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Evaluating the Social and Economic Impacts of Rural Road Improvements in the State of Tocantins, Brazil

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Cover photo: "A school boy walks to school down a road in Vila da Canoas in the Amazon region of Brazil, near Manaus." © Julio Pantoja/World Bank, taken March 26, 2008

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Acknowledgements

This study was undertaken at the initiative of Aurelio Menendez, Program Manager in the Transport Global Practice of the World Bank. The main author of the report is Atsushi Iimi, Senior Economist (GTIDR) at the World Bank. The study was prepared under the leadership of Eric Lancelot, Senior Transport Specialist (GTIDR) at the World Bank, and benefited from contributions by Isabela Manelici, JPA (TWITR at that time) at the World Bank, and Satoshi Ogita, Transport Specialist (GTIDR) at the World Bank.

The study builds on the work carried out by the team formerly in charge of the World Bank-funded project *Tocantins Sustainable Regional Development* (P060573) in Brazil, led by Aymeric Meyer and Jacques Cellier, both former World Bank employees, during the preparation and early execution of the project in 2001–2005. This is when the surveys' methodology was conceived and initial steps of the surveys were undertaken. The methodology used was mainly based on a precedent impact analysis conducted in 2002 for a similar type of project in Vietnam.

Assistance from the Government of the State of Tocantins in Brazil, especially its Secretariats of Planning and Transport and the State Road Agency, is gratefully acknowledged. This assistance was provided in the context of a long-term partnership between the Bank and the State for over 20 years. The commitment and long-standing efforts of the State Secretariat of Planning's Statistics Unit, and particularly the efforts of its head, Joaquín Cifuentes, are highly recognized. This team undertook all field surveys needed for the study both prior to the commencement of road works in 2005–2008, and after the works' completion in 2011–2012, and provided extremely valuable hindsight on both the methodology and the surveys' design and implementation.

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Foreword

Infrastructure interventions have traditionally been underserved by robust impact evaluations (IEs), compared to social sectors such as health and education. Partly at stake is the complexity of measuring the impact of large transport projects, such as roads and development corridors or public transport systems, due to the length of the project construction cycle, the time needed for induced effects to materialize, and the challenges posed by the identification and maintenance of beneficiary populations and control groups over time. The assessment of investment programs' relevance in the transport sector has traditionally relied on standard economic analyses, rather than on impact evaluations, for which robust methodologies have been lacking. As a result, there are only a handful of methodologically full-fledged socioeconomic impact evaluations in the sector. This study is part of an overall effort of the World Bank's Transport and ICT Global Practice to integrate impact analyses more systematically in project design and optimize policy interventions.

With over 20 million people raised from below the poverty line in the past 10 to 15 years, Brazil has achieved spectacular results in the eradication of extreme poverty and the improvement of the wealth of the poorest. As such, the country is often cited for innovative flagship programs such as the *bolsa família.* Other types of initiatives have also contributed to a sustainable improvement in the living conditions of the poorest. Investment programs aimed at improving rural road transport are among these initiatives. By targeting remote poor populations, these investments are aimed at improving people's access to services, jobs and markets. In turn, these investments are expected to boost local economies while at the same time directly improving rural dwellers' quality of life.

The present paper, *Evaluating the Social and Economic Impacts of Rural Road Improvements in the State of Tocantins, Brazil*, builds on an impact evaluation initiative launched during the preparation of the Tocantins Sustainable Regional Development Project in 2001–2003. It investigates and details the results of nearly 10 years of continuous effort to measure the impact of a Bank-supported rural road investment program that targeted the remote poor population of the Brazilian State of Tocantins. It also identifies some of the challenges faced in undertaking the study.

Abstract

The aim of this paper is to provide feedback on the question of socioeconomic benefits from rural road development and the impact of transport infrastructure on the poor, particularly the poorest and the bottom 40 percent of the population. This study relies on impact evaluation methodologies, which are traditionally used in social sectors but less so in the transport sector. These methodologies were launched in 2003 under the Tocantins Sustainable Regional Development Project (P060573).

This paper highlights the context that led to the project's design, which included an impact evaluation of the works envisaged under the project. It also highlights some of the main challenges faced by this impact evaluation and how these challenges were addressed for the present study. It then provides details about the data collected during the surveys and the key relevant characteristics of the population targeted by the surveys. It discusses the possible estimation methods envisioned to undertake the study and provides the main results of the assessment based on these methods.

The analysis shows that improved rural roads changed people's transport modal choice. People came to use more public buses and individual motorized vehicles after the rural road improvements. The paper also finds that the project increased school attendance, particularly for girls. Although the evidence is relatively weak in statistical terms, it indicates that the project contributed to increasing agricultural jobs and household income in certain regions.

I. Introduction

1. Rural accessibility remains a major challenge in developing countries. About 900 million rural dwellers worldwide lack access to all-season roads because theyare located farther than two kilometers (km)—a 20- to 25-minute walk—from main roads (Roberts, Shyam and Rastogi 2006).[1] Time wasted in transit between home and school or hospital or market (which may in many cases even preclude travels) results in missed and reduced economic and social opportunities.

2. It is widely recognized that improved rural roads have a positive impact on rural inhabitants. Such improvements are expected to enhance their ability to access social services, markets and jobs, and therefore contribute to improving their living standards. Although the short-term impacts of such an undertaking are relatively clear—because transport costs and travel time can be reduced by improved road conditions (Jacoby 2000; Khandker, Bakht and Koolwal 2009; Khandker and Koolwal 2011)—longer-term impacts such as increased profitability of firms (Chandra and Thompson 2000) or increased employment in the agricultural and non-agricultural sectors (Lokshin and Yemtsov 2005) may take time to materialize (up to 10 or 15 years) and could depend on other conditions, such as the level of motorization (Escobal and Ponce 2002).

3. However, while ex ante and ex post economic evaluations of infrastructure projects have been used commonly for years to both justify and monitor the relevance of infrastructure investments based on recognized methodologies,2 only a handful of rigorous studies have been conducted to measure the socioeconomic impact of rural road improvements on living standards.[3] This is partially due to the difficulties, inherent in transport projects, in undertaking impact evaluations: (a) the identification of an appropriate comparable control group is a challenge because the characteristics and surrounding conditions often differ from one group of beneficiaries to another, and investment decisions often rely on specific strategies that may introduce bias to perfectly randomized experiments; (b) beneficiaries may be geographically spread out over a large area, especially in cases of long-haulage transport projects, thus making it harder to define not only who the beneficiaries are but also the expected benefits; and (c) redistributed benefits to households may be diluted or mixed with other social and economic development factors, and may be over- or under-estimated, particularly in the short run.

1 The Rural Access Index (RAI) is a key transport headline indicator that was developed as part of the Results Measurement Framework for IDA (the International Development Association) in 2005. In practice, the RAI measures the number of rural people living within two km (typically equivalent to a 20- to 25-minute walk) of an all-season road as a proportion of the total rural population. An "all-season road" is a road that is motorable year-round by the prevailing means of rural transport (typically a pickup or a truck that does not have four-wheel-drive). Occasional interruptions of short duration during inclement weather (e.g., heavy rainfall) are accepted, particularly on lightly trafficked roads.

2 For example, assessments of surplus to consumers and to producers, as well as tools such as Highway Development Management (HDN), a type of software initially developed by the Bank in the late 1970s and aimed at assessing the economic return of road investments.

3 For example, in Papua New Guinea, household consumption, which is used as a general welfare measurement, increased relative to the poverty line (Gibson and Rozelle 2003). Per capita expenditure was also found to increase due to rural road construction and upgrading in Bangladesh (Khandker, Bakht and Koolwal 2009). Poverty incidence declined and consumption increased in Ethiopia (Dercon, Gilligan, Hoddinott and Woldehanna 2008).

4. With respect to road investments planned under the Tocantins Sustainable Regional Development Project (P060573), some of these constraints were levied; investments specifically targeted unpaved rural feeder roads and sought to benefit rural dwellers in the poorest regions of the state who lacked any alternative access to the main transport networks. Moreover, the selection process of roads to be improved was essentially left to rural dwellers, based on a participatory selection process involving all interested dwellers.

5. The main objectives of the present paper are twofold: (i) to describe the methodological challenges related to road-sector impact evaluation activities and lessons learned from the Tocantins experience; and (ii) to document the evidence that emerged in order to demonstrate the impacts of rural road improvements in the state, given the available survey data. The evaluation first focuses on direct outcomes to determine the existence of relatively short-term impacts resulting from the project. Thereafter, traditional social and economic impacts are measured. Two different methods are used—difference-in-differences (DID) matching and DID regression—to minimize issues observed in the control group through the execution of the surveys. In addition, instrumental variable (IV) estimators are also used to verify the robustness of the results.

6. The paper is organized as follows: Section II provides a context for the study. Section III discusses methodological challenges and lessons learned from the experience. Sections IV and V, respectively, present available data and describe the methodology used. Section VI summarizes the main findings. Section VII discusses various empirical issues and policy implications. Section VIII presents the study's main conclusions.

II. Context of the study

7. Brazil has made impressive gains in terms of socioeconomic development in recent years. A steady gross domestic product (GDP) growth of one to six percent over the last decade, combined with sustained social policies, contributed to increasing the GDP per capita (constant 2005 US$) from US$4,400 in 2000 to US$5,700 in 2012.[4] This allowed more than 20 million people to rise above the poverty line in the past decade. However, these overall positive figures mask a wide range of realities on the ground. For instance, depending on the region, inequality remains persistently high in Brazil, with a Gini index of about 0.55 in 2009, even though it decreased from 0.66 in 2001. Many poor live in rural areas (rural dwellers total 27 million in Brazil) and lack access to services, markets and jobs, due to the lack of appropriate transport infrastructure and services.

8. The State of Tocantins is among the least-developed but fastest-growing regions in Brazil. Created under the 1988 Constitution, it is the country's newest state. With a population of 1.38 million on 277,000 square kilometers (km^2) of land, the population density is low at five persons per km^2. Urbanization has accelerated at a fast pace since the state's creation and is now aligned with the national trend in Brazil, where 79 percent of the population lives in urban areas. Tocantins' urban population is concentrated in 10 major cities. Most of its other cities are small: over half of the

4 World Development Indicators.

state's 139 municipalities contain fewer than 5,000 inhabitants, often scattered throughout the municipal jurisdiction's territory.

