K4D | Knowledge, evidence and learning for development

Evidence of the impact of rural road investment on poverty reduction and economic development

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Question

What is the evidence for rural road and transport services impact on poverty reduction and economic development?

Contents

1. Executive summary

Rural transport development is key to economic growth and poverty reduction. Without effective transport rural communities would be isolated from markets, health care and education. Studies carried out by Fan and colleagues at the International Food Policy Research Institute in India (1999), Uganda (2004), and Tanzania (2005) found that investment in rural roads gave the highest, or second highest returns, and lifted more people out of poverty, per dollar spent, compared with any other form of public expenditure. Yet nearly one billion rural residents, approximately 68% of the world's rural population, measured by the rural Access Index (RAI) still do not have all-season access to road networks. With the support of DFID, the RAI, which is defined as 'the proportion of the rural population living within two km of an all-season road' has now been adopted as SDG Indicator 9.1.1. To address the issues of rural accessibility many billions of dollars have been invested in LICs and LMICs to provide safe, reliable, and affordable rural access. It has been estimated that over 4% of World Bank lending is devoted to rural roads (Tsumagari, 2007). India alone has spent over US$ 2 billion per year since 2000 on rural roads.

This report provides a rapid review of some of the recently published evidence of the impact of such investment. This rapid evidence based assessment builds on the more thorough systematic review conducted by Hine *et al.* (2016) which found that published studies in general demonstrated a strong link between good access and indicators of socio- economic benefit. The findings of this rapid review confirm the earlier findings by Hine *et al.* (2016) and demonstrate positive impacts associated with increased income, poverty reduction, employment, agricultural output and sales, education, health, traffic volumes, transport services, transport costs and general economic indicators.

In a number of the recent studies it was found that rural road investment encouraged structural transformations of villages by facilitating non-farm employment and enabling migration to urban areas. However, this did not necessarily translate into substantial increases in incomes. In fact Asher and Novosad (2018) found that the Indian Prime Minister's Gram Sadak Yojana (PMGSY) rural road programme only increased consumption by just 2.3%. In comparison, an earlier study by Asher and Novosad (2016) found the PMGSY programme in India increased incomes by 8% and, a study by Fan et al. (1999) of poverty in rural India, found that rural roads had a relatively large impact, with a benefit cost ratio of three. The Fan et al. (1999) study was based on an analysis of total road length per unit area. However the PMGSY road studies, analysed by Asher and Novosad (2016 and 2018), were very largely on the impacts of upgrading existing roads to a paved standard and hence these interventions did not increase accessibility (per km built), to the same extent.

The systematic review by Hine et al (2016) found that the highest impacts, were observed for countries with lowest road densities. For example in Ethiopia, access to a rural road increased the local growth rate by 9% per year (Dercon et al 2012), similarly Wondemu (2010) found that between 1989 and 1994, households with access to all weather roads generated 90% greater income. In 2000 Ethiopia, only had a road density 0.04 km per sq km, and Tanzania (reported on by Fan et al 2005) had a road density at the time of around 0.09 km/sq km. In comparison for the last 100 years India has had by far the highest road density of any large developing country (i.e., currently 1.67 km per sq km). There is good reason to believe that diminishing marginal returns are present, and that the current Indian experience would not necessarily be reflected in other countries.

Despite the huge expenditure on rural roads in India there have been few robust impact studies published relating to PMSGY. The new substantial study of the effects of the PMGSY programme on health is particularly welcome (Banerjee and Sachdeva, 2015). The study shows a wide range of beneficial effects of the programme on health outcomes. Large scale studies of this sort on health have not previously been carried out. Further studies of the PMGSY, covering all areas, are clearly required.

With increased interest in climate change a small but growing body of literature outlines the potential negative impacts of roads on forest cover and biodiversity, although it depends on the local context and type of road.

2. Background

A lack of access to basic services and markets is recognised to be a major constraint on development and an important contributor to poverty. It is estimated 58% of the population of developing countries, 78% of the extreme poor (Olinto et.al. 2013), and 85% of the multidimensional poor (measured by the Multidimensional Poverty Index (MPI) (Alkire et.al 2014), are located in rural areas. Measured by the Rural Access Index (RAI) it has been estimated that around 900 million people live further than two km from and an all-season road (Roberts et al, 2006). The RAI has now been adopted as the SDG Indicator 9.1.1.

A DFID funded systematic review of published evidence, covering 56 studies, found that rural road investment demonstrated strong links between good accessibility and socio-economic development (Hine et.al. 2016). The study found positive impacts between road investment and increased income, poverty reduction, increased employment, increased agricultural output and sales, increased traffic volumes, reduced transport costs and beneficial outcomes for health and education. Particularly strong evidence of the effects of rural road investment was found in Ethiopia by Dercon et al. (2012) and Wondemu (2010) and by Shenggen Fan and colleagues covering India (1999), China (2004a), Uganda (2004b), Tanzania (2005). However, not all impacts found in the systematic review (Hine et.al. 2016) were, beneficial, for example in some cases better access led to the spread of communicable diseases, although, on balance health impacts of road investment were positive.

A recent study by Asher and Novosad (2018), taking a relatively new approach, has investigated the effects of the Indian PMGSY rural road programme and found relatively weak effects on income generation. The Asher and Novosad study is discussed further in this report. The main purpose of the current investigation is to assess very recent studies to see whether the balance of evidence has changed.

2.1 Road Investment Programmes

To help put the research in perspective it is useful to consider the large sums of money spent on rural infrastructure which has been an important component of donor activity for many years. For example, it was estimated that from 1992 to 2006 The World Bank committed US$ 13.8 billion for rural transport activities with an average spend of US$ 920 million per year, amounting to 4.3% of total World Bank funding. In the 14 year period, out of a total of 3,261 projects, there were 461 projects that had a rural transport component. Of these 13% were dedicated rural transport projects, 16% were highways and main road projects with a rural transport component, while 72 projects were multi-sectoral with rural road components. Over the period the share of rural

transport in World Bank projects increased from 10.3% in 1992-1996 to 16.5% in 2001-2006. (Tsumagari, 2007).

