researchers found four studies that discussed transport costs as an outcome of rural road interventions. Most of these studies examined feeder road rehabilitation interventions, since feeder roads are designed to offer a direct link between productive agricultural areas and agricultural marketing centers. They are expected to lower transport costs for farmers buying inputs or taking crops to market, and for traders buying crops at the farm gate.

All four studies on transport costs analyzed the impacts of road rehabilitation interventions using multivariate regression models. Displayed below in Figure 3 are scatter plots of the t-statistics obtained from each of the four studies.[13] It is not a standard practice to compare t-statistics directly across different studies, because study designs and populations vary greatly, but the statistics help to display findings from the individual studies. An absolute value of t-statistics of about 1.8 or above on the positive side or 1.8 or below on the negative side indicates a significant variation in means between two groups (such as beneficiary and comparison groups). Therefore, the chart provides a good depiction of the findings for each of the three studies. The plots should be considered as a descriptive display of the significance of the results rather than a quantitative metric of the results. Nonetheless, it is clear that in all four studies, the road intervention groups significantly varied from

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[13] In statistics, the *t*-statistic is a ratio of the departure of an estimated parameter from its notional value and its standard error. It is the calculated difference represented in units of standard error. It is used in statistical hypothesis testing, and in the computation of confidence intervals. The greater the magnitude of the t-statistic (it can be either positive or negative), the greater the evidence for rejecting the null hypothesis that there is no significant difference between two groups. Also, the larger the absolute value of the t-value, the smaller the p-value, and the greater the evidence against the null hypothesis. Mostly, a t-statistic value of two and above translates to a smaller p-value. The key property of the *t*-statistic is that it is a pivotal quantity. Therefore, while defined in terms of the sample mean, its sampling distribution does not depend on the sample parameters, and thus it can be used regardless of what these may be.

the comparison groups that did not receive any intervention, and were highly correlated with lower transport costs. The results suggest that farmers were able to transport their crops to markets at lower costs when they had better feeder road access.

Figure 3. Strength of Findings on Roads' Impact on Transport Costs
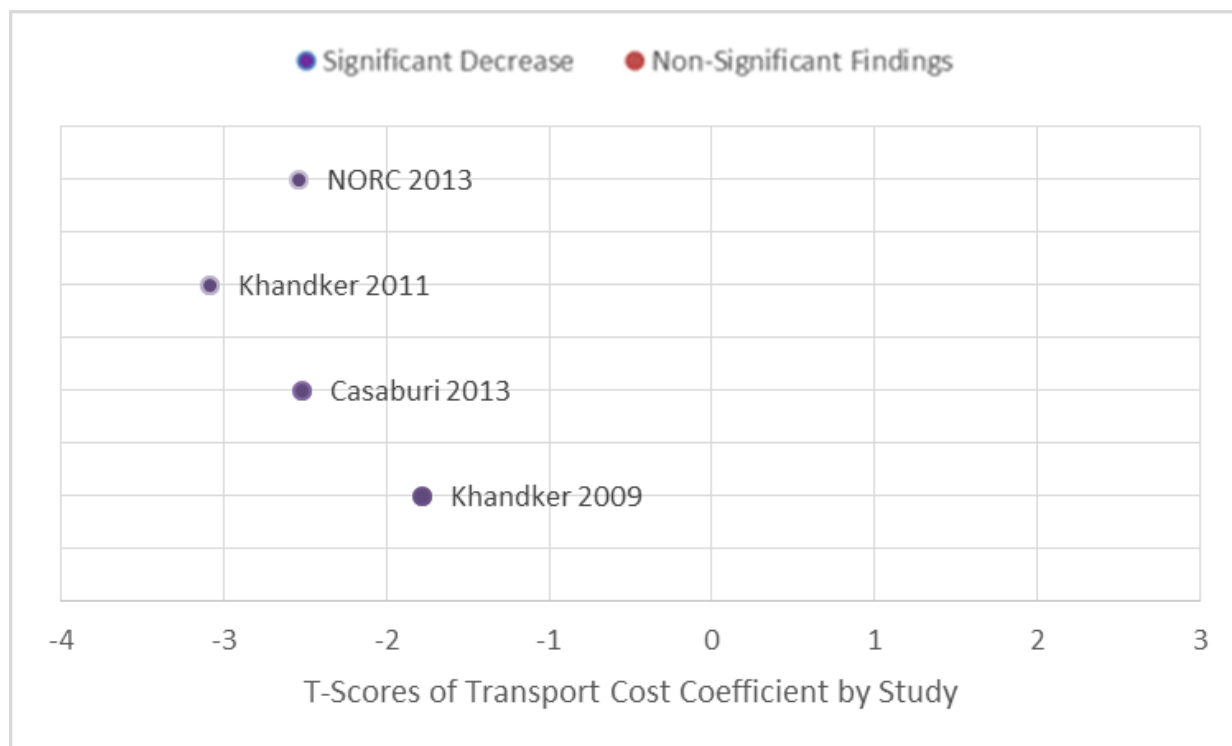
t-statistics are not directly comparable across studies, but they show whether findings are significant within each study. This scatterplot shows that 4 out of 4 authors found that Roads decreased transport costs with statistical significance.

The results were the strongest in Khandker's (2011) study of India's RRMIMP intervention which included improvement of 574 km of feeder roads constructed to bitumen-surfaced standard. The Khandker 2011 study was the endline evaluation of the RRMIMP project while the 2009 study was the midterm evaluation. While it is tempting to regard these results as the short term and long term effects of the feeder road program on transport costs, the author used different measurements of transport costs during both studies. While the 2009 study looked at the overall household transport costs for taking agricultural products to market, the 2011 study focused on transport costs during the rainy season when non-improved roads could become inaccessible. In this context it makes sense that the effect of all-weather feeder roads on transport costs would be greater during a season in which transporting goods on non-treated roads could become an expensive and potentially destructive task.

Additionally, Khandker's (2009) midterm evaluation of feeder road rehabilitation on overall transport costs showed that, on average, farmers reduced their transport cost per trip by 22%, significant at the 10% level. In the follow up final evaluation of the same project, the author examined the transport costs during both the dry and rainy seasons. He found that during the dry season, the

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effect of feeder road rehabilitation on transport costs was not significant, although the coefficient was negative in keeping with the program logic. However, during the rainy season, feeder road rehabilitation was responsible for a 38% decrease in transport costs for farmers bringing their products to market, and the results were highly significant at the 1% level.