9. Although the state's GDP per capita has nearly doubled in the past six years, (a) it currently stands at a relatively low R$12,891 (2011)[5] (equivalent to US$7,400,[6] using the 2011 average exchange rate), placing Tocantins 16th among Brazil's 27 states; (b) the Human Development Index (HDI) was 0.756 in 2005 (vs. 0.61 in 1991),[7] but about 11 percent (2008) of the population remains below the poverty line; (c) the infant mortality rate (2010) is 20.5 deaths per 1,000 children under the age of one (14.5 on average in Brazil); and (d) the literacy rate has improved significantly, from 62 percent in 1991 to 85 percent in 2007, but test scores remain well below Brazil's average at both the primary and secondary levels, as does access to early childhood education. Finally, two vulnerable groups live in Tocantins, including (a) 13,100 indigenous peoples who reside mostly in six main indigenous territories (as per FUNAI,[8] IBGE 2010), and (b) about 7,500 residents of quilombos,[9] grouped in 15 dispersed rural communities.

10. Long-term development strategies aimed at promoting sustainable development and quality of life for citizens, under a state modernization approach, have been prioritized consistently under successive four-year, multi-annual plans (*Planos Plurianuais,* PPAs) adopted by different government administrations over the last 20 years. During the early stages of the state's development, this translated into a strong focus on building core infrastructure, due to the state's relative remoteness. While continuing to work on major infrastructure, in the early 2000s policy makers then focused on increasing accessibility to services, jobs and markets for the state's remote poor populations.

11. In this context, the World Bank's Board approved the Tocantins Sustainable Regional Development Project in December 2003. The project aimed to foster the improved effectiveness of road transport and the enhanced efficiency of selected public services. It included three components: (i) Participatory planning and management of regional and municipal development (US$6.5 million); (ii) Environmental management (US$10.2 million); and (iii) Rural road improvements (US$42.7 million). An impact evaluation was designed as a means to assess the impact of rural road improvements aimed at providing all-season accessibility to selected rural populations of the State of Tocantins.

12. The rural road improvement component targeted 67 municipalities within the four poorest regions in the eastern part of Tocantins: Northeast, Bico do Papagaio, Southeast and Jalapão (see Figure 1). Road improvements mostly comprised the construction of concrete bridges and culverts crossing rivers and streams, to allow year-round passage especially in rainy seasons. A participatory process, through forums open to the population of each municipality, was used to prioritize road

5 IBGE: Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estadística*).

6 Brazil's GDP per capita in 2011 (current) was US$12,567 (World Development Indicators).

7 Defined by the Brazilian Federal Government as families with per capita income up to R$70 monthly.

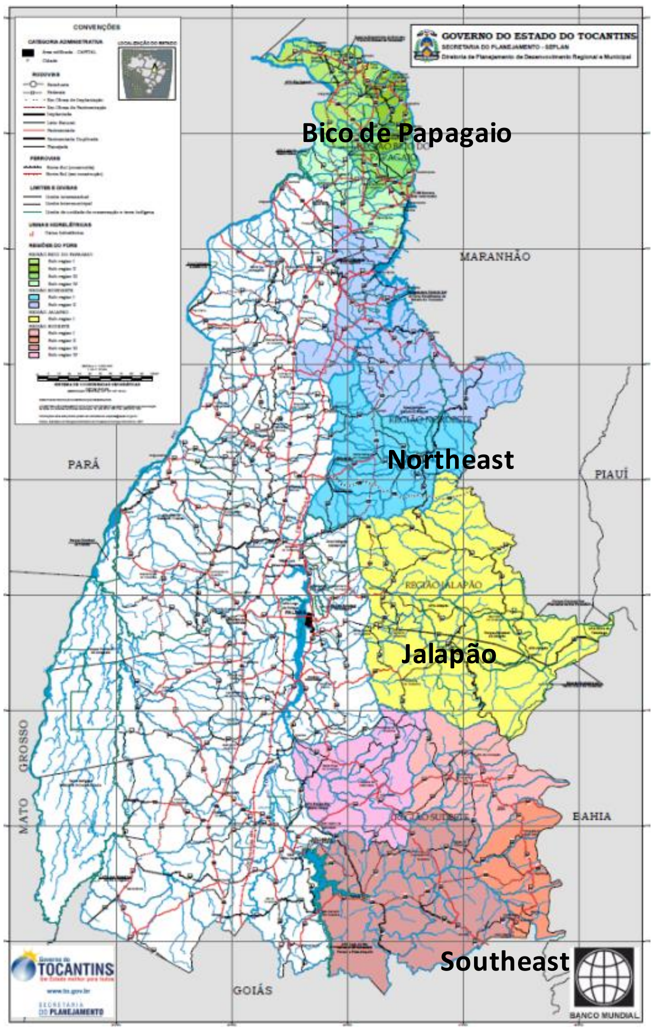
8 FUNAI: Brazil's National Indian Foundation (*Fundação Nacional do Índio).*

9 *Quilombolas* are Afro-descendent groups whose ancestors fled slavery in remote regions. Of a total estimate of 3,000 *quilombola* communities in Brazil, 171 have been officially recognized.

interventions. Typically, 3 to 10 rural road sections were upgraded in each municipality, each representing 3 to 15 km of road length. At the outset, 63,000 rural dwellers [10] were expected to benefit from the road improvements. After having identified the roads, engineers identified the type of intervention needed at each location.

13. The civil works were implemented between 2006 and 2011. The timing of project implementation varied from one region to the next: most of the works were completed in the first region (Southeast) by 2010, and in the second region (Bico do Papagaio) by early 2011; works in the Northeast and Jalapão regions were completed, for the most part, only in late 2011. In total, close to 700 bridges and 2,100 culverts were built on about 4,400 km of unpaved municipal roads between 2006 and for all but six municipalities.[11]

Figure 1: Project regions in Tocantins, Brazil



10 The total rural population in the project's 67 municipalities is 162,000 (source: IBGE 2010). The project's area of influence area has been 39% of the area of these 67 target municipalities (source: Implementation Completion Report, Tocantins Sustainable Regional Development Project, World Bank, 2012).

11 The works have been postponed in 6 municipalities: 3 in Bico do Papagaio, 1 in Northeast, and 2 in Jalapão.

III. Methodological challenges

14. The conduction of rigorous impact evaluations is generally challenging in the transport sector. The main reason is that, typically, transport projects are not randomly assigned, but rather targeted. There must be good reasons for selectingand implementing a particular project at a specific site, and each location has unique underlying characteristics. The identification of an appropriate comparable group is not a simple proposition. In addition, transport projects often generate a wide range of direct and indirect benefits that impact a large number of people. Of particular note, roads are typical public goods (with the exception of toll roads). This compounds the difficulty in identifying a comparable group.

15. Maintaining a control group as intended is another challenge in conducting impact evaluations of infrastructure projects. Even if a good control group is defined at the outset, many unanticipated events can occur during the project's implementation. Unlike relatively simple health interventions, the preparation and implementation of infrastructure projects take considerable time, during which the specifications and schedule might be revised. As a result, the intended control group may ultimately become another "treatment" group. Close collaboration and communication between the project implementation and evaluation teams are essential in designing and modifying the evaluation framework, if necessary.

16. The road project evaluation in Tocantins was initially designed following one of the pioneer studies in this subject conducted by Mu and van de Walle (2011). This team surveyed 100 project communes and 100 non-project communes in six selected provinces of Vietnam and, to compare the two groups, applied the difference-in-differences (DID) technique with score matching. With respect to Tocantins, however, before starting the surveys the State Government decided not to interview rural dwellers who would not benefit from the project (the control group), because it was feared that (a) they would be reluctant to answer the survey, and (b) it would trigger frustration and dissatisfaction, thus placing the government in a politically difficult situation.

17. Despite the absence of a control group *stricto sensu*, the following analysis relies on some naïve definitions of this group. The first approach is a retrofit pipeline comparison thanks to the above-detailed staggered execution of the works depending on the region. All road improvement works had been completed in the Southeast region by the time of the follow-up survey, while only 30 percent of the communities, or 228 households out of 540, had benefited from the completed works in the Bico do Papagaio region.[12] In the remaining communities, works were ongoing or had just been initiated. Using this time difference in project implementation, certain comparisons can be made between these two regions.

18. The second possibility relies on the fact that some road improvement works were postponed, although they had been planned. In Bico do Papagaio, works were postponed in seven communities belonging to three municipalities. In addition, in turned out that five other communities never benefited from the project because of the relocation of the planned works from the original sites. In the Northeast and Jalapão regions, all communities saw the completion of project works before the

12 The completion of the project works was confirmed by households that were surveyed.

follow-up survey was conducted, with the exception of 11 communities in which projects were postponed.

19. For the purposes of this study, these communities with uncompleted or postponed works were defined as a control group because: (a) these changes were mainly due to the community's difficulty in paying counterpart funds for the works, which was somewhat linked to the socioeconomic or geographical characteristics of households/municipalities, resulting in little endogeneity when the control group was chosen; and (b) all communities surveyed in the evaluation—including control and treatment groups—were selected through public consultations in order to be treated at the beginning of the project and therefore to mitigate risks of incomparability between the two groups.

20. Although the manner in which the control group is defined may be practical, it may still be potentially controversial. In particular, it leaves reservations about the comparability of the two groups. As discussed below, the Southeast and Bico do Papagaio regions are different in certain aspects. From a statistical point of view, unbalanced sample sizes may also be a matter of concern. In the case of the Northeast and Jalapão, the control group is much smaller than the treatment group. The difference in means between the two groups is still an unbiased estimator of the project's impact, but the standard errors tend to be larger.

21. A useful and practical remedy, although not perfect, is score matching. As discussed in the literature (e.g., Mu and van de Walle 2011), score matching can ensure comparability between two groups in a quasi-experimental evaluation. Our data suggest that the two groups in question are comparable at least in a statistical sense, excepting several outliers.