Ambitious rural road programmes have been undertaken in a number of countries including Ethiopia, India and Vietnam. The growth in Ethiopia's classified road network has reportedly risen five-fold from 1997 to 2014. Most of the growth can be attributed to the Universal Rural Road Access Programme (URRAP). Between 2010 and 2017, 56,000 km were built under URRAP (at a cost of approximately US$ 2 billion) and a further 29,000 km of unclassified rural roads were built under the multi-sectoral Productive Safety Net Programme (PSNP). In 2014 committed funds to the PSNP amounted to US$ 2.6 billion, of which the Government of Ethiopia was to contribute US$ 500 million, the World Bank $600 million, DFID $412 million and other donors $1.1 billion. So far URRAP has been exclusively funded by the Ethiopian Government. It is estimated that both programmes have now benefitted over 10.5 million people (World Bank, 2018a).

In 2015 India had a total road length of 5.42 million km of roads. However between 2000 and 2018 the PMGSY programme constructed 550,586 km of all-season roads connecting 135,764 habitations. The whole project has cost US$ 38 billion. Although the World Bank and Asian Development Bank have committed funds to the programme (eg. US$ 500 million from World Bank in 2018, and US$ 250 million from the ADB in 2017) the overwhelming majority of the funding has been from the Government of India (World Bank 2018b).

In Vietnam an ambitious rural roads programme was undertaken from the 1990's to 2015. The programme covered both gravel and paved roads. During the programme, the paved Commune road network increased from 3, 000 km to 84,000 km. The overall cost of the Commune paving programme alone was around US $2.4 billion, with the majority of the programme funded domestically. The World Bank provided finance for various stages of the rural transport programme. i.e. RT1, programme (US $ 55 million, completed in 2001), RT2 (US$ 104 million, completed in 2006) and RT3 (US$ 250 million completed in 2014). DFID helped provide technical advice under the SEACAP rural transport research programme, which helped to significantly lower costs of paving the network using surface dressing rather than the more expensive penetration macadam, or unreinforced concrete surfacing, that had been widely used in the past (Kaenzig et al.2018).

2.2 Road Maintenance and Rural Access

It should be noted that improving socio-economic development through improved large scale rural access is costly both in terms of construction and maintenance costs. There is an affordability question on what level of rural access is acceptable and affordable to a country. For example, the maintenance of a rural road network that provides access to 70% of the rural population in Sierra Leone and Togo is estimated to cost about 2.5% annually of the current GDP of the countries (Rozenberg and Fay, 2019).

Improving the Rural Access Index (RAI) in Sierra Leone by 1% would cost US$30 million (about 1% of GDP) when the RAI is 30%, but US$200 million when the RAI is 70%. While mountainous Bolivia, which has a similar rural population to Togo, would need to spend US$2 billion to increase its RAI from 20% to 30%. A similar investment would allow Togo to increase it's RAI from 30% to 65% (Rozenberg and Fay, 2019). The Sustainable Mobility for All (SuM4ALL) Universal Road Access (2019) co-chaired by DFID and RECAP advocates different levels of rural access ranging from tracks to sealed low volume roads.

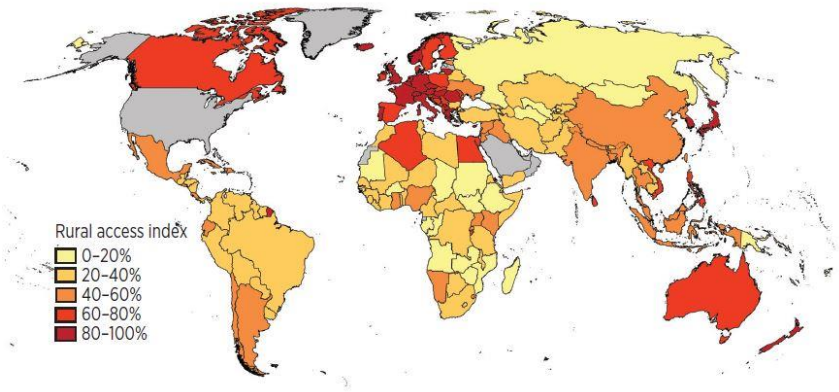

Figure 1 Rural Access Index (RAI) by region
Source: Rozenberg, Julie, and Marianne Fay, eds. 2019. Beyond the Gap: How Countries Can Aff ord the Infrastructure They Need while Protecting the Planet. Sustainable Infrastructure Series. Washington, DC: World Bank. doi:10.1596/978-1-4648-1363-4. License: Creative Commons Attribution CC BY 3.0 IGO

3. Recent rural transport literature

A literature search was carried out using the University of Birmingham's search engine findit@bham which allows all of the databases of the major academic journals in all subject areas to be searched, GoogleScholar.com, Google.com and Science Direct. The search was augmented by probing DFID Development Tracker, the RECAP, the World Bank and Asian Development Bank's on-line web portals. Twenty impact studies were identified for inclusion in this report. The criteria for selection were that the studies had to be published from 2014 onwards and that they must identify impact from rural transport interventions on socio-economic welfare (i.e. income, poverty, agriculture, traffic, employment, health, education etc.) or the environment. Similarly studies covering multiple infrastructure interventions, where the rural transport component could not be identified, were also omitted. In the literature search the impact of rural transport service interventions studies were included, however only one suitable study –relating to a bicycle programme - was found and included in report. In many ways this is unsurprising as rural infrastructure interventions tend to dominate. In the review or the World Bank's rural transport programme by Tsumagari (2007) it was found that 98% of the World Bank's lending for rural transport is for road building and maintenance, with only 2% covering transport services.