Casaburi (2013) found similar results in his study of a feeder road rehabilitation project in Sierra Leone. The project targeted local dirt feeder roads, rehabilitating existing roads but not building any new roads. The roads rehabilitated were designed to link local markets to villages or to larger, more connected roads. Due to the unique selection criteria used to determine which segments of road would be rehabilitated, Casaburi was able to use a Regression Discontinuity[14] design to examine the impact of those feeder roads on transport costs. Using this method, Casaburi found that the feeder road rehabilitation led to a 59% decrease in transport costs per kilometer, and the result was significant at the 5% level. These results were based on a year-round average, and were not disaggregated by season, so they are more comparable to the results found in Khandker's 2009 study.

NORC's 2013 study of the MCC Compact in Honduras found that the rural road rehabilitation project led to a significant decrease in the cost to access the nearest market. This study measured impact based on the monetary reduction in costs, rather than on percentage change, so it is more difficult to directly compare results to the other studies discussed above. Nonetheless, all share the same result that the road projects led to reduced transport costs.

A summary statistic on the size of reduction in transport costs due to roads interventions, based on meta-analysis of two studies (Casaburi, 2011 and Khandker, 2009) is shown in Section 6. The meta-analysis shows that road interventions tend to lower transport costs with an overall effect size of 1.237 standard deviations, but with a very broad confidence interval spanning from -2.711 to 0.238. While both studies found a reduction in transport costs, the confidence interval was much broader in Casaburi's study than in Khandker's study. The results indicate wide variations which could have been affected by several factors beyond road construction and rehabilitation, and need further examination. As discussed above, the meta-analysis here should be interpreted with caution due to the very small sample of papers reviewed. As more studies become available, a more detailed analysis will be possible to explain variations due to several moderators, such as country contexts and more nuanced categories of intervention.

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[14] In 2003, the EU feeder road rehabilitation program conducted field investigations with local stakeholders which led to the identification of a base list of 47 rural roads eligible for rehabilitation, totaling about 800 km. The roads were then ranked on a scale comprised of (1) economic production per km, (2) population per km, (3) road condition assessment, (4) social value (availability of social services), and (5) length. The decision rule was that, in each district, roads would be rehabilitated starting with the highest-priority one (based on the score), following in order of decreasing score until as close to 150 km of road as possible was allocated to be rehabilitated in each district. This 150 km length marks the cutoff in the Regression Discontinuity design, as road segments that are just over and just under the total length limit should be similar in terms of underlying characteristics, making them appropriate treatment and control groups.

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5.2 FARMER INCOME

Overall the studies showed that road interventions tend to increase farmer incomes.

As shown in Figure 5, researchers found eight studies that discussed farmer income as an outcome of rural road interventions. Each of these studies examined either feeder road rehabilitation or more general rural road rehabilitation interventions. According to the theory of change associated with these types of interventions, they both should have a positive impact on farmer income, but through different causal chains. Feeder roads should have a larger effect on output-side determinants of income, such as crop prices and transport costs, due to the increased access to local markets, while wider-scale rural roads should have a larger effect on input-side determinants such as modern farming technology.

SI researchers reviewed a total of eight studies that examined impacts of road rehabilitation projects on farmers' income. Of the eight, six studies (75 percent) found that roads programs helped increase income with statistical significance of at least the 10 percent level.

NORC's 2013 study of the MCC Compact in Honduras found a positive effect of the road rehabilitation project on income from agricultural employment. Dercon (2009) studied the effect of road rehabilitation on consumption growth in 15 Ethiopian villages. The results from this evaluation suggested that improved roads had a strong positive impact on consumption, a common proxy for income. This study was frequently cited in the literature on roads, and drew attention from many policymakers and donors. Through its Replication Grant, the International Initiative for Impact Evaluation (3ie) funded another researcher, Bowser (2015), to replicate the study findings and further analyze the original data. It is to be noted that only one study included in this review on farmer income has been subject to replication to date. According to 3ie, their Replication Program is designed to disseminate replication studies that re-analyze the data from an original paper in order to validate the results, with the broader goal of improving the quality of evidence for use in policymaking and program design.

Dercon's study used a dummy variable of access to an all-weather road to test the effect of road quality on consumption growth. He found that access to an all-weather road increased consumption by 16.3%, with the results significant at the 1% level. In Bowser's replication study, in the pure replication section where he ran similar analyses on the same data collected by Dercon, he confirmed the above results and showed that under the key assumptions of slow changes in levels of capital stock and access to technology, access to an all-weather road increased consumption by 16.2%. Bowser further analyzed the data to examine the effects on consumption if these key assumptions were not met, and found that access to an all-weather road significantly increased the percentage change in the consumption growth rate by 45.5% in the short term, but did not have any statistically significant effect in the long term.[15]

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[15] Bowser called into question Dercon's use of a second order lag in the dependent variables, given to the presence of serial correlation in the levels of the idiosyncratic disturbances.

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Although the results of the replication study by Bowser (2015) are new and currently under review, the study underscored the importance of the length of time needed to detect impacts and impact sustainability. In the logic model of road interventions, income outcomes for farmers are usually considered to be long term, rather than short term, unless there is a bump in short term employment due to beneficiaries working on the road project itself, as sometimes happens. For example, Figure 4, below, shows a logic model of road interventions adapted from Mathematica (2015), which shows the relative timeframe for when outcomes would materialize.

According to this logic model, in the immediate aftermath of a road intervention, the better road quality leads to reductions in travel time and the cost to operate vehicles which will enhance farmers' access to markets in the short term. Lower transport costs then lead to greater access to inputs at cheaper prices as traders can access the market more cheaply, which then leads farmers to increase their production in the medium term. In addition to increased agricultural production, better road infrastructure leads to outside investment in beneficiary communities and employment opportunities, all of which improves household income and consumption and decreases poverty in the long term. Regarding the time frame of these outcomes, Mathematica (2015) suggests that reduced travel time and costs could materialize immediately after road rehabilitation, enhanced market access within several months, increased investment and production within two to three years, and increased income and reduced poverty in three or more years. It is therefore important to keep in mind these rough timelines when trying to detect certain outcomes, and to look at the follow-up period for each study for a possible explanation of why certain results do or do not materialize.