22. Impact evaluation in the transport sector is also challenging due to the complexity of results chains. The theory of change is critical when the possible causal chain that links inputs, outputs, outcomes and impacts is considered. However, a transport project can generate multisectoral and multidimensional benefits. In addition, there may be other interventions that could affect outcomes and impacts of interest. Notably, project life is long in the transport sector. Thus, the causality between interventions and results might become complicated over time, and measured impacts might be either over- or underestimated.

23. With regard to the Tocantins road project, a wide range of outcomes and impacts will be measured based on the following results chain (Figure 2). First, bridges and culverts will be rehabilitated, and are project outputs. When the works are completed, local residents are likely to feel some benefits from the project, although these may not be quantifiable. Subjective assessment can include, for example, whether personal travel became easier than before, and whether the living conditions, in terms of roads, improved in the last 12 months.

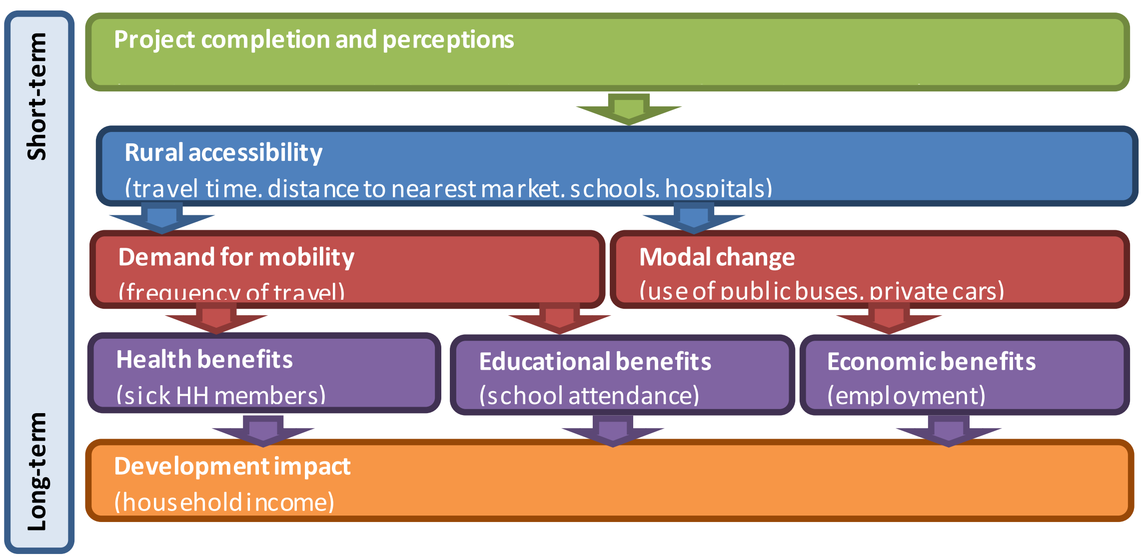
24. As people actually pass through the areas with the rehabilitated bridges and culverts, subjective as well as objective outcomes are likely to emerge over time. The bridge and culvert works might well change physical accessibility in rural areas, especially during the rainy season. Accessibility to certain locations should be improved, particularly in terms of travel time. Thereafter, improved accessibility will likely affect transport demand. People might travel more frequently, and available transport modes and services can also be expected to change as a consequence.

25. In the long run, an even wider range of economic and social benefits may be measured. In theory, improved accessibility may increase school attendance. Health conditions are also expected to improve thanks to enhanced road accessibility. Similarly, such changes might stimulate new local businesses (e.g., Lokshin and Yemtsov 2005; Mu and van de Walle 2011) and encourage farmers to sell their agricultural products in the market, eventually resulting in job creation and household income growth.

26. Due to the limited timeframe of the evaluation in Tocantins (see Figure 2 below), it is unlikely that all of the above outcomes and impacts could be captured in the surveys. It is also less likely that the individual impacts will be clearly separated; some may be overlapped and intermixed, possibly complicating the interpretation of results. Nonetheless, the following analysis will detail various ways in which the populations concerned are benefiting from the project works.

27. Finally, it is also noteworthy that impacts are not always measured. Whether or not they are captured depends largely on the questionnaire design, which always presents a challenge. The surveys must include well-conceived questions capable of capturing the intended impacts. People may feel benefits only under particular circumstances. For instance, they may not perceive benefits from improved accessibility during the dry season, because they experienced few difficulties even before the project's launch. Furthermore, many members of these communities may not travel frequently; as such, it may be difficult to measure increased demand for transport by asking how many times a respondent traveled in the last two weeks.

Figure 2: Expected transport, social and economic impacts of rural road interventions



IV. Data

Sampling and Surveys

28. To understand the project's development impacts, the State Government and the World Bank designed a comprehensive impact evaluation survey in 2004, with the aim of quantifying the project's social and economic benefits and identifying the underlying causal chains between the project and potential outcomes. The surveys were administered at different times, due to the variation in project execution schedules. The analysis has thus been divided to reflect these differences and to exclude different time-fixed effects, pairing the Southeast and Bico do Papagaio regions, and the Northeast and Jalapão regions.

29. Surveys in the Southeast and Bico do Papagaio. For the first group, baseline data were collected between September and December 2005 from a total of 1,069 households in 110 communities (Table 1).[13] Works were completed in the Southeast by 2010 and in Bico do Papagaio by early 2011. The follow-up survey was conducted between June and July 2011 and covered 1,001 households in the same municipalities.[14] The sample size was determined based on the preliminary survey of population distribution in the project areas. The sample size was similar for both regions: 529 households were surveyed in 41 communities of the Southeast region, and 540 households in 69 communities were covered in the Bico do Papagaio region. The total sample size was determined based on the standard power calculations, which indicate that a sample of 1,500 households would be sufficient. The baseline survey is supportive of this. For instance, the average travel time was 84 minutes, with a standard deviation of 87.1. Under standard assumptions (power=0.8; Type I error=0.05), it should be enough to detect a more than five percent improvement in travel time. The sample size of each region was decided based on population data. The subsample size of each community was then determined in proportion to the number of households that it contained.

30. Surveys in the Northeast and Jalapão. For the second group, the baseline data were collected between May and November 2008. The sample was relatively smaller than in the first group because the density of population is lower in these regions. In total, 422 households in 110 communities were interviewed (Table 2): 170 households in 27 communities of the Jalapão region and 252 households in 46 communities of the Northeast region. Works in the Northeast and Jalapão were completed, for the most part, in late 2011. Accordingly, the follow-up survey, conducted from October to December 2012, covered 319 households: 290 in the Northeast and 29 in Jalapão.

13 The term "community" does not cover an administrative or jurisdictional reality. For the purpose of the survey, the term "community" covered the cluster of residents along a road segment where the works were executed. It often corresponds to the boundaries of local business associations, if any.

14 The follow-up survey does not cover 11 relatively small municipalities that were included in the baseline survey.

Table 1: Sample size for Bico do Papagaio and Southeast Regions (Group 1)

Region	Treatment t=0	Treatment t=1	Control t=0	Control t=1	Rural Population 2000	Rural Population 2010
Southeast	529	471			43,508	34,029
Bico do Papagaio	109	117	431	413	62,768	67,000
Total	638	588	431	413		

Table 2: Sample size for Jalapão and Northeast Regions (Group 2)

Region	Treatment t=0	Treatment t=2	Control t=0	Control t=2	Rural Population 2000	Rural Population 2010
Jalapão	140	103	30	0	13,034	11,527
Northeast	224	187	28	29	42,815	39,898
Total	364	290	58	29		

31. The baseline and follow-up surveys were conducted in different months of the dry season. However, this would not affect measuring the envisaged impact during the rainy season because: (a) most items in the questionnaire asked about the general conditions of households or infrastructure, which were little affected by month or seasonality; (b) it is expected that accessibility during Tocantins' long rainy season (almost six months) will affect basic welfare over the entire year, including the dry season; and (c) it is impractical to conduct interview surveys during the rainy season due to access difficulty, especially in the case of the baseline survey before the works.

Basic Characteristics of the Population

32. The baseline survey provided an overview of household characteristics in the State of Tocantins (Table 3). The average household size is roughly four, and household heads are mostly male. The adult literacy rate is approximately 70 to 80 percent across the regions. A household has, on average, 1 to 1.5 school children. The survey data indicated that some children could not attend school due to illness, but few children were prevented from attending because of transport difficulties.

33. Every two or three households had at least one person who had been ill in the previous two months. Doctors and nurses appear to be available: they are present five to six days per week at the nearest health centers. Transport does not pose a major constraint for those seeking to reach a health center or hospital. Meanwhile, the infrastructure access of households varies across regions. The Southeast in particular appears to lag behind other regions.

34. The average household income ranges from R$370 in the Southeast to R$540 in the Northeast. Notably, there is significant variation within each region, ranging from nearly R$0 to R$6,000.

35. The economic structure does not differ significantly across regions. Although agriculture is the main sector, land distribution is highly skewed. Most households own fewer than 5 ha of land; 90 percent of households own fewer than 20 ha; and only 1 percent of the total number of households uses more than 100 ha of land for

agricultural production. About 20 percent of households are engaged in some form of cottage industry, of which half are selling a portion of these products in the market.

36. People appear to be lightly indebted. About 50 to 60 percent of households borrow money. The average debt varies from household to household but represents between two and six months of household income.