The studies identified are summarised in **Table 1** and relate to Bangladesh, Brazil, China, Congo, Ethiopia, India, Indonesia, Nepal and Vietnam. A composite study of Sub Saharan Africa is also included. While some of the literature investigates the impact of rural roads through the evaluation of national-level programmes, e.g. Ethiopia's URRAP and India's PMGSY programmes, most of the studies focused on impacts within selected households, communities and villages. It is evident that additional impact evaluations, such as those being undertaken by the DFID funded ieConnect project, are crucial to continue building our understanding of rural transport and poverty given the large funding annually invested in rural roads by LICs and LMICs.

Table 1: Methodology and data used by the identified studies

Country	Study	*Methodology*	*Study Description*	*Data Sources*	*Duration of Impact Evaluation*
Bangladesh	Ahmed and Nahiduzzaman (2016)	Historical analysis	Assessed the impact of rural accessibility on women empowerment within the district of Chuadanga with 1.1mn population	Bangladesh Bureau of Statistics Bangladesh National Portal Ministry of Local Government, Rural Development and Cooperatives.	2007-2009
Brazil	Limi *et al.* (2015)	Difference-in-differences matching and regression	Assesses the socio-economic benefits from rural roads for 1,100 households within the state of Tocantins	Questionnaire based survey	2005-2011
	Pfaff et al. (2018)	Regression analysis with controlling factors	Assess the environmental impact of rural road construction to the Amazon forest cover	Tropical Rain Forest Information Centre, Transport Ministry,	1976-1992
China	Wang and Sun (2016)	Autoregressive distributed lag model	Quantifies the impact of rural transport infrastructure on development of rural communities	World Development Indicators, China Bureau of Statistics	1980-2013
Congo	Damania et al. (2018)	Instrumental variable strategy, HDM-4 software	Reviews the economic growth, deforestation, and biodiversity loss in Congo	African Infrastructure Country Diagnostic, National Oceanic and Atmospheric Administration, Spatial Production Allocation Model	2000-2012
Ethiopia	Nakamura *et al.* (2019)[1]	Difference-in-difference	Quantifies the impacts of constructing a rural road on welfare and economic outcomes among 204 communities	Federal Road Network data from Ethiopian Roads Authority; Ethiopian Rural Socioeconomic Survey	2012-2016
	Stifel *et al.* (2016)	Willingness to Pay estimation and sensitivity analysis	Investigates the economic benefits of rural feeder roads for 851 households	Questionnaire based survey	2011
India	Wagale *et al.* (2019)	Fuzzy framework and econometric modelling	Assesses the impact of rural road construction on the local livelihood diversification for 27 villages with an average population of 350-390	Target focus group via panel/focus group discussions at habitation	2016
	Aggarwal (2018)[1]	Difference-in-difference	Assesses the nationwide impact of roads on a wide variety of economic	Online Management and Monitoring System (OMMS);	2001-2011

			outcomes in rural areas. The analysis is based on villages with no roads at the baseline.	Population census; National sample survey (household consumption) and Agricultural inputs survey from Government of India (GOI)	
	Asher and Novosad (2018)[1]	Fuzzy regression discontinuity	Measures the impact of PMGSY programme by assessing the economic benefits to 11,474 villages across 11 states.	OMMS; Below Poverty Line census, Population census, Socioeconomic and Caste Census (SECC), and Economic census from GoI; Remote sensing data from ML Infomap	2001-2011
	Bell and van Dillen (2018)[1]	Historical analysis with controls.	Investigates the effect of PMGSY programme on morbidity using data on 279 households from 30 villages	Questionnaire based survey	2001-2013
	Muralidharan and Prakash (2017)	Triple difference estimate	Studies the impact of cycle-scheme for girls in the rural areas within the state of Bihar	Indian District Level Health Survey (Bihar)	2006-2008
	Asher and Novosad (2016)	Fuzzy regression discontinuity	Estimates the economic impact of PMGSY programme using high spatial resolution dataset covering 7 states.	OMMS; SECC, Population and Economic censuses from GoI; ML Infomap and data from national Oceanic and Atmospheric Administration	2001-2011
	Shamdasani (2016)	Difference-in-difference	Investigates the role of improvement of rural roads on the agricultural production of 114 farmers in 18 villages	Panel survey of rural households, the administrative OMMS database, the Indian Population Census, the universe of geocoded natural villages in India	1991-2011
	Banerjee and Sachdeva (2015)	Fuzzy regression discontinuity	Estimates the impact of PMGSY programme on the usage, provision and awareness of preventive healthcare within 5,331 villages	OMMS, Household survey (DLHS) from GoI	2001-2011
	Bell and Van Dillen (2014)	Historical analysis with controls.	Analyses the effects of all-season rural roads on net output prices, education and health for 240 households across 30 villages	Questionnaire based survey	2001-2010
Indonesia	Yamauchi (2016)	Fixed-effect instrumental variable	Examines the impact of road condition on labour supply and wages from 98	Household Surveys, Effects of Infrastructure on Millennium	2007 & 2010

		estimation	villages	Development Goals in Indonesia (IMDG)	
Nepal	Charlery *et al.* (2016)[1]	Difference in difference	Estimates the impact of rural road construction on the income and income inequality within177 households	Questionnaire based survey	2006-2012
Sub Saharan Africa	Berg *et al.* (2018)	Regression analysis	Assesses the relationship between access to markets and land cultivation within 43 countries in Sub Saharan Africa	HYDE 3.2 geo-references dataset	1970-2010
Vietnam	Nguyen *et al.* (2017)	Difference in difference	Measures the impact of rural roads on welfare of 720 households across 9 provinces	Endline survey, Vietnam Household Living Standard Survey	2010-2014