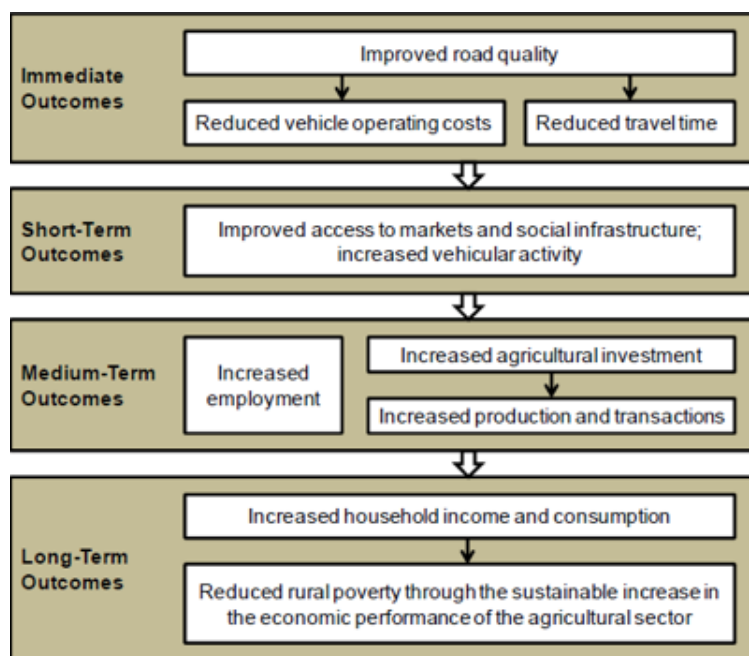**Figure 4: Logic Model for Road Interventions**

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Figure 5, below, displays a scatter plot of the individual *t*-statistics found in the regression analysis of each study. As previously mentioned, the plots should be considered as a descriptive display of the significance of the results, rather than a quantitative metric of the results. Quantitative summary statistics are discussed in Section 6 based on a meta-analysis of this outcome.

Figure 5: Strength of Findings on Roads' Impact on Income
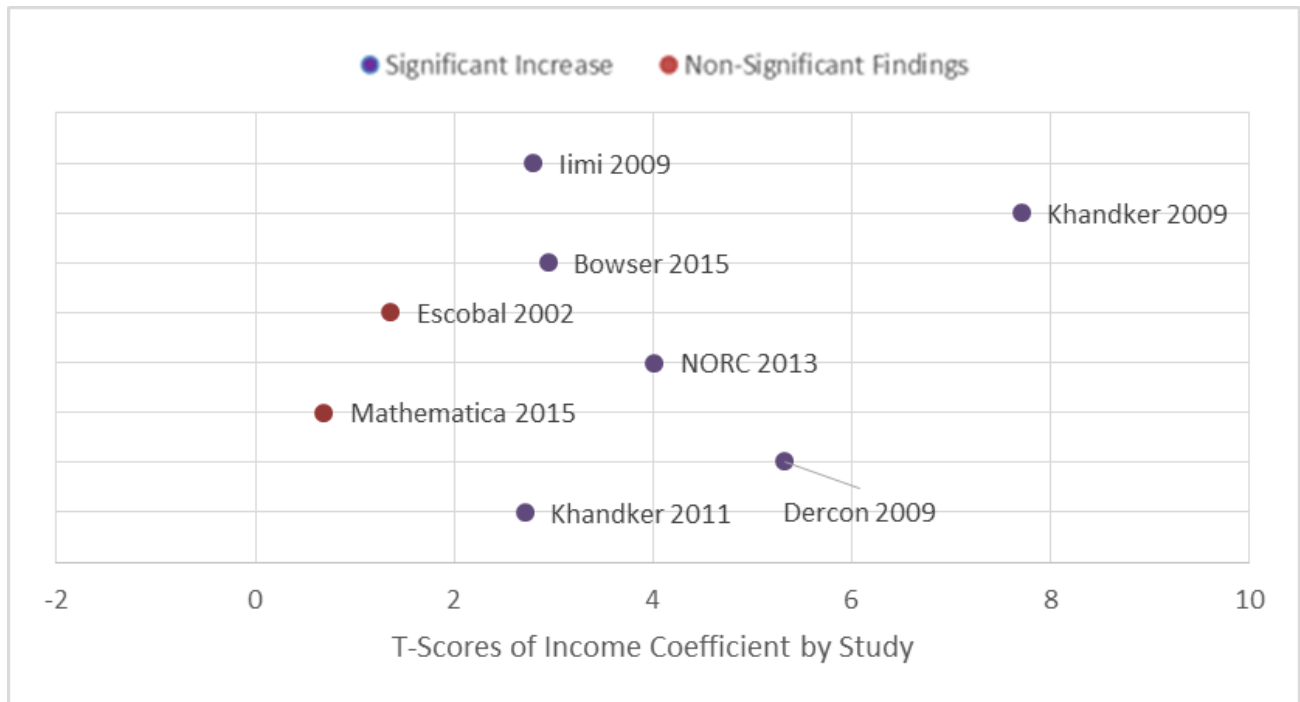
t-statistics are not directly comparable across studies, but they show whether findings are significant within each study. This scatterplot shows that 6 out of 8 authors found that roads interventions increased income with statistical significance.

As the chart above shows, only two of the eight studies on farmer income did not have a statistically significant result. Mathematica's 2015 study of the MCC-funded (and later World Bank-funded) Rural Road Rehabilitation Project in Armenia was among the two studies that did not show a significant effect on income. The project was initiated in areas where farmers grew fruits, vegetables, potatoes, grains, beans, and grass. The authors attributed the lack of positive results on income to a combination of the relatively long six-month agricultural cycles in Armenia, combined with only a one-year time lag for the evaluation to take place. Even though the project did lead to improved market access, a more direct short term outcome, there was simply not enough time for farmers' increased access to cheap inputs to have had an effect, as the farmer would have to wait until the following season to utilize any of those inputs. The authors estimate that a full transition to a new high-value crop would likely take several years to generate measurable increases in sales and income for farmers.

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A summary statistic on the impact of roads interventions on farmer income, based on meta-analysis of two studies (Escobal, 2002 and Khandker, 2011) is shown in Section 6. The analysis shows that road interventions tend to increase farmer income with an overall effect size of 0.609 and a relatively narrow confidence interval spanning from 0.537 to 0.680. Both studies found an increase in farmer income, and the confidence intervals for both were relatively narrow. The results indicate some consistency in effect sizes, which suggests that roads have a positive impact on farmer income. As discussed above, the meta-analysis here should be interpreted with caution due to the very small sample of papers reviewed. In the future, as more studies become available, a more detailed analysis will be possible to explain variations due to several moderators such as country contexts.

5.3 PRODUCTION AND YIELD

The studies showed mixed results on the effect of road interventions on crop production and yield.

The SI research team reviewed five studies that examined the effects of road interventions on agricultural production. The team found that in two of those studies, road interventions significantly increased agricultural production. In both studies, production was measured as an index of agricultural output. For example, Narayanamoorthy (2006) showed that a 1% increase in road coverage in India would increase agricultural output by 46 rupees of value (US$0.85, at 2015 exchange rates). The remaining studies showed negative results, but they were not statistically significant with the exception of Kingombe's 2012 study, which showed a significant decrease in cotton production as a result of a feeder road project. Kingombe also presented results on cotton yields, which reflected similar results as those found with cotton production. One potential reason for the difference in findings is that the studies that showed positive effects were looking at more general agricultural output levels, whereas the studies that showed negative or non-significant effects were focused on specific crops (such as cotton), which might be subject to more volatile swings in production depending on crop prices, weather, or other factors.