Table 3: Basic household characteristics by region (baseline survey)

	Bico do Papagaio	Southeast	Northeast	Jalapão
Demographics				
HH size	4.25	3.98	3.78	3.96
HH head = male	0.90	0.81	0.89	0.87
Adult literacy	0.77	0.73	0.80	0.74
HH head education > secondary	0.09	0.07	0.07	0.14
Schooling				
No. of school children	1.43	1.14	1.06	0.98
No. of school boys	0.72	0.64	0.61	0.46
No. of school girls	0.70	0.50	0.46	0.52
No. of children not attending school because of disease	0.04	0.04	0.01	0.03
No. of children not attending school because of transport difficulties	0.00	0.01	0.00	0.01
Health				
No. of sick HH members	0.43	0.45	0.47	0.31
No. of days that doctor is available per week	5.02	4.32	4.91	3.55
No. of days that nurse is available per week	5.97	5.91	5.84	5.42
HH not going to hospital because of transport difficulties	0.01	0.02	0.01	0.01
Infrastructure access				
HH using wood for cooking	0.35	0.88	0.76	0.76
HH using coal for cooking	0.43	0.00	0.02	0.00
HH using gas for cooking	0.22	0.11	0.21	0.21
HH using power for cooking	0.00	0.00	0.00	0.00
HH using power for lighting	0.71	0.39	0.66	0.61
HH using generator for lighting	0.01	0.06	0.01	0.01
HH using tap water for cooking	0.42	0.34	0.51	0.59
Income and jobs				
Monthly HH income (R$)	400.3	367.0	543.5	481.0
No. of HH members engaged in agriculture	1.199	1.062	0.968	0.735
No. of HH members engaged in industry	0.002	0.002	0.000	0.000
No. of HH members engaged in commerce	0.024	0.011	0.016	0.012

No. of HH members engaged in service	0.004	0.011	0.012	0.006
No. of HH members engaged in public sector	0.112	0.161	0.167	0.200
Agriculture				
Land for rice (ha)	2.88	3.72	2.73	1.61
Land for beans (ha)	0.72	0.37	0.52	0.66
Land for soy (ha)	0.01	0.01	0.00	0.04
Land for corn (ha)	2.48	4.10	1.52	1.63
Land for cassava (ha)	0.95	0.78	8.83	0.95
Land for fruit (ha)	7.03	2.96	1.61	0.52
Land for cane (ha)	0.31	0.77	0.08	0.45
Land for pasture (ha)	1.60	1.09	2.18	0.84
Cottage industry:				
HH engaged in cottage industry	0.18	0.25	0.25	0.22
HH engaged in cottage industry for sales	0.10	0.11	0.13	0.09
Credit access:				
HH borrowing money	0.62	0.65	0.49	0.51
Amount of debt (R$)	1987.1	1342.2	3147.8	992.4

Selected variables

37. First, to assess local residents' perception of and satisfaction with the project, the survey asks how each household benefited in the following domains: access to health, access to schools, access to work, and ease of personal travel.

38. To measure improved physical accessibility, two measurements are considered: distance to a certain destination, and travel time required to reach it. Although the former may measure a more direct outcome of the project, the latter may be affected by other factors, such as available modes of transportation. Trips with the following four destinations are examined: populated area, municipal center, health center, and elementary school.

39. In theory, improved accessibility is expected to increase demand for transport. To measure such effects, the frequency of trips with the following five basic purposes is examined: purchasing food, purchasing other goods, going to work, doing business, and visiting friends and relatives. Improved accessibility is also expected to change people's transport behavior. Although the provision of public bus service normally depends on a policy or regulatory decision, the regularity of public transport services may be improved thanks to improved road accessibility. As a result, the number of people using public buses may increase. The individual motorcycle and vehicle ownership rate may increase directly due to better road conditions and indirectly due to income increases resulting from improved transport accessibility. This, in turn, may result in increased numbers of people using cars to reach particular places.

40. To capture longer-term economic and social benefits, the following impacts are considered: Improved accessibility may increase school attendance, although such an impact may be difficult to observe in the present case, given the low level of school non-attendance due to difficult transport conditions even before the project's

launch (as mentioned above and shown in Table 3). Health conditions are also expected to improve in the long run. Although it is recognized that survey respondents did not generally consider transport to be a critical constraint when they visit hospitals, according to the baseline survey (Table 3) the level of difficulty in reaching a hospital due to road conditions is factored in, along with the number of sick household members. The reduction in travel time may increase competitiveness because people may use saved time for more productive activities. Improved rural accessibility may also allow farmers to sell their agricultural products more easily in the market, and may result in job creation in the agricultural sector. Moreover, new businesses, such as retailers and agro-businesses, may also be fostered.

41. Finally, household income was examined in order to evaluate the intervention's overall development impact.[15] All of the direct and indirect benefits mentioned above are expected to contribute to improving these rural populations' welfare, which is theoretically measured by household consumption. Although household consumption is generally difficult to gauge, household income was used as a proxy for welfare improvement. The summary statistics of all these variables are presented in Table 4 below.

Table 4: Summary statistics of outcome variables (baseline data)

	Bico do Papagaio & Southeast					Jalapão & Northeast				
	Obs.	Mean	Std. Dev.	Min.	Max.	Obs.	Mean	Std. Dev.	Min.	Max.
Perceptions of benefits										
(measured as the proportion of households perceiving benefits out of the total number of households interviewed):										
Improved access to health posts	1,093	0.29	(0.46)	0	1	393	0.33	(0.47)	0	1
Improved access to schools	1,093	0.28	(0.45)	0	1	393	0.31	(0.47)	0	1
Improved access to work	1,093	0.26	(0.44)	0	1	393	0.26	(0.44)	0	1
Easier personal travel	1,093	0.27	(0.44)	0	1	393	0.29	(0.45)	0	1
Rural accessibility										
Distance to nearest populated place (km)	1,097	14.2	(21.6)	0	120	422	22.9	(23.1)	0	100
Distance to municipal center (km)	1,097	29.3	(22.8)	0	120	422	44.6	(32.6)	0	500
Distance to nearest hospital (km)	1,097	26.6	(22.5)	0	120	422	38.6	(21.9)	0	100
Distance to nearest school (km)	1,097	3.5	(7.3)	0	120	422	6.7	(17.9)	0	200
Distance to nearest populated place (minutes)	818	67.3	(77.6)	2	480	319	77.7	(87.4)	1	840
Distance to municipal center (minutes)	1,087	91.0	(142.4)	1	2,880	406	116.2	(189.0)	5	2,040
Distance to nearest hospital (minutes)	1,091	81.6	(85.8)	2	1,230	418	93.1	(96.5)	1	870
Distance to nearest school (minutes)	1,084	24.6	(72.8)	1	1,800	411	24.7	(31.7)	1	240
Demand for mobility										
Number of trips to buy food in the last 7 days	1,097	0.34	(0.86)	0	20	422	0.16	(0.40)	0	3
Number of trips to buy other goods in the last 7 days	1,097	0.04	(0.27)	0	4	422	0.03	(0.16)	0	1

15 The household income variable in the follow-up survey is adjusted to the 2005 price, using consumer price indices of 1.340 and 1.412 in 2011 and 2012, respectively. In the data obtained, there is no other variable in nominal terms.

Number of trips to go to work in the last 7 days	1,097	1.17	(3.06)	0	52	422	0.91	(1.85)	0	7
Number of trips to do business in the last 7 days	1,097	0.15	(0.57)	0	7	422	0.31	(3.08)	0	62
Number of trips to visit friends or relatives in the last 7 days	1,097	0.13	(0.54)	0	7	422	0.09	(0.33)	0	3
Modal shift										
Dummy for bus use to go to nearest populated place	1,097	0.09	(0.29)	0	1	422	0.02	(0.15)	0	1
Dummy for bus use to go to municipal center	1,097	0.20	(0.40)	0	1	422	0.08	(0.28)	0	1
Dummy for bus use to go to nearest hospital	1,097	0.17	(0.38)	0	1	422	0.07	(0.26)	0	1
Dummy for bus use to go to nearest school	1,097	0.022	(0.15)	0	1	422	0.002	(0.05)	0	1
Dummy for car use to go to nearest populated place	1,097	0.037	(0.19)	0	1	422	0.002	(0.05)	0	1
Dummy for car use to go to municipal center	1,097	0.06	(0.24)	0	1	422	0.01	(0.10)	0	1
Dummy for car use to go to nearest hospital	1,097	0.07	(0.25)	0	1	422	0.01	(0.08)	0	1
Dummy for car use to go to nearest school	1,097	0.014	(0.12)	0	1	422	0.005	(0.07)	0	1
Dummy for HH with bicycle	1,097	0.54	(0.50)	0	1	422	0.44	(0.50)	0	1
Dummy for HH with motorcycle	1,097	0.17	(0.37)	0	1	422	0.29	(0.45)	0	1
Dummy for HH with car	1,097	0.08	(0.28)	0	1	422	0.09	(0.28)	0	1
Social benefits										
HH with children who cannot go to school because of road conditions	1,097	0.005	(0.074)	0	1	422	0.002	(0.049)	0	1
Number of school children in HH	1,097	1.28	(1.54)	0	11	422	1.03	(1.46)	0	7
Number of school boys in HH	1,097	0.68	(1.01)	0	7	422	0.55	(0.92)	0	5
Number of school girls in HH	1,097	0.60	(0.94)	0	6	422	0.48	(0.83)	0	4
Number of students going to preschool	1,097	0.18	(0.50)	0	5	422	0.14	(0.41)	0	3
Number of students going to elementary school	1,097	1.03	(1.37)	0	11	422	0.89	(1.24)	0	6
Number of students going to secondary school	1,097	0.12	(0.43)	0	4	422	0.13	(0.46)	0	4
Number of students going to university	1,097	0.01	(0.13)	0	2	422	0.03	(0.20)	0	3
HH with difficulty going to hospital because of road conditions	1,097	0.012	(0.108)	0	1	422	0.009	(0.097)	0	1
Number of HH members sick in the last 2 months	1,097	0.44	(1.18)	0	24	422	0.40	(1.24)	0	22
Economic benefits										
Number of HH members working in agriculture full time	1,097	1.131	(0.92)	0	6	422	0.874	(0.84)	0	4
Number of HH members working in industry full time	1,097	0.002	(0.04)	0	1	422	0.000	(0.00)	0	0
Number of HH members working in commerce full time	1,097	0.017	(0.16)	0	3	422	0.014	(0.12)	0	1
Number of HH members working in services full time	1,097	0.007	(0.09)	0	1	422	0.009	(0.10)	0	1
Number of HH members working in public sector full time	1,097	0.137	(0.38)	0	2	422	0.180	(0.45)	0	3
Household wage in the last month (BRL)	888	384.1	(400.7)	0	5,300	329	520.7	(600.8)	0	6,000

V. Methodology

Self-selection and comparability between treatment and control groups

42. As previously mentioned, the fundamental challenge when impact evaluations in the road sector are conducted is that the localization of the road/prioritized work is not randomly assigned and is likely to cause bias in the evaluation (van de Walle 2009; Rand 2011). In general, the prioritization of works—whether they involve construction, rehabilitation or upgrading—depends on public policies based on the socioeconomic environment particular to each project area. For example, rural roads may be relatively abundant in productive agricultural areas (Jacoby 2000). Transport policy makers may also wish to develop or favor particular areas of the state in view of land-use planning and management.