1. Relevant data and results are presented in Appendix A

4. Impact of rural roads

The impact of rural roads on income, poverty reduction, economic growth, employment, agricultural output and sales, education, health, traffic volume, transport services and costs within the rural areas are reported in the following sub-sections.

a. Income

The evidences presented in Table 2 suggests a positive impact of rural roads on income and household consumption of grains and non-food items. The studies in low income countries (i.e., Bangladesh, Ethiopia, and Nepal) reported a substantial impact on income. It is interesting to note that the highest impacts were amongst the poorest and most remote communities, for example 109% increase for the poorest in Nepal and 28% for the most remote in Ethiopia. However, Asher and Novosad (2018) found only a 2.3% increase in consumption for India, this compares with their earlier estimate of an 8% increase in income (2016). It is not clear why such large differences in effect are observed. India has a very high road density at 1.66 km/sq km, compared with other developing countries, which may help to explain the limited impact reported by the 2018 study. The issue is discussed further later in the report.

Table 2: Impact of rural roads on income

Country	Study	*Effect of rural roads*
Bangladesh	Ahmed and Nahiduzzaman (2016)	The study reported an overall 47% increase in household income for poor households during the survey period, but it is unclear as exact contribution of the road investment. A raise in women's income from direct employment was also reported. 95% of the questioned women felt that their future income would improve.
Brazil	Limi *et al.* (2015)	Significant increase in agricultural employment (+17%) and monthly household income (rising between US48 and US$67).
China	Wang and Sun (2016)	The study found that a 1% increase in the size of the rural road network leads to a statistically significant 0.14% increase in per capita net income of rural households in the short term. No statistically significant long-term impact was identified.
Congo	Damania et al. (2018)	The study found that reducing the transport costs to the local market by 10% would lead to an increase in local GDP by between 0.3% and 1.41%
Ethiopia	Nakamura *et al.* (2019)	While average household consumption increased between 2012 and 2016 by 16.1%, the increase was larger amongst remote communities at., 27.9%.
India	Asher and Novosad (2018)	The mean consumption per capita in villages was reported to be approximately $267 per year. The study estimated an increase in consumption of 2.3%, which translates into an additional $6.14 annual consumption per person, or $4274 per year for the village as a whole. The study observed that rural roads do not appear to transform village economies. It rules out a 10% increase in consumption with 95% confidence with no significant impact on consumption distribution of goods. Night light intensity at village level, as an alternative measure of consumption was explored and was found to be almost zero.

		Statistically no significant economic impact was observed on the share of households whose primary earner made more than INR 5000 (approximately $100) per month. The impact of new roads on asset ownership suggested a small but statistically insignificant 0.14% increase. The study concluded that rural roads do not greatly increase income, asset ownership, or consumption, even for relatively inexpensive assets such as mobile phones.
	Aggarwal (2018)	The study found that that overall, monthly per capita expenditure in rural households grew by 7.5% from 2001 to 2011 indicating a 0.75% per annum increase in real consumption. It was estimated that calculated impact of road investment, through a decrease in consumer prices alone, was the equivalent to 4 years of economic growth, (i.e. by 3%). Households which were provided with access for the first time were found to consume on average 0.4 fewer types of cereals and lentils but 0.1, 0.4 and 0.37 more dairy products, fruits and processed foods respectively. The study also found large and significant gains in the many non-food categories of goods consumed by the households.
	Asher and Novosad (2016)	The study found that road construction leads to an increase in monthly household earnings by INR 326 or 8% (approximately $6). Gains in income are supported by a 5.5% increase in the percentage of households living in a home with a solid roof and walls. The study also reported that night light luminosity increased 2.5% following the construction of a road.
Nepal	Charlery *et al.* (2016)	The study reports that a new road had a significantly positive impact on the mean household income of 28% (increase of US$ 253). Significantly positive impacts of road construction on total household income were found for the poorest (109% or US$ 313) and intermediate (72% or US$ 459) households, while the effect for the least-poor households was negative but statistically insignificant. The results imply that the new road increased household environmental income by US$ 122, remittances by US$ 100, wage income by US$ 29 and 'other income' by US$ 164. The impact on income from remittances may be due to increased access to banking services in the town centres. The significant positive impacts on wage income and other income appear to be a direct result of villagers commuting more frequently to the more developed town centres to provide labour and to participate in other income-generating activities. Rural roads provides easier access to natural resources. For e.g. fuel wood which in addition to subsistence use is also traded in the local market. The study also reported that roads had a positive but insignificant impact on income from livestock.

b. Poverty reduction

Rural roads are seen to have an important impact on poverty reduction, particularly for areas in less developed counties that did not previously have access to transport infrastructure, such as Ethiopia and Nepal. For example in Ethiopia, the presence of rural roads reduced the chance of households becoming even poorer due to calamities such as droughts.