5.4 PRICES

The studies showed mixed results on the effect of road interventions on crop output prices.

Of the five studies that examined the effects of road interventions on crop prices, two found significantly positive results, one found significantly negative results, and two found no significant effects. The variations are based in part on relative market access between buyers (traders) and sellers (farmers), and the structure of the market. Relative market access affects price through the level of competition; more farmers gaining market access can increase competition and drive down prices, while increased competition among traders may lead them to offer higher prices to farmers. Alternatively, considering market structure, if farmers' market access increases, the wider variety of selling opportunities may enable them to raise their prices, and if traders' market access increases, they may bring an inflow of cheaper products into the market from elsewhere which push prices down.

Casaburi (2013) showed significant negative impacts on prices for rice and cassava, which are the two main staple crops produced locally on subsistence farms. Furthermore, Casaburi found that the price reduction was stronger in markets located farther away from main urban centers, and price reduction was weaker in markets that were located in more productive areas. He explained that this was due to the fact that more isolated areas have smaller, less competitive markets that are likely to suffer from inefficient pricing due to lack of access. In more productive markets strong demand exists for the crops that compensates for any other market inefficiencies that dampen prices.

5.5   MARKET ACCESS

Overall the studies showed that road interventions tend to increase market access for farmers.

All three studies that looked at the effect of road rehabilitation on market access found that market access increased as a result of the projects. Market access was measured differently by each author, but the results are similar. Iimi (2015) found that as a result of paved rural roads and construction of concrete bridges, the distance from farmers to the nearest populated place decreased by 6 kilometers. Mu's (2011) study on the Vietnam Rural Transport Project, which aimed to link commune centers to markets through the rehabilitation of 5,000 kilometers of rural roads, found that the probability that a farmer could access a market rose by 9% as a result of the project. Interestingly, Mathematica's 2015 evaluation of the MCC Armenia Compact was the only study to include sex-disaggregated data. It found that treatment households were 20 percentage points more likely than comparison households to report no problems with market access during a typical month with results significant at the 1% level; however, these benefits were not gender neutral. While male-headed households were 23% more likely to report improved market access, that number dropped to 12% for female headed households, and the results were significant at the 5% level. The study also found, however, that female-headed households were more likely to report using roads for other purposes such as visiting family and other non-income-generating activities, and that this positive impact was not present in male-headed households. While the authors make no attempt to explain this gender differential in terms of the use of roads and market access, this could be an indication of men being more involved than women in commercial agricultural production.

5.6   ADOPTION OF MODERN TECHNOLOGY

The one study that looked at adoption of modern technology found that road interventions increased the use of modern technologies.

Only one study looked at the effect of road interventions on the adoption of modern farming technology. Ali (2011) found that the Rural Development Project (RDP), which was a feeder road rehabilitation project in Bangladesh, increased the adoption of improved crop inputs. Specifically, he found that the project increased the number of acres dedicated to High Yielding Variety (HYV) rice. The main channel through which this increase in technology adoption was achieved was a significant reduction in transport costs related to crop production.

The study indicated that although improvement in access to markets and extension services, as a result of rural road rehabilitation, encouraged substitution of local rice for HYV, farmers did not completely substitute local for HYV rice production. However, road improvement seemed to encourage those who were growing only local variety before the project to grow both local and HYV. Those who still grew only local rice after the project tended to increase acreage for local rice. The author concluded that these results suggest that substantial reduction in production-related transport expenses encouraged intensification of production through technology as well as an increase in total acreage for crops.

5.7 POVERTY

Overall the studies showed that road interventions tend to reduce poverty.

The SI research team reviewed three studies that examined the effects of road interventions on poverty. The team found that in two of those three studies, road interventions significantly decreased poverty while the other showed no significant results. The two studies that showed reduction in poverty included the original study by Dercon (2009) and its replication by Bowser (2015), and may be considered as one study. Nonetheless, both found that the poverty headcount rate reduced by 6.86% as a result of increased access to an all-weather road. The third study by Mathematica (2015) showed an opposite result, in that treatment households were 10 percentage points more likely to be poor than comparison households (p=.06), and that this effect was increased for male-headed households who were 13 percentage points more likely to be poor. The authors suggested there was no compelling reason behind these results; however, they also repeatedly cited the short time period of this study, which was undertaken soon after the end of the project. Poverty is a long term effect that takes many years after the end of a project to materialize. Studies undertaken soon after the end of a project are unlikely to capture the true effect of the road intervention on poverty, though they might pick up on short term employment boosts that are unlikely to lead to sustainable poverty reduction.

5.8 TRANSPORTATION TIME

Overall the studies showed that road interventions tend to reduce transportation time for farmers.

Of the four studies that looked at the effect of road interventions on transportation time, three showed significant reductions in the time to get to market areas, while the fourth showed no significant results. Casaburi (2013) found that as a result of feeder road rehabilitation in Sierra Leone, average speeds on those roads increased by 12.8 km per hour, which would naturally lead to a reduction in the travel time to reach markets. Similarly, Iimi (2015) found that the transport time in minutes to the nearest populated place reduced by 12.9 minutes as a result of road rehabilitation and construction of bridges in rural Brazil. Khandker (2009) found a significant reduction in the transport time to the nearest village as a result of a road rehabilitation project in Bangladesh. NORC (2013) found that although the trend was negative, there was no significant effect of improved road access

on the transport time to market, measured as the number of minutes of travel time reduced per unit change in the average travel speed to the nearest town of 1,000 inhabitants in Honduras. The authors did not offer any explanation for why this result was not significant.

5.9   CHANGES IN CROPPING PATTERNS

The studies did not show any significant results of road interventions on cropping patterns.

Only one study looked specifically at changes in cropping patterns as a result of rural road rehabilitation. Danida (2010) found that households within both treatment and comparison communities reduced the diversification in terms of number of crops grown for market sale, but that the difference between the two groups was not significantly different. Bell (2012), based on qualitative analysis from field group discussions, suggested that the provision of an all-weather road prompted a cropping pattern switch to more commercial crops, including a reduction in the number of acres dedicated to pulses and oilseeds, and an increase in the number of acres dedicated to paddy and cotton.