43. In the case of the Tocantins Sustainable Regional Development Project, this self-selection problem is further compounded by the mechanism through which road sections are selected for improvement, that is, through a participatory approach that involves public consultations with local residents of each municipality. As a result, the process of selecting priority roads may be based on different perspectives and strategies, depending on the municipality (e.g., some municipalities may have given priority to social perspectives, focusing on the poorest, while others may have prioritized economic aspects, such as agricultural production).

44. Our definition of the control groups, defined as the communities that were given priority but in which actual work had not been executed or had been postponed at the time of the survey, makes it possible to attenuate this bias. In reality, the communities in the treatment and control groups differ both explicitly and implicitly from one another, no matter how these groups are defined. Although they are equally poor and, by and large, share similar demographics and social characteristics according to the survey data (Tables 5 and 6),[16] some differences between the two regions of the first analysis—Bico do Papagaio and the Southeast—remain significant in specific areas, such as infrastructure access. The control group, which is essentially composed of communities in the Bico do Papagaio region, has better access to basic infrastructure services, such as gas, electricity and water supply. As a result, the diffusion rates of certain home appliances also look different from one group to the other. For example, with better access to grid power, 54 percent of households in the control group own refrigerators, while the same is true of only 34 percent in the treatment group. About 68 percent of households in the control group were using electricity for lighting, but this figure reached only 22 percent in the treatment group.

16 According to the FIRJAN Index of Municipal Development (*Índice FIRJAN de Desenvolvimento Municipal,* IFDM), there was no significant difference in the 2005 data between the two groups. IFDM is a municipal-level human development index prepared by the FIRJAN System (Rio de Janeiro State Federation of Industries *[Federação das Indústrias do Estado do Rio de Janeiro]*) based on the following three areas: Employment/Income, Health, and Education.

Table 5: Summary statistics of explanatory variables (baseline): Bico do Papagaio and Southeast

Explanatory variable (baseline)	Control group Obs.	Mean	Std.Dev.	Treatment group Obs.	Mean	Std.Dev.	Difference Zelen	t stat.	
Household size	441	4.17	(0.09)	656	4.08	(0.08)	0.09	(0.12)	
Adult share	438	0.63	(0.01)	655	0.65	(0.01)	-0.02	(0.02)	
HH head sex: Male	441	0.90	(0.01)	656	0.83	(0.01)	0.07	(0.02)	***
HH head education: Elementary	441	0.66	(0.02)	656	0.66	(0.02)	-0.01	(0.03)	
HH head education: Secondary	441	0.07	(0.01)	656	0.04	(0.01)	0.04	(0.01)	***
HH head education: University	441	0.007	(0.004)	656	0.014	(0.005)	-0.007	(0.006)	
Appliance ownership: Refrigerator	441	0.54	(0.02)	656	0.34	(0.02)	0.20	(0.03)	***
Appliance ownership: Color TV	441	0.52	(0.02)	656	0.29	(0.02)	0.23	(0.03)	***
Appliance ownership: Radio	441	0.65	(0.02)	656	0.61	(0.02)	0.04	(0.03)	
Appliance ownership: Gas stove	441	0.82	(0.02)	656	0.69	(0.02)	0.14	(0.03)	***
Appliance ownership: Washing machine	441	0.11	(0.01)	656	0.10	(0.01)	0.01	(0.02)	
Gas use for cooking	441	0.21	(0.02)	656	0.13	(0.01)	0.08	(0.02)	***
Power use for lighting	441	0.68	(0.02)	656	0.46	(0.02)	0.22	(0.03)	***
Tap water for cooking	441	0.44	(0.02)	656	0.34	(0.02)	0.09	(0.03)	***

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Table 6: Summary statistics of explanatory variables (baseline): Jalapão and Northeast

Explanatory variable (baseline)	Control group Obs.	Mean	Std.Dev.	Treatment group Obs.	Mean	Std.Dev.	Difference Zelen	t stat.	
Household size	58	3.81	(0.27)	364	3.86	(0.11)	-0.05	(0.30)	
Adult share	58	0.65	(0.04)	364	0.68	(0.01)	-0.03	(0.04)	
HH head sex: Male	58	0.93	(0.03)	364	0.88	(0.02)	0.05	(0.05)	
HH head education: Elementary	58	0.62	(0.06)	364	0.65	(0.03)	-0.02	(0.07)	
HH head education: Secondary	58	0.000	(0.000)	364	0.058	(0.012)	-0.06	(0.03)	*
HH head education: University	58	0.017	(0.017)	364	0.041	(0.010)	-0.024	(0.027)	
Appliance ownership: Refrigerator	58	0.45	(0.07)	364	0.55	(0.03)	-0.10	(0.07)	
Appliance ownership: Color TV	58	0.21	(0.05)	364	0.46	(0.03)	-0.26	(0.07)	***
Appliance ownership: Radio	58	0.59	(0.07)	364	0.60	(0.03)	-0.02	(0.07)	
Appliance ownership: Gas stove	58	0.74	(0.06)	364	0.80	(0.02)	-0.06	(0.06)	
Appliance ownership: Washing machine	58	0.02	(0.02)	364	0.11	(0.02)	-0.09	(0.04)	**
Gas use for cooking	58	0.12	(0.04)	364	0.23	(0.02)	-0.10	(0.06)	*
Power use for lighting	58	0.64	(0.06)	364	0.64	(0.03)	0.00	(0.07)	
Tap water for cooking	58	0.71	(0.06)	364	0.52	(0.03)	0.19	(0.07)	***

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Estimation methods

45. To deal with the abovementioned self-selection problem, two estimation techniques were primarily applied: (i) simple DID matching, and (ii) DID regression with covariates included. Subsequently, to verify the statistical robustness of the estimation results, the instrumental variable (IV) estimation was also partly used. The rationale behind the use of these different methods is that the impact evaluation is often sensitive to the estimation methods used. Different identification assumptions are required for different methods. In addition, each method has advantages and disadvantages. For instance, some methods—such as DID matching—are relatively simple to perform, while others—such as IV estimation—may require careful construction of the empirical model, because the validity of the model is examined on a case-by-case basis.

46. DID matching estimator. The DID matching estimator simply compares the outcome averages in the treatment and control groups in two separate periods (before and after the intervention). One advantage of the DID estimator is that it can control the unobserved heterogeneity between the treatment and control groups by mitigating the self-selection bias, as long as the time-variant factors of the selected outcome indicators are negligible (e.g., Todd 2008). As often discussed, however, it may be a strong assumption that no time-variant factor affects the outcome indicators (e.g., Jalan and Ravallion 1998). For instance, if the initial conditions between the treatment and control groups vary significantly, the development paths of the outcomes may also differ in important ways. Unfortunately, there is not much freedom to test this trend assumption in the data, because the data were only collected at two periods of time and there is no possibility to compare the time trends prior to and following the intervention.

47. To mitigate the risk of unbalanced characteristics, propensity score matching was combined with DID. This combination is normally expected to perform well in obtaining an experimental benchmark (Smith and Todd 2005; van de Walle and Mu 2008).[17] Propensity score matching is a useful technique to ensure comparability between the two groups, at least in a statistical sense, and is often used in the impact evaluation literature for the road sector (e.g., Lokshin and Yemtsov 2005; Mu and van de Walle 2011).

48. Since there are cross-section data from two periods of time, rather than panel data,[18] the simple DID matching estimator is arrived at in this manner:

$$\alpha_{DDAVG} = \frac{1}{n_1}\sum_i \left\{Y_{i1} \middle| D=1 - \sum_j w(i,j) Y_{j1} \middle| D=0\right\} - \frac{1}{n_0}\sum_i \left\{Y_{i0} \middle| D=1 - \sum_j w(i,j) Y_{j0} \middle| D=0\right\} \quad (1)$$

17 Propensity score matching is a statistical technique to match each treatment unit to a control unit that does not benefit from a program but has a similar probability of receiving the program, given all observed characteristics. It ensures that the treatment unit and control unit are comparable in a probabilistic sense.

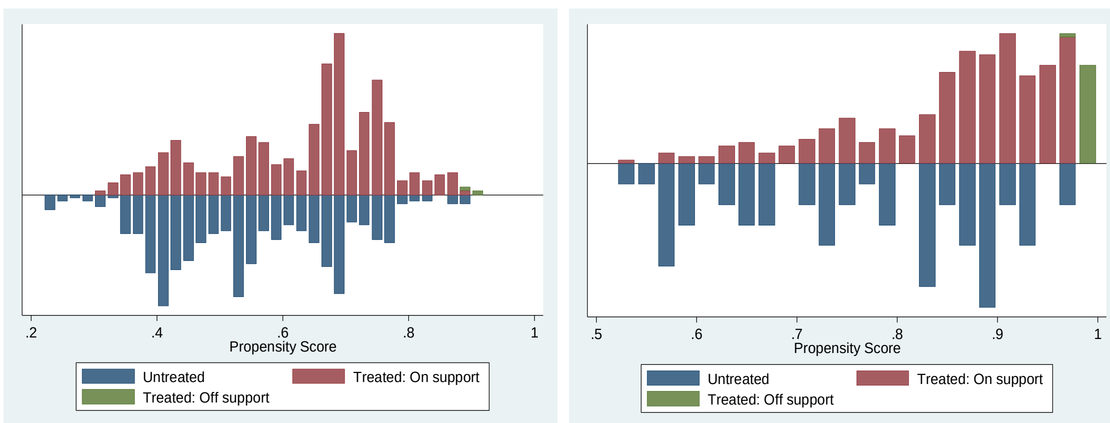
18 It is not possible to match the observations between the baseline and follow-up surveys because no household identification was recorded in the surveys.

where Y is outcome of household i at time t. Time t is set at zero before project implementation (baseline) and unity after project completion (follow-up). D denotes a dummy variable for treatment, which is set as unity if household i received an intervention. w is the weight given by kernel matching (Heckman, Ichimura and Todd 1997). n is the number of households in the treatment group under the common support.