Table 3: Impact of rural road on poverty

Country	Study	*Effect of rural roads*
Ethiopia	Nakamura *et al.* (2019)	Results suggested that when connected to rural roads, rural residents were about 10.4 percent less likely to fall into or remain in poverty between 2012 and 2016. Moreover, rural roads households with rural roads exposed to the 2015/16 drought lowered their chance of becoming poor by around 14.4%.
India	Asher & Novosad (2018)	The study found that a new road did not significantly change the share of households that are landless, own less than 2 acres, or have between 2-4 acres of agricultural land. However, a 3.4% increase in the share of households with over 4 acres of land was observed.
	Asher & Novosad (2016)	Road construction led to a 2.6% decrease in the percentage of households in the lowest income category and 1.5% increase of households in the highest income category.
Nepal	Kodongo and Ojah (2016)	Provision of rural roads had a positive impact on economic growth and development, especially in countries which previously had little or no access to road infrastructure.
Vietnam	Nguyen *et al.* (2017)	Rural road projects significantly increased a household wealth index by 0.17%. There was an 11% increase in access to safe drinking water, a 12% increase in ownership of a mobile phone and a 6.8% increase in having a line telephone. The study showed that households with male heads benefited less from rural road development. Households with higher levels of education showed higher levels of benefit.

c. Employment

The studies presented in Table 4 suggest that rural roads have a positive impact on the choice of occupation and on job creation. Apart from the study by Wagale et al. (2019) it was also found that access to rural roads results in an increased and waged jobs and mobility of labour from rural to urban areas and from agriculture to non-farm employment. These impacts were most significant among households without land. The studies in Table 4 confirm the findings from the systematic review by Hine et al. (2016), that investment in rural roads consistently promotes and increase in non-agricultural employment.

Table 4: Impact of rural road on employment

Country	Study	*Effect of rural roads*
Ethiopia	Nakamura *et al.* (2019)	Access to rural roads increased the share of household members with waged jobs by 2.8%. The impacts were particularly large among women (+2.6%) and the youth (+7.5%) in remote areas.
India	Wagale *et al.* (2019)	It was found that rural roads development increased agricultural activities (80% of the population). No significant changes in any other occupations were identified. An increase in the number of working age members has contributed to a significant increase in the household income. This was attributed to providing access to new employment opportunities in neighbouring areas.
	Asher and Novosad (2018)	The study explored the impact of new roads on the occupational choice of workers aged 21-60. It was found that new roads cause a 10.1% reduction of workers in agriculture and an 8% increase of workers in (non-agricultural) manual labour. The study found that the movement out of agriculture was found to be strongest for workers in households without land. This effect was found to monotonically decrease with landholding size. 35% of workers who did not own land left the agricultural sector, compared to just 10% of households with more than 4 acres. Men are more likely to leave agricultural employment compared to women, particularly in the younger cohort (-9.6% for men compared to -3.8% for women). The study estimated that a new road on average creates 3.7 new jobs in a village. The study also reported a 34% growth for the retail sector as an occupational choice, as the result of a new road. A range of employment changes were demonstrated, from 1.6 jobs lost in livestock to 2.6 jobs gained in manufacturing, albeit these findings were shown to be statistically insignificant. These small impacts on firms imply that roads are facilitating access to external labour markets rather than stimulating the growth of jobs within the village firms.
	Aggarwal (2018)	Apart from urban-oriented occupations brought about by the increased local mobility of labour with respect to nearby urban centres, a small increase in textile manufacturing as an occupation was found. Also, it was found that there was a 3% increase among men working as retailers. Once provided access to a road, there is a 25% increase in the probability of prime aged women to start working. An increase in animal husbandry as an occupation choice among the newly-employed was observed causing an increase in the types of dairy and meat products consumed by the village inhabitants.
	Asher and Novosad (2016)	The study estimated that road construction is associated with a large and stable reduction in the share of households engaged in cultivation (9.6 percentage point reduction) and corresponding increase in manual labour (10.9 percentage point increase). Labour reallocation out of agriculture was found to be greatest in areas with high rural-urban wage gaps. Workers living in rural areas are 43% more likely to report working in an urban area when their village were connected with a road. The study observed a 1.2% decrease in the share of households deriving their primary income from a business.
	Shamdasani (2016)	Result of a field survey showed an increase in mobility of agricultural labours across connected communities. This has resulted in a substantial 52% increase in hiring of casual agricultural labours.
Indonesia	Yamauchi (2016)	The study found that rural road investment resulted in increased transportation speeds in general and initiated an increase in wages in both agricultural and non-agricultural employment. A movement in the

		labour market was found from the agricultural to non-agricultural sector, especially by relatively well-educated households.
Vietnam	Nguyen *et al.* (2017)	It was found that people in villages with road projects are more likely to find jobs in the industrial sector and less likely to work in the service sector.

None of the studies directly investigated road construction and maintenance itself as a source of employment. This is a major policy objective for many donor funded road programmes. The Roads 2000 Programme in Kenya, supported by French Aid, is an example. The largest rural road programme supported by DFID is the Rural Access Programme (RAP) in Nepal which was started in 2001. This is a poverty alleviation programme that uses labour-intensive construction and maintenance of transport infrastructure as an entry point for improving the poorest and most marginalised people in remote areas. Other components include technical assistance and training in road engineering, maintenance and transport planning and through partnership with the private sector the development of agricultural marketing. RAP is now in its third stage of implementation. Since its start in 2001 RAP has built 1,100 km of new roads and provided 19.5 million person days of employment for poor people. Under RAP3, 335 km of new roads have been constructed, (of which 60 km are in extremely remote locations) and maintained 2,253 km. Surveys indicate that 4.9 million vehicle journeys are made being made annually on the RAP core road network. Currently 2.1 million people benefit from improved access and 17,000 person training days have been delivered to engineers and technicians (DIFD 2018).

d. Agricultural output and sales

The studies given in Table 5 show a diversity of effects on agriculture from better access and reduced transport costs. For Ethiopia (Nakamura et al. 2019) and the Congo (Domania et al 2018) improved roads and reduced transport costs were shown to have an important positive effect on increasing agricultural production. For India the effects are clearly mixed. On the one hand it was found, that road investment was associated with an increase in the use of hybrid seed and fertiliser (Aggarawal 2018), a diversification of crop types (Shamdasani, 2016) and higher selling prices for farmers and an increase in cultivated area (Bell and Van Dillen 2014). While Asher and Novosad in their 2016 study, found a decrease in agricultural area and movement of labour out of agriculture while for their 2018 study, a small increase in agricultural yields was identified but no other substantial changes were identified.