5.10 SUMMARY TABLE OF FINDINGS

Table 5: Trends for Significant Effects for Outcome Measures

Outcome	Trend in Significant Impact		# of Studies that Show Significant Trend	Total # of Studies	% of Studies w Significant Findings
Income		↑	6	8	75%
Transport Costs		↓	4	4	100%
Production & Yield	Case A	↑	2	5	40%
	Case B	↓	1	5	20%
Prices	Case A	↑	2	5	40%
	Case B	↓	1	5	20%
Market Access		↑	3	3	100%
Adoption of Modern Farming Technology		↑	1	1	100%
Poverty		↓	2	3	66%
Transportation Time		↓	3	4	75%
Changes in Cropping Patterns	Not Significant		0	1	0%

6 META-ANALYSIS

6.1 STATISTICAL PROCEDURES USED IN META-ANALYSIS

SI applied a two-step meta-analysis methodology to calculate figures for the four studies included in the meta-analysis section of this report. First, SI calculated a summary statistic (including averages, standard deviations, and standard errors) for each study in order to describe the intervention effect. Since all studies included in the meta-analyses were reporting results as continuous rather than discrete/binary outcomes, the research team calculated the standardized effect sizes by assessing the differences in means between the beneficiary and control or comparison groups. In doing so, the team followed Lipsey and Wilson's (2001) well-established practice in conducting meta-analyses and calculated the standardized mean differences (Cohen's d) for the two continuous outcomes – income and transport costs.

The Cohen's 'd' statistic is the most appropriate statistic for measuring effect sizes through group differences (between beneficiary and comparison groups) in mean levels of continuously measured outcomes, and is expressed in units of standard deviations. Researchers entered the information needed to calculate Cohen's 'd' into the Comprehensive Meta-Analysis (CMA) software,[16] then calculated the pooled-effect size as a weighted average of the intervention effect calculated above, with the weights assigned based on the standard error for continuous outcome studies. Because of the presumed heterogeneity in different interventions, populations, and countries, researchers used a random-effects model to produce the pooled effect from all the individual studies. The team then used the CMA software to depict the above information, individual effects, and pooled effects through forest plots.

SI entered the data for calculating Cohen's 'd' into the CMA software, which produced Cohen's 'd' values with confidence intervals for each study. Cohen's 'd' values can be compared across studies, but interpreting them can be somewhat ambiguous. Unlike t-statistics, which have a definitive interpretation related to standard deviation, Cohen's 'd' values have no such direct interpretation.

In cases where there were missing data, SI contacted authors by e-mail. Up to three follow-ups were made within a period of three months to obtain the missing data. The data most commonly missing related to the pooled standard deviations of the outcome variables for beneficiary and comparison groups. In cases where the pooled standard deviation was not available in the study or from the authors, the overall standard deviation was used as a very close proxy. If the overall standard deviation was also unavailable and could not be obtained from the author, the study was dropped from the meta-analysis.

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[16] See Appendix 5 for more information on how the research team calculated Cohen's 'd.'

6.2 TRANSPORT COST SUMMARY STATISTICS

Two studies were available for inclusion in the meta-analysis of transport costs. These studies are included in Table 6, below, along with their effect sizes expressed in standard deviations as Cohen's 'd' values and confidence intervals:

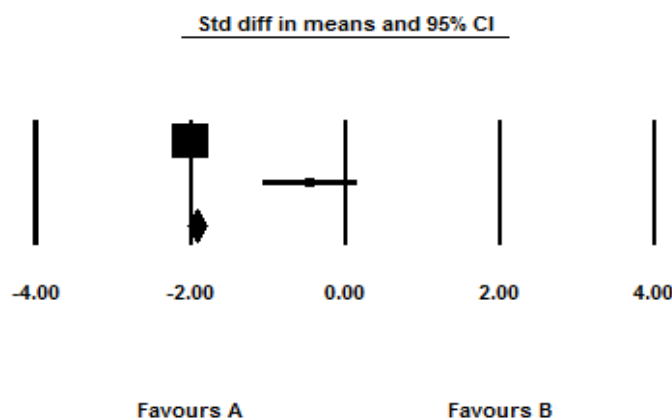**Table 6: Transport Cost Meta-Analysis Statistics**

Study	Standardized Difference in Means (D Values)	Standard Error	Lower Limit	Upper Limit
Casaburi 2013	-.457	.307	-1.059	0.145
Khandker 2011	-2.000	.071	-2.138	-1.862
Summary Statistic	**-1.258**	**.771**	**-2.768**	**0.253**

Using Comprehensive Meta-Analysis Software (CMA), SI generated the forest plot depicted in Figure 6, below,**Error! Reference source not found.** which shows changes in transport costs due to roads interventions. The plots reflect effect sizes as the standardized mean differences, calculated using the methodology discussed in Appendix 5. The confidence intervals are based on an inverse weighting of the pooled standard deviation within each study. This means that more precise outcome measurements were weighted more heavily than those that were less precise. As specified in the Campbell Collaboration method, all forest plots and meta-analyses were based on random effects models due to the high degree of heterogeneity.

Generally, the road interventions appeared to lower transport costs, but not always, as the overall effect size was -1.237 but the confidence interval band encompassed zero. While Khandker's 2011 paper has a negative effect size with a confidence interval that doesn't include zero, Casaburi's 2013 paper, although having a negative effect size, also has a confidence interval that includes zero.

Due to the very small number of studies with sufficient information to include in the transport cost meta-analysis, the team has refrained from analyzing the moderators for transport cost.

Figure 6. Transport Cost Forest Plot

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6.3 INCOME SUMMARY STATISTICS

SI found two studies that met the criteria for meta-analysis of income-related road-intervention outcomes. These studies are listed in Table 7**Error! Reference source not found.** along with their effect size and confidence intervals:

Table 7. Income Meta-Analysis Statistics

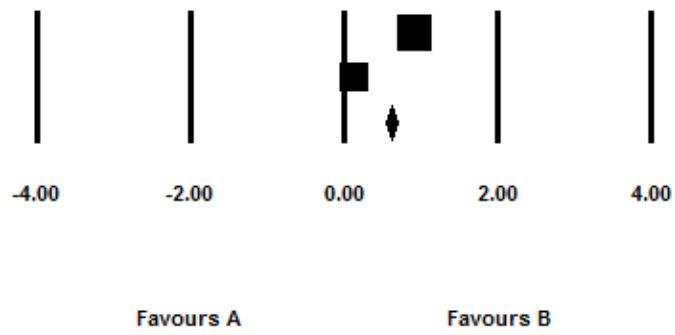| Study	Standardized Difference in Means (D Values)	Standard Error	Lower Limit	Upper Limit
Khandker 2011	.128	.059	.014	.243
Escobal 2002	.913	.047	.821	1.004
Summary Statistic	**.609**	**.036**	**.537**	**.680**

The research team used CMA to generate the forest plot depicted in Figure 7, which shows changes in farmer agricultural incomes due to road interventions. Just as in the meta-analysis for transport costs, the plots reflect effect sizes as the standardized mean differences, calculated using the methodology discussed in Appendix 5. The confidence intervals are based on an inverse weighting of the pooled standard deviation within each study. This means that the more precise outcome measurements were weighted more heavily than those that were less precise. As specified in the Campbell Collaboration method, all forest plots and meta-analyses were based on random effects models due to the high degree of heterogeneity.