49. The kernel propensity score matching was performed with the initial observable characteristics presented in Tables 4 and 5. It ultimately corresponded well to the balancing property of the propensity score met, meaning that households with the same propensity scores have indifferent distributions of all relevant covariates. In the baseline data for Bico do Papagaio and the Southeast, four observations were located outside of the common support and were excluded from the sample. Twenty-nine observations were not supported in the case of Jalapão and the Northeast (Figure 3). These were also excluded from the analysis because they cannot be matched to any of the non-beneficiary households.

Figure 3: Predicted propensity scores of the treatment and control groups

(Bico do Papagaio and Southeast) (Jalapão and Northeast)



DID regression with covariate included. The second estimation method is the DID regression with covariates included (after restricting the analysis to the common support). As mentioned above, one potential limit of the DID estimator comes from its assumption that there is no time-variant, group-specific effect, meaning that the development trends would be the same regardless of the intervention. Should this not be the case, the DID estimator would not be valid. To mitigate this risk, time-variant household characteristics can be included on the right-hand side of the regression equation (e.g., Jalan and Ravallion 1998).

$$\ln Y_{it} = \alpha_{DDREG} D_{it} t + \beta_D D_{it} + \beta_t t + X_{it}\beta + \varepsilon_{it} \quad (2)$$

X is a time-variant observable that can control potential differences in development paths between the two groups. Note that logarithms are taken of the dependent variable and all the covariates that are continuous.

50. Two methods are used to estimate Equation (2) when the outcome variable is a binary variable, as in the cases of car ownership and public bus use. One approach

is the linear probability model in which the dependent variable is treated as continuous, although it takes either 0 or 1. A potential problem is that the predicted probabilities may be greater than 1 or less than 0.

The other approach is to use a probit model. An advantage of this model is that the predicted values are between 0 and 1. However, a disadvantage is that the evaluation of the coefficient α_{DDREG} becomes complex. The magnitude of the interaction effect, i.e., $D_{it}t$, in a probit model is not merely the coefficient of the interaction term; it also depends on the independent variables (Ai and Norton 2003). Since both D_{it} and t are discrete variables, the interaction effect is estimated by:

$$\hat{\alpha}_{DDREG} = \frac{\Delta^2 F\left(X, \hat{\beta}\right)}{\Delta D \Delta t} \tag{3}$$

VI. Main estimation results

51. Both simple DID matching and DID regression have been performed. The estimation results, by and large, turned out to be similar to each other. See the Annex tables for the full estimation results of the DID regressions. The main findings are detailed below.

Perceived benefits from the project

52. On the subjective level, people perceived various benefits from the project. Not surprisingly, in the Bico do Papagaio and Southeast regions, the proportion of households that confirmed they had benefited from the project is 18 to 20 percentage points higher in the treatment group (Table 7). In the case of Jalapão and the Northeast, evidence is less clear, although people consistently perceived benefits in terms of improved access to schools and workplaces.

53. The DID regression shows similar results, particularly for the Bico do Papagaio and Southeast regions. Households responded that they benefited from the project thanks to improved accessibility. In Jalapão and the Northeast, the results are less conclusive, but access to work seems to have improved significantly.

Table 7: Estimated impacts on rural accessibility

	Bico do Papagaio & Southeast				Jalapão & Northeast			
	Simple average DID		DID regression		Simple average DID		DID regression	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Benefited from:								
Improved access to health	0.199	(0.037) ***	0.201	(0.041) ***	-0.092	(0.069)	-0.083	(0.120)
Improved access to school	0.192	(0.036) ***	0.199	(0.040) ***	0.116	(0.067) *	0.159	(0.109)

Better access to work	0.175	(0.036) ***	0.160	(0.039) ***	0.149	(0.066) **	0.190	(0.107) *
Easier personal travel	0.185	(0.036) ***	0.186	(0.040) ***	0.045	(0.069)	0.026	(0.119)

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Rural accessibility

54. As expected, rural accessibility was found to have improved, particularly in terms of distance and travel time to the nearest populated area and municipal center. In the Bico do Papagaio and Southeast regions, the distance to the nearest populated area is estimated to have been shortened by 6 km, and the travel time reduced by 13 minutes (Table 8). The distance to the nearest populated area in the Jalapão and Northeast regions was also found to have decreased by 25 km. The difference in the measured impacts seems attributable to the dramatically deteriorated rural accessibility in areas of the Jalapão and Northeast regions where the project was not implemented (Figure 4). Because the sample size of the control group in these regions is very limited, statistical concerns may be raised with respect to the results.

55. Results are mixed regarding the distance and travel time to reach schools: they increased in the Bico do Papagaio and Southeast regions, and decreased in Jalapão and the Northeast. One possible factor may be related to the government's recent policy involving the consolidation of many rural schools into larger schools, while providing for improved school bus services enabled by better roads. In fact, the use of public school buses has indeed increased in the Bico do Papagaio and Southeast regions. This has resulted in an increase of both distance and travel time to reach schools between the baseline and follow-up surveys. This assumption is also consistent with the fact that the average speed en route to schools increased from 9.7 to 16.8 km per hour in the project areas of these regions, as opposed to a smaller increase from 10 to 14 km per hour in the comparison group (Figure 5). The surveys do not indicate any impediment to reaching schools due to transport difficulties.

56. The positive results mentioned above may be tempered by the fact that the project did not aim to construct new road infrastructures, but rather to ensure year-round trafficability on existing roads. One possible explanation factor is that impassable roads in rainy seasons may have obliged road users to take alternative longer roads.

Table 8: Estimated impacts on rural accessibility

	Bico do Papagaio & Southeast				Jalapão & Northeast			
	Simple average DID		DID regression		Simple average DID		DID regression	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Distance (km) to:								
Nearest populated place	-6.07	(1.04) ***	-0.37	(0.29)	-25.40	(3.10) ***	-2.18	(0.82) ***
Municipal center	-3.37	(1.68) **	-0.36	(0.15) **	1.09	(5.34)	0.19	(0.37)
Nearest hospital	-1.02	(1.70)	-0.18	(0.16)	-0.65	(3.27)	0.64	(0.56)
School	10.01	(4.96) **	0.60	(0.19) ***	-9.51	(2.37) ***	-0.38	(0.45)
Time (minutes) to:								

Nearest populated place	-12.93	(6.57) **	-0.01	(0.10)	-15.10	(11.08)	-0.28	(0.22)
Municipal center	-9.38	(8.94)	-0.08	(0.07)	-23.26	(16.90)	-0.37	(0.14) ***
Nearest hospital	-3.50	(5.94)	-0.11	(0.08)	-11.26	(10.87)	-0.01	(0.28)
School	15.71	(6.16) **	0.42	(0.10) ***	-4.61	(4.62)	-0.14	(0.29)

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Figure 4: Distance to the nearest populated area: simple average comparison

(Bico do Papagaio and Southeast) **(Jalapão and Northeast)**

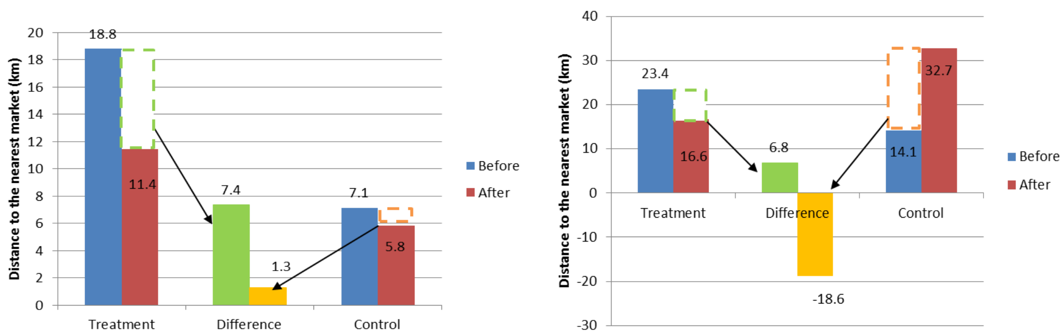
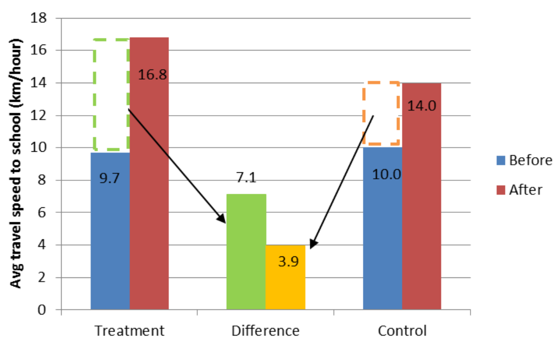


Figure 5: Average travel speed to school (Bico do Papagaio and Southeast)



Demand for mobility

57. The estimated impacts on transport demand remain unclear. Although the number of trips to buy food increased in the Jalapão and Northeast regions, they decreased in the Bico do Papagaio and Southeast regions (Figure 6). After the intervention, inhabitants traveled less to buy food but more to purchase other goods in the Bico do Papagaio and Southeast regions (Table 9).