Table 5: Impact of rural road on agricultural output

Country	**Study**	***Effect of rural roads***
Congo	Damania et al. (2018	It is estimated that a 10% decline in transport costs would increase the production of bananas (depending on the model used) by 7.9% and 17.5%, groundnuts by 6.3% and 20.9%, rice by 5.4% and 20.5%, cassava by 2% and 18.8% and maize by 0.5% and 9.7%.
China	Wang and Sun (2016)	The study showed that a 1% increase in the size of the rural road network lead to a 0.05% and 0.19% change in cereal yield in the short and long term respectively.

Ethiopia	Nakamura *et al.* (2019)	Rural households were 3.6% more likely to use fertilizer when provided with access to a rural road resulting in an average 32.2% increase in the amount of crops sold by rural household. In remote areas, households were 16.1% more likely to sell crops when connected to rural roads.
India	Asher and Novosad (2018)	This study did not find any evidence of substantial changes in agricultural production in villages after a new road was built. While a 1.6% higher agricultural yield per village was found, no evidence for increases in ownership of mechanized farm or irrigation equipment was reported. The study found no indication of a movement away from subsistence crops, of land intensification, or of changes in the distribution of land ownership.
	Aggarwal (2018)	The provision of improved access and the associated reduction in transport costs and better access to goods and labour markets resulted in 2% and 3% increase in the use of hybrid seeds and fertilizers and per crop type respectively. Such a trend was mainly concentrated on food crop cultivation instead of cash crops.
	Asher and Novosad (2016)	The provision of a road was linked to a 10% decrease in agricultural cultivation and was postulated to be due to large movements of workers out of agriculture. No evidence for increases in the size of landholdings or increases in agricultural mechanization and consolidation were observed
	Shamdasani (2016)	It was found that households who gain access to an improved road diversify their crop portfolio, and cultivate higher return, non-cereal hybrid crops. They also intensify their labour hiring and there is an increase in mobility across village markets.
	Bell and Van Dillen (2014)	The study found that there is evidence that improvements in the quality of roads improved the selling price of paddy rice. For a typical 5km earth road that was converted to an all-weather PMGSY road the selling price of rice increased by 5%. There was evidence to suggest that more outside brokers visited villages with improved roads, and farmers joint marketing of their produce to take account of the higher prices. Access to an all-season had a positive impact on the cropping patterns with an increase in cultivated area of paddy fields, cereals, cotton and vegetables.
Sub Saharan Africa	Berg *et al.* (2018)	It was estimated that a doubling of an index of market access will result in an increase in overall crop land by 0.6% (about 2 million hectares) and by no more than 3.7% for best yielding cash crops. While a 10% decrease in time to the nearest port is associated with a 0.5% increase in crop land. (Market access for a given location is calculated to be a function of the weighted sum of all other populations, with a weight that decreases with transport time.)
Vietnam	Nguyen *et al.* (2017)	It was found that the presence of a rural road project is associated with a 31% reduction in cultivated land and a 33% reduction in land devoted to rice. This suggests that villages with project roads devote more land for other (possibly industrial) purposes.

e. Education

The studies identified showed that improved rural roads and access to bicycles have a generally positive impact on school enrolment and attendance, particularly for younger children and girls (Table 6). However, in one example there was a decline in attendance of 14 to 20 years (Aggrawal, 2018) which is interpreted as resulting from better access to employment opportunities. A reduction in involuntary days lost at school was believed to be because of better attendance by teachers, following road improvement.

Table 6: Impact of rural road on education

Country	Study	*Effect of rural roads*
Brazil	Limi *et al.* (2015)	In two of the four regions studied, it was found that there was a decline in households with children who could not attend school because of poor road condition, and this marginally improved girls' attendance at school.
India	Aggarwal (2018)	At the village level, the study reported a 5% increase in school enrolment among 5-14 year old children living in villages provided access to a rural road. It was suggested that this might be due to the greater presence of teachers due to improved access. The study also reported a fall of 11% in 14-20 year olds in villages due to easier access to employment.
	Muralidharan and Prakash (2017)	It is reported that there was a 32% increase in age appropriate enrolment in secondary school amongst girls, when provided with bicycles, in the Indian state of Bihar.
	Bell and Van Dillen (2014)	Overall, the study found that school attendance both at primary and secondary level was higher for villages with all-weather roads compared with villages without all-weather roads. However the difference was found not statistically significant. However, it was found that primary school children in villages with an all-weather road lost 1.7 days involuntarily, and those without all-weather road lost 8.6 days. For secondary schools the corresponding figures were 2.9 days and 9.4 days. Both results are significantly different. The result suggests that it is probably teachers' attendance, at all levels, that is most affected by the presence of an all-weather road. The analysis found that the provision of an all-weather road had no effect on the travel time to primary schools, but did have an effect on travel to secondary schools, saving 3.4 minutes per km, or between 17 and 34 minutes per day, in before and after comparisons for those villages receiving PMGSY roads.

f. Health

The evidence of the studies presented in Table 7 suggest a positive impact of rural roads on health through increased and faster access to health care resulting in improvements in the adoption of preventive health care practices and reduction in morbidity. Access to an all-season road was found to have significant positive impacts for women with increases in the awareness of contraceptives and the presence of women welfare committees within villages. Rural households were also found to be more likely to have access to potable drinking water.

Table 7: Impact of rural road on health

Country	Study	*Effect of rural roads*
Bangladesh	Ahmed and Nahiduzzaman (2016)	The travel time to the nearest health centre using all means of transport was 89 minutes faster for areas with access to rural roads, in comparison to the ones without access.