Generally, the road interventions appeared to significantly increase farmer income. The overall effect size was .609 and the confidence interval band did not encompass zero. While the lower limit of Khandker's 2011 study came close to zero, it still remained positive.

Due to the very small number of studies with sufficient information to include in the income meta-analysis, the team has refrained from analyzing the moderators for income.

Figure 7: Income Forest Plot

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Std diff in means and 95% CI

-4.00   -2.00   0.00   2.00   4.00

Favours A   Favours B

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7 CONCLUSIONS

7.1. KEY FINDINGS

Overall, most of the studies examined in this review concluded that road interventions do indeed have the potential to improve farmers' livelihoods by improving two intermediate outcomes. Road interventions commonly reduce transport costs and improve market access. Road interventions were also found to indirectly affect higher-level impacts, such as increasing farmer income.

Regarding transport costs, all the studies concluded that **road rehabilitation led to reduced transport costs for farmers.** This effect was most pronounced during the rainy season when non-improved roads may become impassable. Khandker, in studying impacts of road improvements on transport costs in Bangladesh, found positive results overall. When disaggregating the analysis by season, he found that results were very significant during the rainy season, but not significant during the dry season (2009; 2011). It is likely that farmers in areas with high levels of rain are more likely to benefit from road improvements than farmers in areas with less rain, at least in terms of reduced transport costs.

All studies, despite some variations in measuring market access, showed that **market access increased as a result of the projects.** However, there was some indication that the benefits were not gender neutral, in that male-headed households benefitted significantly more than female-headed households.

The results on effects of roads on output prices were mixed; among the outcomes discussed in this review, results for output prices varied the most. Of the five studies that examined the effects of road interventions on crop prices, two found significantly positive results, one found significantly negative results, and two found no significant effects. The variations appear to be partly driven by whether the road intervention was used by urban buyers or rural sellers in rural markets: use by urban traders tended to drive up prices in rural markets while use by farmers drives them down. Also, prices for rice and cassava changed with roads, and the price reduction was stronger in markets that were farther away from main urban centers and price reduction was weaker (not notable) in markets that were located in more productive areas (Casaburi, 2013).

Nearly three quarters of the papers that included income as an outcome concluded that **road rehabilitation led to increased income for farmers.** Lack of notable effects in the rest of the studies were associated with shorter time frames for the evaluation that did not allow time for the impacts to take effect, as well as type of crops (such as high-value crops). It was indicated in one study that although total income (agricultural and non-agricultural) increased, farmers did not allocate that income to consumption, but rather to savings (Escobal, 2002). The author suggests that

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income increases were not perceived by farmers as a change in their permanent income but only a temporary benefit before lack of road maintenance takes its toll.

7.2. GAPS IN THE LITERATURE

In conducting this systematic review, SI found a number of gaps in the existing body of research on the impacts of road interventions on income, transport costs, production, poverty, market access, prices, and transportation time, as discussed below.

7.1.1 Road Maintenance

While some of the interventions included complementary capacity-building activities with local governments and enterprises to ensure the continuation of road maintenance, there were no evaluations of the maintenance activities themselves. This is likely due to the fact that maintenance activities would be required years after the end of the project. Donors funding the intervention may not be willing to fund follow up evaluations years later, particularly since they are usually not responsible for the road maintenance. However, maintenance activities are just as important as the original construction or rehabilitation because if not properly maintained, the roads will deteriorate back to their original condition, necessitating another project.

7.1.2 Outcomes with Limited Studies

As mentioned in the sections above, SI found that there were very few studies on some of the key outcomes of interest for roads interventions—such as adoption of modern farming technology, yield, and changes in cropping patterns. Additional studies examining the effects of roads interventions on these outcomes could prove very beneficial to policymakers. Furthermore, studies on the effects of road interventions for prices are mixed. Casaburi suggests that road rehabilitation may allow the introduction of cheaper products into the local market that will compete with local agricultural products and could drive down prices. Additional research on how country context or other moderators affect impacts on price could be very useful and informative given the variation in findings (Casaburi, 2002).

7.1.3 Length of Study Periods

Most impact evaluations are conducted over short time frames that rarely exceed a few years. This is a problem in studying agriculture because crop cycles are slow, and it can take a long time to see effects on outcomes, especially outcomes related to income. Additional research on the long-term effects of road interventions may reveal greater impacts on beneficiaries, or at a minimum, enable researchers to examine the sustainability of results from road interventions.

7.1.4   Environmental Concerns

None of the studies included in this review discussed any environmental consequences, intended and unintended, caused by road construction and rehabilitation. However, construction and rehabilitation are known to lead to soil erosion and flooding.[17]

7.1.5   Political Risk

Although issues of political risk and collusion have occurred in some historical road improvement projects, none of the studies included in this review discussed any instances of this occurring in the evaluated projects. The only study that alluded to possible political risk was Mathematica (2015): MCC withdrew their original funding of a road rehabilitation project in Armenia due to concerns over the democratic governance of the country. The authors noted that the decision to withdraw funding was the result of a sharp decline in Armenia's political indicators following the government's response to protests over the 2008 presidential election. Studies on more macro-level outcomes of road interventions may be more likely to cover issues such as political risk, but discussion of this topic constitutes a gap in studies focused on agricultural outcomes.

7.1.6   Sex-Disaggregated Data

One initial goal of the review was to track the percentage of beneficiaries in each study who were female so as to disaggregate findings by sex. This became difficult because very few of the researchers provided sex or gender information for beneficiaries in their descriptive statistics. While many authors mentioned that regressions controlled for the sex of the respondent, few discussed sex-disaggregated findings or addressed deeper questions about the role of sex in the success of interventions. Additional research on this could help decision-makers better assess potential differences between the sexes and genders to target each appropriately.

7.1.7   Geographical Coverage

Some studies were clustered in a few specific countries. Countries that had more readily available data may be over-represented, while countries with less data may be under-represented. The research team found no studies in the Middle East, for example. To more fully understand what makes road interventions work, researchers need more studies worldwide on each of the outcomes.