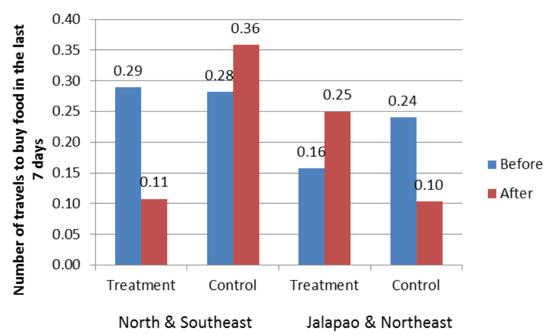
58. Possible explanation factors of these mixed results include: (a) potential seasonal sensitivity of demand for mobility. In fact, baseline and follow-up surveys were implemented during two different seasons; and (b) a bias may have been caused by the wording of the question, which was focused on the number of trips during the seven days prior to the survey.

Table 9: Estimated impacts on demand for mobility

	Bico do Papagaio & Southeast						Jalapão & Northeast					
	Simple average DID			DID regression			Simple average DID			DID regression		
	Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.	
Number of trips (in the last 7 days) to:												
Buy food	-0.26	(0.06)	***	-0.88	(0.17)	***	0.23	(0.07)	***	0.46	(0.36)	
Buy other goods	0.04	(0.02)	**	0.05	(0.07)		0.03	(0.03)		0.13	(0.13)	
Go to work	-0.04	(0.19)		0.24	(0.21)		-0.39	(0.23)	*	-0.86	(0.47)	*
Do business	0.07	(0.05)		-0.03	(0.14)		-0.13	(0.31)		0.09	(0.37)	
Visit friends or relatives	-0.14	(0.06)	**	0.04	(0.13)		-0.03	(0.05)		-0.15	(0.25)	

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Figure 6: Demand for mobility: number of trips to buy food



Modal choice

59. The impact of road improvements on respondents' modal choice of transport is much clearer. More people began to use public buses and individual cars following improvements (Table 10), possibly because more public transport services were provided or because the regularity and reliability of these services improved. Individual car ownership also increased. Similarly, people came to own more bicycles in both pairs of regions. This development may be interpreted as a combination of the direct effect of improved roads and the indirect impact of income growth induced by road improvement. Motorcycle ownership increased only in the Jalapão and Northeast regions.

60. Evidence shows that more people also began to use public buses to reach schools, in particular in the Bico do Papagaio and Southeast regions. This is consistent with the abovementioned result that the distance to the nearest school grew longer. No impact on bus use was observed in the Jalapão and Northeast regions.

Table 10: Estimated impacts on modal choice

	Bico do Papagaio & Southeast						Jalapão & Northeast					
	Simple average DID		DID regression				Simple average DID		DID regression			
			Linear Prob. Model		Probit				Linear Prob. Model		Probit	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Public bus use (dummy variable) to reach:												
Nearest populated place	-0.02	(0.02)	0.00	(0.02)	0.24	(0.20)	-0.08	(0.03) ***	-0.05	(0.06)	-0.58	(0.56)
Municipal center	0.04	(0.03)	0.08	(0.03) **	0.44	(0.14) ***	0.05	(0.05)	0.08	(0.08)	0.58	(0.43)
Nearest hospital	0.03	(0.03)	0.07	(0.03) **	0.34	(0.15) **	0.03	(0.04)	0.06	(0.06)	0.66	(0.55)
School	0.03	(0.01) ***	0.03	(0.01) **	3.97	(0.23) ***	0.00	(0.01)	0.00	(0.00)		
Individual car use (dummy variable) to reach:												
Nearest populated place	0.05	(0.02) ***	0.05	(0.02) ***	0.53	(0.23) **	0.10	(0.03) ***	0.06	(0.06)	4.73	(0.67) ***
Municipal center	0.07	(0.02) ***	0.06	(0.02) **	0.36	(0.17) **	0.11	(0.03) ***	0.08	(0.06)	1.09	(0.56) **
Nearest hospital	0.04	(0.01) ***	0.08	(0.02) ***	0.45	(0.16) ***	0.23	(0.03) ***	0.15	(0.05) ***	5.88	(0.65) ***
School	0.07	(0.02) ***	0.04	(0.01) ***	0.72	(0.30) **	0.15	(0.03) ***	0.08	(0.05) *	5.79	(0.75) ***
Transport equipment ownership (dummy variable):												
Bicycle	0.08	(0.04) **	0.07	(0.04) *	0.17	(0.12)	0.12	(0.07) *	-0.01	(0.10)	0.05	(0.36)
Motorcycle	0.01	(0.03)	-0.01	(0.04)	0.00	(0.13)	0.15	(0.06) **	0.13	(0.08)	0.32	(0.42)
Car	0.04	(0.02) *	0.04	(0.03) *	0.22	(0.16)	0.07	(0.04) *	0.06	(0.06)	0.36	(0.63)

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Social benefits

61. The educational impact of improved roads is found to be partially positive in the Bico do Papagaio and Southeast regions. The number of girls attending school in these two regions has increased by 0.03 and 0.59, respectively, based on the simple average DID model and the DID regression model.[19] The number of households with children who cannot attend school due to poor road conditions experienced a statistically significant decline, although the number was very small even before the project's launch (Table 11).

62. In contrast, the impacts on school attendance are all negative in Jalapão and the Northeast; some of them are statistically significant. The main reason for this evolution is the substantial increase in the control group's school attendance, while the treatment group (Figure 7) remained stable for the most part.

63. The health impacts are inconclusive in all regions. Most of the estimated impacts are not statistically significant. The number of households that have experienced transport-related difficulties in visiting hospitals declined in Bico do Papagaio and the Southeast, but increased in the Northeast and Jalapão. The number of household members who were sick during the two months prior to the survey declined from about 0.3–0.4 to about 0.15–0.2 across the regions. However, the trend was similar among both the treatment and control groups. This prevented the perception of any net impact resulting from the road project.

Table 11: Estimated impacts on education and health

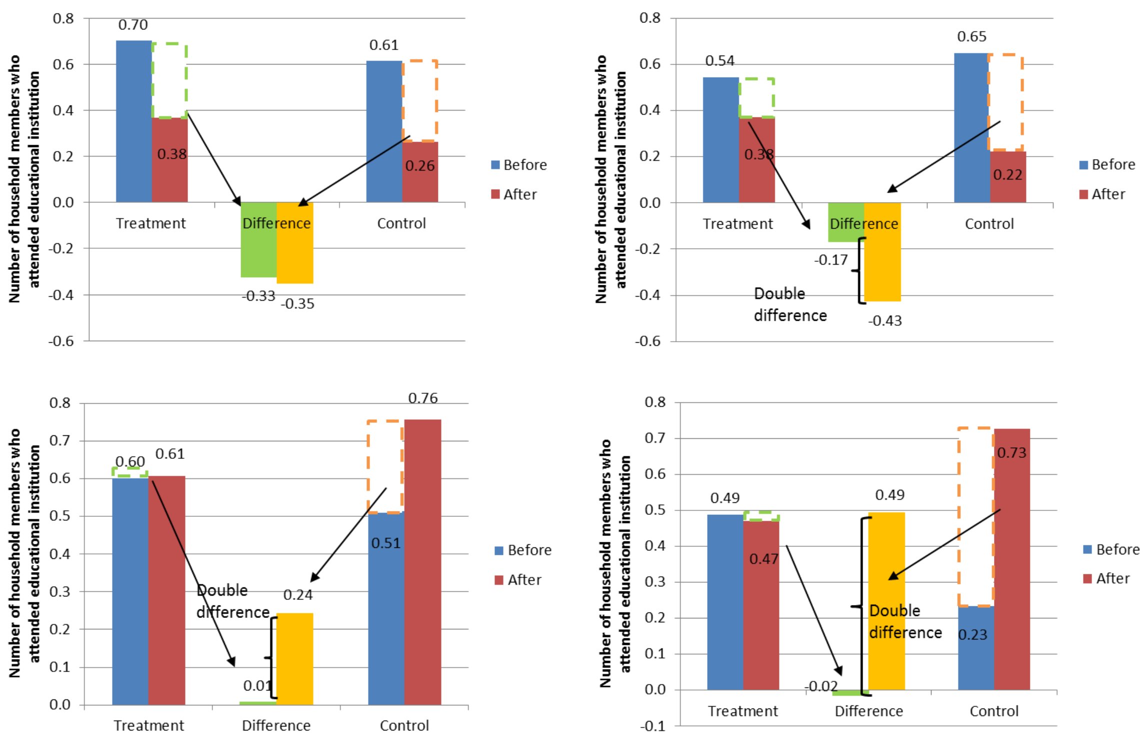
	Bico do Papagaio & Southeast						Jalapão & Northeast					
	Simple average DID			DID regression			Simple average DID			DID regression		
	Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.	
HH with children who could not attend school due to road conditions	-0.009	(0.004)	**	-0.008	(0.003)	**	-0.003	(0.005)		-0.0019	(0.002)	
Number of children in HH who attend school:												
Total	0.28	(0.11)	**	0.43	(0.19)	**	-0.74	(0.20)	***	-0.59	(0.41)	
Boys	0.03	(0.07)		0.16	(0.18)		-0.24	(0.14)	*	-0.21	(0.46)	
Girls	0.03	(0.07)	***	0.59	(0.18)	***	-0.51	(0.10)	***	-1.23	(0.43)	***
Preschool	0.03	(0.04)		0.15	(0.13)		-0.09	(0.06)		-0.51	(0.42)	
Elementary school	0.15	(0.11)		0.14	(0.17)		-0.42	(0.17)	**	-0.72	(0.39)	*
Secondary school	-0.01	(0.04)		0.24	(0.14)	*	-0.16	(0.06)	***	-0.25	(0.28)	
University	0.00	(0.01)		0.00	(0.05)		0.04	(0.02)	**	0.18	(0.11)	
HH having difficulty reaching hospital due to road conditions	-0.008	(0.007)		-0.005	(0.007)		0.07	(0.02)	***	0.04	(0.03)	

19 In fact, the absolute number of girls attending schools has decreased in both the treatment and control groups, but the reduction was smaller in the treatment group than in the control group. This may be related to the fact that the total number of children aged 5 to 9 years has been declining in the State of Tocantins (IBGE 2012).