India	Bell and van Dillen (2018)	The study found that the probability that an individual fell sick fell by 4.5 percentage points for each km of an unpaved track converted to an all-weather PMGSY road. Similarly the expected duration of a bout of sickness was reduced by 0.53 days per km of road improvement. The overall incidence of morbidity in the whole sample was statistically lower in 2013 compared to the year before the intervention. Only 26% of all individuals suffered any days of sickness, as opposed to 44% in 2009.
	Banerjee and Sachdeva (2015)	The study reported a significant improvement in preventive health care for villages connected with an all-season road. For villages with populations of 1,000 and above the provision of an all season road had the following impacts: - Women are 20% more likely to seek antenatal care. - No change in the probability of the child delivery at the formal health care centre. - Home delivery was 8% more likely to be conducted by a trained health care personnel. - The likelihood of having an auxiliary nurse mid-wife and health information worker in the village increases by 25% and 30% respectively. - Women rely more on female sterilization and are 12% less likely to use traditional methods of contraception. - The likelihood that a household is aware of the Tuberculosis and the prevention of sex selection programmes increased by 12% and 13.8% respectively. - The likelihood of a youth club by 37%, a women's representative body by 6%, a self-help group by 25% and a welfare committee for the sick by 31%. The likelihood that the inter-village committee takes a decision related to health increased by 35% For villages with populations of 500 - 999 provision of a road was shown to have the following impacts: - The likelihood of a woman using a contraceptive pill increased by 3.5%. - Households are 5% more likely to treat water. - An increase in the likelihood of the village having a health guide (11% increase), a health information worker (12% increase) and having a health camp organised in the village (16% increase). A positive yet insignificant impact on the presence of an auxiliary nurse midwife was also observed. - Household awareness of the AIDS, TB and prevention of sex selection programmes increased by 6%, 3.8% and 3% respectively. - The likelihood that a village has a women's representative body increased by 18% and has a self-help group by 22%.
	Bell and Van Dillen (2014)	For residents of villages with all-season roads, the average distances travelled for treatment at primary health centres and hospitals were 9.3 and 14.7 km, respectively; for residents in villages without, the corresponding distances were 8.0 and 14.5 km, respectively. The study also found that an all-season road reduced the duration of the journey to the nearby health-centre by about 130 minutes for the villages surveyed. The study suggested that was too early to determine whether the new PMGSY roads had any long term effects on morbidity and mortality, although some reductions in mortality were found, these were not significant. However focus group suggested that the local

		communities believed that the new roads had reduced mortality; the average estimate was a reduction of about 2.5 deaths per year in each village.
Vietnam	Nguyen *et al.* (2017)	The probability of having access to safe drinking water was increased by 10% as a result of construction of rural roads.

g. Traffic volumes and transport services

Four studies reported on traffic volumes or transport services. Evidence was found of significant increases in traffic volumes and public transport services (Table 8).

Table 8: Impact of rural road on transport services

Country	Study	*Effect of Rural Roads*
Bangladesh	Ahmed and Nahiduzzaman (2016)	The study reported an increase of traffic levels by 140% and 57% for motorised and non-motorised traffic respectively after access to rural roads were provided. However this is not in comparison with a control.
Brazil	Limi *et al.* (2015)	The study showed an increased usage of public buses and motorised vehicles following the improvement of rural road conditions.
India	Asher and Novosad (2018)	The construction of a new road was found to cause a statistically significant 12.8% increase in the availability of public bus services. The impact on private buses was nearly as large but was measured with less precision. The use of taxis and vans, which are more expensive forms of transportation, were not shown to experience significant growth. The availability of auto-rickshaws, the least expensive private form of motorized transport, was found to increase by 7.8%.
	Asher and Novosad (2016)	The study found that a new rural road increased the probability of a new bus service by 32 percentage points, for villages closest to a large city.

h. Transport costs

Rural roads were found in the studies identified to benefit rural households by reducing the transport costs of both passengers (of up to 65%) between and goods (up to 35%) (Table 9).

Table 9: Impact of rural road on transport costs

Country	Study	*Effect of Rural Roads*
Bangladesh	Ahmed and Nahiduzzaman (2016)	Possible transport cost reductions amounted to 65% for passengers and 35% for goods, respectively with improved rural roads.

Ethiopia	Stifel *et al.* (2016)	The study showed that a hypothetical rural road project that reduces the transport cost for each household by 50 US$/m ton would benefit household consumption by around 35%, with a range of 15% to 54%.
India	Bell and Van Dillen (2014)	Replacing an existing 5 km track with a PMGSY all-season road was found to yield an estimated saving of Rs 420 per tonne of paddy rice in transport costs, equivalent to about 5% of the average value of the crop to the farmer.

i. Economic indicators

The studies reported in Table 10 suggest positive impacts of rural roads on a variety of economic indicators, although the Asher and Novosad (2018) suggest relatively weak returns compared with the costs.

Table 10: Impact of rural road on economic indicators

Country	Study	*Effect of Rural Roads*
Ethiopia	Stifel *et al.* (2016)	It was estimated that internal rates of return for a hypothetical gravel roads was is the range of 12% to 35%.
India	Asher & Novosad (2018)	It is estimated that connecting a PMGSY road to a village will increase consumption by around 2.3%, which amounts to $6.14, per person, per year, for an average village of 696 inhabitants giving $4274 benefits per village per year. This is in comparison with an average PMGSY connection cost, per village of $150,000.
Sub Saharan Africa	Berg *et al.* (2018)	The study found that an increase in market access leads to an increase in local GDP growth that goes beyond the effect on cropland expansion.

j. Environment

The studies reported in Table 11 suggests that in Brazil and the Congo rural road investment may reduce the area of forest cover. This is not surprising. In both countries deforestation and increasing road infrastructure is part a long term process leading to an increase in the spread of land settlement and an increase in the amount of land devoted to agriculture and cash crops. In fact, forestry roads and tracks, built specifically to extract timber, are often the forerunner of initial farming settlements which later lead to more substantial roads, larger scale settlements and a further increase in land cleared for agriculture. Clearly controls on road building may be part of the measures needed to protect forests. However, it is interesting to note than in Brazil the association between rural roads and deforestation declined in the period from 1986 to 1992 compared with 1976 to 1987 (Pfaff et al., 2018).