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[17] While roads bring economic and social benefits, they can also come with social costs such as pollution or deforestation. The Amazon rainforest is crisscrossed by almost 100,000 km of roads—enough to circle the Earth two and a half times. The transport sector accounts for about 23% of global energy-related carbon dioxide emissions and a significant share of local particle pollution. Such tradeoffs need to be weighed when planning any road or transportation interventions (Berg, C., U. Deichmann, Y. Liu, and H. Selod (2015) "Transport Policies and Development," World Bank Policy Research Working Paper 7366. Nov. 2015).

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7.1.8 Language of Publication

Lastly, despite searching for studies in four different languages, SI found that almost all impact evaluations on the effect of road interventions on agricultural outcomes were written in English. Increasing the number of impact evaluations published in other languages could increase their usefulness for local policymakers. The excessive publication in English may indicate that researchers present to the academic community (which generally uses English) more often than they disseminate findings to local policymakers in the countries where evaluations are conducted.

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8 POLICY IMPLICATIONS

Lessons from the review that are of policy relevance are discussed below:

8.1 FOCUS ROAD PROJECTS IN AREAS THAT EXPERIENCE ADVERSE WEATHER

Areas that are susceptible to torrential rains and other types of adverse weather are likely to benefit more from access to an all-weather road than areas with milder climates. As found in Bangladesh, farmers significantly reduced their costs to transport their products to market when they had access to an all-weather-road during the rainy season, but there was no significant impact on costs during the dry season. This is likely due to the fact that farmers with access to only a dirt path or other non-all-weather road are unable to use these paths when there is inclement weather (or, the paths may become very expensive and time-consuming to travel). Therefore, when choosing potential project areas, *ceteris paribus*, the climate of the area should be taken into account and priority should be given to those areas that experience frequent rains that disrupt transportation.

8.2 INVEST IN ROAD MAINTENANCE

As discussed previously, none of the studies included in this review conducted an evaluation of road maintenance work; however, several discussed the importance of maintenance for the sustainability of road projects. Road maintenance is increasingly becoming a part of the planning process of roads projects as donor agencies work with local governments to plan for the future of the roads beyond the scope of the project itself. This is important, not only for sustainability of the benefits rural roads provide, but also as a method to enhance local government capacity.

8.3 SET REALISTIC TIMEFRAMES FOR EVALUATIONS

Road projects, by their nature, are an investment in a public good that will likely be completed only by a government or major donor agency and will take years to complete, even if everything goes according to plan. The time frame for conducting evaluations on the effects of these investments should therefore be conducted over time to allow any impacts to become visible. This is particularly true for longer-term outcomes, such as income and poverty reduction, which are major areas of interest for donors and government agencies. Studies that attempt to measure effects on income too soon after completion of a road project could be capturing effects of the temporary employment offered by the road project itself, rather than any sustainable changes affecting long-term poverty rates. Changes in income which are due to improved opportunities in agriculture, rather than temporary employment on a road crew, will take much longer to materialize. Additionally, a full transition to a new high-value crop or a new processed food would likely take several years to generate measurable increases in sales and income.

APPENDIX 1: SEARCH WEBSITES

WEBSITES:

- Websites: Google, Google Scholar, Scirus.com,
- World Bank IEG, World Bank Agricultural/Economic Office, World Bank Rural Development Research, IADB, ADB, AfDB,
- CIDA, DANIDA, AusAID, USAID DEC, FFPr, FFP, FAS, UNDP, DfID, FAO, GTZ, IFAD, OECD, CGIAR
- University of Nebraska-Lincoln, Kansas State University, Florida State University, Michigan State University, University of Northern Colorado, Tuskegee University, Arkansas Tech University, Florida State University, Cornell University, University of Minnesota Twin Cities, University of California-Davis, University of Massachusetts-Amherst, Tufts University, University of Wisconsin-Madison, University of Florida, Rutgers State University, Texas A&M, Penn State, Oxford University, Universite Libre de Bruxelles, Dissertation abstracts.
- AGRIS, CARIS, WTO, FEWSNET, IFPRI, MCC, 3ie, JPAL, IPA, Centre for Environmental Economics (CEE) and Policy in Africa, Transport Research Information Services (TRID), R4D, IFRTD (International Forum for Rural Transport Development),

Peer Reviewed Journals:

- World Development
- Journal of International Development
- Journal of Development Effectiveness
- Agricultural Economics
- The Journal of Development Studies
- Journal of Development Economics
- National Bureau of Economic Research
- Economic Development and Cultural Change
- Journal of Transport Economics & Policy Impact Factor Info.
- Research in Transportation Economics

APPENDIX 2: SEARCH TERMS

Keywords used for the searches followed PICOS format (Population, Intervention, Comparison, Outcomes, Study design). Combinations (or permutations) of the keywords were used to identify relevant studies. Further, searches were conducted through the reference lists and bibliographies of relevant studies.

POPULATION SEARCH TERMS:

South and South East Asia,
Eastern Europe
Middle East
Latin America
Africa
NIS countries (developed countries in these regions will not be included)
Rural populations
Farm households
Farmers
Agriculture
Agribusinesses

STUDY DESIGN SEARCH TERMS:

Impact Evaluation
Propensity Score Matching
Randomized Controlled Trial
Instrumental Variables
Difference in Difference
Panel Data Based Evaluations

INTERVENTION SEARCH TERMS:

Rural Infrastructure
Roads
Feeder roads
Bi-pass roads
Access roads
Arterial roads
Road networks
Road rehabilitation
Road extensions

COMPARISON SEARCH TERMS:

Control
Group
Comparison Group
Treatment Group
Comparator
Counterfactual

OUTCOMES SEARCH TERMS:

Income
Profits
Revenues
Output, crop & input prices
Market access
Market participation
Production, productivity
Yield
Crop area/type
Poverty
Expenditure
Consumption
Transport costs and time

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APPENDIX 3: SEARCH DETAILS BY SITE

No.	Website/Database	# of combinations searched	Notes
1	Google Scholar	145	Keywords 'rural' and roads' were used. Dates range from 2000 to present. Only the first 2 pages were coded.
2	World Bank	120	Filters were used to select only studies relevant to rural development. Results on first 4 pages were documented/analyzed. Under the Open Knowledge repository, search was conducted under Journals, technical papers and working papers.
3	USAID DEC	22	Under 'evaluations', all studies conducted after 2000 and relating to agricultural infrastructure were coded
4	MCC	28	Using 'roads' as the keyword, all evaluations conducted after 2000 were coded.

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No.	Website / Database	# of combinations searched	Notes
5	Bibliographies	NA	From the initial search results, bibliographies of studies that qualified for systematic review were mined and documented
6	IFPRI	25	'Agriculture and food production' was used as a filter
7	Journal of International Development	12	'Rural' and 'infrastructure' were used as filters. Only results on first page were documented
8	AfDB	8	'Rural' was used as filter
9	World Development	10	'Rural' and 'infrastructure' were used as filters.
10	ADB	34	Under 'evaluation documents' all rural infrastructure related studies were documented
11	EMBRAPA	17	No filters were used. Search terms used were in Portuguese language. The most basic search (single word, "estradas") yielded the most relevant results. Other combinations largely replicated results found in the initial simplified search where the single word "estradas" was used as a search term.
12	Google Scholar (Brazil)	2	No filters were used. Search terms used were in Portuguese language. Specific authors Mauro de Rezende Lopes and D.R. Freitas were among search terms used. No results for Database 2 were yielded.

No.	Website / Database	# of combinations searched	Notes
13	Economic Commission for Latin America and the Caribbean (ECLAC or CEPAL)	2	No filters were used. Search terms used were in Portuguese language. No relevant results were yielded from the search.
14	Centre for Environmental Economics (CEE) and Policy in Africa	1	Single search term "roads" did not yield any results.
15	TRID	1	No filter was used. The search yielded one relevant study that used rigorous methods. Additional search results besides the rigorous method study were included in Database 1.
16	IFRTD	1	No filter was used. A single search term, "impact evaluation," did not yield any results.
17	CIDA	4	No filter was used. The search for relevant publications yielded zero results.
18	AGRIS	3	No filter was used. Results yielded were actually duplicates of previous successful searches found at TRID.
19	CARIS	1	No filter was used. The search for relevant publications yielded zero results.

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No.	Website/Database	# of combinations searched	Notes
20	USDA/FAS	1	No filter was used. The search for relevant publications yielded zero results.
21	FEWSNET	2	No filter was used. The search for relevant publications yielded zero results.
22	University of Oxford	5	No filter was used. Original searches did not yield relevant results. Using the "Didn't find what you were searching for?" search box allows a search of all Oxford University websites.
23	University of Florida	5	No filter was used. One relevant article was applied to Database 1, excluding the remaining search results. No rigorous studies were found for Database 2.
24	Inter-American Development Bank	3	No filter was used. The search for relevant publications yielded zero results.
25	TRID	1	No filter was used. The search yielded one relevant study that used rigorous methods. Additional search results besides the rigorous method study were included in Database 1.

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APPENDIX 4: CALCULATING COHEN'S D

In statistics, Cohen's d is calculated as follows:

$$d = \frac{\bar{X}_T - \bar{X}_C}{s_{pooled}}$$

Where:

      d represents Cohen's d

      $\bar{X}$ represents the mean for the indexed group

      T represents the treatment (beneficiary) group

      C represents the comparison group

The numerator in the above equation represents the average difference between the beneficiary and comparison groups attributed to treatment.

Since almost all of the studies included in the meta-analysis used regressions with various controls to analyze data and display results, the research team used the regression coefficients for the numerator. In cases where there were multiple regression models, the team selected the author's primary model (where specified). If the primary model was not specified, as a general practice, researchers used the model with the maximum number of controls in order to minimize bias.

The denominator in the above equation is generally calculated using the following equation:

$$s_{pooled} = \sqrt{\frac{s_T^2(n_T - 1) + s_C^2(n_C - 1)}{n_T + n_c - 2}}$$

Where:

      n represents the number of observations in the specified group

      s represents the standard deviation of the outcome variable for the indexed group.

However, individual standard deviations were not available for the beneficiary and comparison groups in some papers. In such cases, researchers used the overall standard deviation as a close proxy.

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APPENDIX 5: BIBLIOGRAPHY

1. Iimi, A., Lancelot, E., Manelici, I., & Ogita, S. (2015). Evaluating the Social and Economic Impacts of Rural Road Improvements in the State of Tocantins, Brazil. *World Bank Group.*

2. Bakht, Z., Koolwal, B., & Khandker, S. (2006). The Poverty Impact of Rural Roads: Evidence from Bangladesh. *World Bank Policy Research Working Papers.*

3. Bell, C., & Dillen, S. (2012). How Does India's Rural Roads Program Affect the Grassroots? Findings from a Survey in Orissa. *World Bank Policy Research Working Papers.*

4. Berg, C., U. Deichmann, Y. Liu, and H. Selod (2015). Transport Policies and Development. World Bank Policy Research Working Paper 7366. http://blogs.worldbank.org/developmenttalk/how-roads-support-development.

5. Bowser, W. (2015). The long and short of returns to public investments in fifteen Ethiopian villages. *3ie Replication Paper 4.*

6. Casaburi, L., Glennerster, R., & Suri, T. (2013). Rural Roads and Intermediated Trade: Regression Discontinuity Evidence from Sierra Leone. *SSRN Journal.*

7. DANIDA. (2010). Impact evaluation of Danida support to rural transport infrastructure in Nicaragua.

8. Dercon, S., Gillian, D., Hoddinott, J., & Woldehanna, T. (2008). The Impact of Agricultural Extension and Roads on Poverty and Consumption Growth in Fifteen Ethiopian Villages. *IFPRI Discussion Paper 00840.*

9. Escobal, J., & Ponce, C. (2002). The benefits of rural roads: Enhancing income opportunities for the rural poor. *Grupo de Análisis para el Desarrollo, GRADE. Working Paper 40*

10. Khandker, S., & Koolwal, B. (2011). Estimating the Long-Term Impacts of Rural Roads: A Dynamic Panel Approach. *World Bank Policy Research Working Papers.*

11. Kingombe, C., & Falco, S. (2012). The Impact of a Feeder Road Project on Cash Crop Production in Zambia's Eastern Province between 1997 and 2002. *CSAE Conference, Oxford, March 2012.*

12. Mathematica Policy Research. (2015). Evaluation of a Rural Road Rehabilitation Project in Armenia. *Millennium Challenge Corporation.*

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13. Mu, R., & Walle, D. (2011). Rural Roads and Local Market Development in Vietnam. *The Journal of Development Studies.*

14. NORC. (2013). Impact Evaluation of the Transportation Project in Honduras. *Millennium Challenge Corporation.*

15. Narayanmoorthy, A., & Hanjra, M. (2006). Rural Infrastructure and Agricultural Output Linkages: A Study of 256 Indian Districts. *Indian Journal of Agricultural Economics.*

16. Rubaba, A. (2011). Impact of Rural Road Improvement on High Yield Variety Technology Adoption: Evidence from Bangladesh. *University of Maryland.*

17. Carruthers, Robin, Ranga Rajan Krishnamani, and Siobhan Murray (2009), "Improving Connectivity: Investing in Transport Infrastructure in Sub-Saharan Africa", Africa Infrastructure Country Diagnostic Background Paper 7 (Phase II), World Bank (From Casaburi 2013).