Table 8: Impact of rural road on environment

ountry	Study	*Effect of Rural Roads*
Brazil	Pfaff et al. (2018)	In an analysis of deforestation in the periods 1976-1987 and 1986-1992 it was found that road building was a highly significant and important explanatory variable in both periods. However the coefficient for road building fell from 0.99 for the first period to 0.12 in the second period, in explaining the forest hazard rate (defined by the area deforested divided by the initial forest area). Hence in the latter period other factors are likely to have become more important.
Congo	Damania et al. (2018)	The study found that forest cover declines with an increase in road quality and proximity to the road. So at 2 km distance to a road 7% of previously forested land was cleared for a road in poor quality; while 19% of previously forested land was cleared, at the same distance to a road in good condition.

5. Discussion and conclusions

The recent literature reveals that the impact of improvements in rural road provision and transport services was broadly positive in terms of impacts to income, poverty reduction, employment, agricultural output and sales, education, health, traffic volumes, transport services, transport costs and general economic indicators. The findings of the studies considered also support those of the studies discussed by Hine *et al.* (2016). Improved rural access was found in some studies to encourage structural transformations of villages by facilitating non-farm employment and enabling migration to urban areas. There is also a small, but growing, body of evidence which reports the negative impact of rural access on the environment.

The provision of access to all-season rural roads (SDG target 9.1.1) was shown to increase living standards in rural areas by reducing transport costs between villages and markets and thereby generating market activity, affecting input and output prices, and enhancing agricultural production through the increased use of modern technologies and the changes in crop choice. The evidence presented in this study overwhelmingly shows that transportation infrastructure contributes to economic growth and improvements in living standards, as measured by improvements in education, health and transport services within rural areas.

Rural roads potentially promote structural transformation in rural areas by facilitating non-farm employment and enabling migration to urban areas (Aggarwal, 2018). The movement of agricultural to non-farm employment was found to be common to those studies of middle income countries such as India and Indonesia (Asher and Novosad, 2018; Wagale *et al.*, 2019). Such a trend was found to be strongest in locations close to large cities, where commuting and short-term migration from rural areas is most profitable and amongst workers in households without an ownership of land (Aggarwal (2018); Asher and Novosad (2018).

Perhaps the most controversial finding of the recent studies identified in this report is the relatively limited impact found by Asher and Novosad (2018) which suggested that the PMGSY programme in India increased consumption by just 2.3 %, this in comparison with their earlier finding which

suggested that PMGSY increased incomes by 8%, (Asher and Novosad, 2016). Although there are similarities in the approach (a fuzzy regression discontinuity analysis) the exact methodologies and data sets were different. The 2018 data set were drawn from 11 states, while the 2016 data set were from seven states. Both papers found that there was a substantial movement out of agriculture towards other jobs, however in the 2018 analysis, this was not apparently translated into large increases in incomes.

An advantage of discontinuity analysis is that it helps to overcome the placement effect that tends to affect other types of analysis whereby roads selected for intervention could be very different from those that are not selected. An earlier significant study of rural roads in India found that rural roads had a relatively large impact, with a benefit cost ratio of three (Fan et al 1999). This study was based on an analysis of total road length, per unit area. While the PMGSY roads, analysed by Asher and Novosad (2016 and 2018 studies), were very largely upgrading existing roads to a paved standard hence did not increase accessibility (per km built), to the same extent. The systematic review by Hine et al (2016) found that the highest impacts were observed for countries with the lowest road densities such as Ethiopia and Tanzania. For example in Ethiopia, access to a rural road increased the local growth rate by 9% per year (Dercon et al 2012), similarly Wondemu (2010) found that between 1989 and 1994, households with access to all season roads generated 90% greater income. In the year 2000 Ethiopia only had a road density 0.04 km per sq km, and Tanzania had a density of 0.09 km/sq km. In comparison for the last 100 years India has had by far the highest road density of any large developing country (currently 1.67 km per sq km). There is good reason to believe that diminishing marginal returns are present, and that the current Indian experience would not necessarily be reflected in other countries. However, there have been very few substantial studies of the PMGSY programme and in view of its importance there is clearly a need for further investigation.

The new evidence on the positive effects of road investment in health and education are welcome, particularly the large and detailed study by Banerjee and Sachdeva (2015). In the previous review by Hine et al (2016), although for health the findings were broadly positive, negative effects relating to the spread of infectious diseases were also found. Also previously for education the positive effects were limited to three studies, with two studies showing no effect.

A growing body of literature reports the potential negative impacts of roads on forest cover and biodiversity, although it depends on the local context and type of road. Damania *et al.* (2018) and Pfaff *et al.* (2018) provide examples for the Congo and Amazon forest in Brazil.

Two recent studies suggest new types of analysis to prioritise rural roads based on both their economic and social benefits and their potential negative environmental impact (Laurance *et al.*, 2014; Damania *et al.*, 2018). There is obviously a trade-off between the local short-term economic and social benefits of better access and the long-term 'costs' to the environment. This is clearly a complex topic and it is unlikely that one approach will be appropriate for all situations. Consultation is required with local inhabitants as well as with ecologists and environmental experts. Research can be done to provide rough economic values for the marginal loss of forest cover and habitat from already settled areas. However, a strong political framework is also required to ensure the long term preservation of indigenous forests and unique habitats.

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