Number of HH members who were sick (last 2 months)	-0.05	(0.07)	0.08	(0.18)	-0.17	(0.14)	-0.19	(0.56)

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Figure 7: School attendance: Simple average comparison on number of household members who attended an educational institution
(Bico do Papagaio and Southeast)



Economic benefits: jobs and income

64. Rural road intervention is found to have had positive impacts on job creation. But the statistical significance of these impacts varies depending on estimation methods, and the economic sector benefiting from the project varies depending on the regional economic structure. The simple average DID matching shows that agricultural employment increased 17 percent in Bico do Papagaio and the Southeast (Table 12).[20] This specific trend may be linked to the relatively large number of people involved in agriculture in these regions.[21] Numerically, it means that the project contributed to the creation of about 220 jobs in 110 communities with about 4,500 people. The statistical significance of this development disappeared in the DID regression, but the *p*-value of the coefficient of agricultural employment remains relatively high at 0.113, indicating a likely positive impact of improved roads on agricultural employment in Bico do Papagaio and the Southeast. There is no clear indication of job creation in other sectors in these regions.

20 Although the estimated marginal effect is 0.206 people, the sample average of the number of household members engaged in agriculture is 1.13.

21 Although the number of household members engaged in agriculture was 1.2 in Bico do Papagaio and the Southeast, it was about 0.9 in Jalapão and the Northeast.

65. In the Jalapão and Northeast regions, the number of jobs increased in the service and public sectors, which are relatively large in these regions.[22] Again, the DID regression results have no statistical significance at the conventional level. Similarly, however, the *p*-value is relatively high for public sector jobs at 0.162.

66. According to the average DID matching, the monthly household income is estimated to have increased by R$100, or about US$67, in the Bico do Papagaio and Southeast regions due to improved rural accessibility. The DID regression shows a smaller impact with a coefficient of 0.17, of which the marginal impact is estimated at R$72.4, or US$48. In fact, household income has tended to increase regardless of the project, but the increase was larger in areas where the project was implemented (Figure 8).

67. In contrast, the impact on income is unclear in Jalapão and the Northeast. The measured net impact is negative. The income change was smaller in the treatment group than in the control group, with no statistical significance.

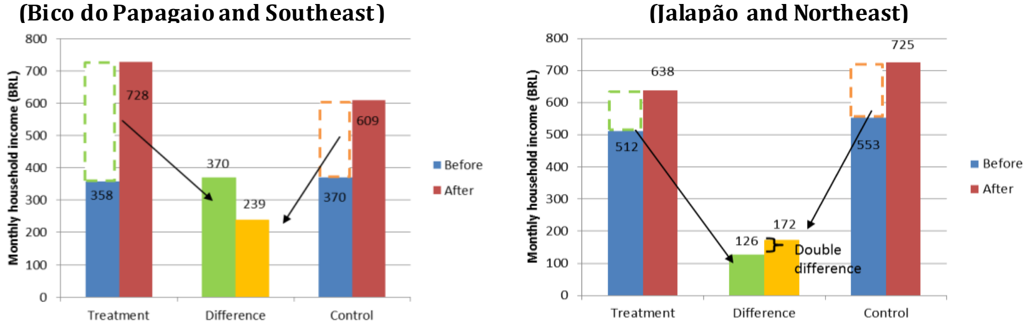
Table 12: Estimated impacts on employment and household income

	Bico do Papagaio & Southeast				Jalapão & Northeast			
	Simple average DID		DID regression		Simple average DID		DID regression	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Number of HH members working (full-time) in:								
Agriculture	0.21	(0.07) **	0.30	(0.19)	-0.08	(0.11)	-0.59	(0.56)
Industry	0.00	(0.00)	0.02	(0.02)	0.01	(0.01)	0.03	(0.03)
Commerce	0.02	(0.01)	0.07	(0.06)	0.03	(0.02)	0.05	(0.19)
Services	0.00	(0.01)	-0.01	(0.04)	0.03	(0.01) **	0.10	(0.08)
Public sector	0.00	(0.03)	0.11	(0.12)	0.14	(0.07) **	0.51	(0.37)
Household income in the last month (BRL)	100.40	(35.86) ***	0.17	(0.10) *	-45.96	(83.85)	0.03	(0.24)

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Figure 8: Monthly household income: Simple average comparison

(Bico do Papagaio and Southeast) **(Jalapão and Northeast)**



22 The number of household members engaged in public services was 0.2 on average, which is greater than in Bico do Papagaio and the Southeast (i.e., 0.1).

VII. Discussion

Robustness check

68. As mentioned previously, verifying the robustness of the above results through the use of different methods is important because impact evaluations are sometimes sensitive to empirical specifications. For the present evaluation, the instrumental variable (IV) estimator was used to check such robustness,[23] but was applied only for the first group (the Bico do Papagaio and Southeast regions) in cases where the required information was available (notably, the detailed location of the project works). The main challenge in estimating Equation (2) is the endogeneity of the project's localization, i.e., D_{it}. In theory, the instruments must be independent from the outcome variables but relevant to the project localization decision.

69. Several ways of constructing instruments exist in the literature. When Chandra and Thompson (2000) examined the impact of the U.S. interstate highways on earnings of firms, they argued that the non-metropolitan counties served by highways were thought to have received the new highway as an exogenous benefit, because the interstate highway's first aim was to connect metropolitan areas. Banerjee et al. (2012) applied the same concept to the Chinese railways case, calculating the distance from counties to straight lines connecting historic cities and ports.[24] Gibson and Rozelle (2003) used, as an instrument, the timing in which the national highway system penetrated into each district in Papua New Guinea, demonstrating that a community's proximity to a highway resulted in a higher likelihood of receiving a feeder road.

70. Two instruments were constructed to verify the robustness of the above results in the present evaluation, so as to assess whether there could be a correlation between the localization of the works on the rural roads and the proximity to existing paved federal and state road networks, as discussed by Gibson and Rozelle (2003): (i) the distance from each community to the nearest paved state road before the project; and (ii) a dummy variable representing the existence of a paved state road in each municipality. The data are based on information about the state road network prior to 2005, just before the civil works got under way, to avoid further endogeneity between the works localization and the outcome variables. Notably, during the intervention period the government was not only investing in rural roads but also upgrading state highways.

71. Both (i.e., distance to the nearest paved state road before project commencement and the dummy variable representing the existence of a paved state road) were found to be valid, with signs contrary to prior expectations. Table 13 shows the first-stage regression result with household income used as an outcome variable. All indications are that a community is more likely to receive rural road intervention if it lacks good access to the state's main road network. This may be consistent with the objective of the project in Tocantins, which focused in particular on lagging, remote communities situated in critical spots along the municipal road

23 When the outcome variable is a binary, the instrumental variable probit model is used.

24 In the context of dynamic panel estimation, lagged variables of household characteristics may also be used as a set of instruments (Dercon et al. 2008).

network. This result tends to demonstrate that rural road improvement localizations are likely to be based on the level of their connectivity to state or federal roads.

72. Statistically, both instruments have significantly negative coefficients, possibly suggesting that the civil works were implemented earlier in the areas where road connectivity was worse. The evidence indicates that the probability of having civil works executed at the earlier stage of the project was high when a municipality did not have any paved state road. The work was also likely to get under way early if a community was located far from the paved state road network. These instruments are found to be valid in the sense that they can be treated as excluded variables and are not correlated with the error terms. Both the Sagan overidentifying restriction test and the Hausman exogeneity test statistics are shown for each regression result in the Annex tables.

73. The IV estimation results are broadly consistent with the DID regression results (Table 14). Rural accessibility to a populated area would likely be improved, but not to a school. Overall use of public transportation increased, as did the use of individual cars. However, the impact on individual car ownership disappeared. There was a visible positive impact on girls' school attendance. In contrast to the above DID result, the IV estimation indicates that the project might have resulted in increased jobs in both the service and public sectors.

74. Although economic impacts exist, they may be statistically weak. The DID regression estimated a significant coefficient of household income increase only in the Bico do Papagaio and Southeast regions. When evaluated at the sample means, the marginal effect is appraised at R$59.8, with a standard error of 36.5. This is smaller than the previous estimate, but is more or less consistent.

75. In terms of employment, the significance of the impact on agricultural jobs disappeared in both pairs of regions. However, the *p*-value of the coefficient of agricultural employment remains relatively high, at 0.113, in the Bico do Papagaio and Southeast regions. Similarly, in the Jalapão and Northeast regions, the *p*-value is relatively high for public sector jobs, at 0.162. These figures are consistent with the above simple DID matching estimates.

Table 13: First-stage regression of IV estimation on household income

Dependent variable = *D*	Coef.	Std. Err.	
Municipality having paved state road	-0.384	(0.069)	***
lnDistance to paved state road	-0.030	(0.005)	***
ln HH size	-0.026	(0.043)	
Adult share	-0.042	(0.088)	
HH head sex: Male	-0.036	(0.051)	
HH head education: Elementary	-0.018	(0.036)	
HH head education: Secondary	0.026	(0.062)	
HH head education: University	-0.042	(0.128)	
Appliance ownership: Refrigerator	-0.040	(0.053)	
Appliance ownership: Color TV	-0.141	(0.049)	***
Appliance ownership: Radio	-0.034	(0.032)	
Appliance ownership: Gas stove	-0.113	(0.052)	**
Appliance ownership: Washing machine	0.070	(0.038)	*
Gas use for cooking	-0.059	(0.037)	

Power use for lighting	-0.057	(0.053)
Tap water for cooking	-0.110	(0.033) ***
Constant	1.388	(0.161) ***
Obs.	859	
R-squared	0.15	
F-stat	10.67	

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Table 14: IV OLS/Probit estimation results

Dependent variable	IV OLS or IV probit Coef.	Std.Err.
Rural accessibility		
Distance to:		
Populated area	-2.414	(1.004) **
Municipal capital	-0.536	(0.628)
Hospital	-0.631	(0.671)
School	2.550	(0.727) ***
Travel time to:		
Populated area	0.274	(0.417)
Municipal capital	-0.146	(0.242)
Hospital	-0.438	(0.281)
School	1.007	(0.297) ***
Demand for mobility		
No. of trips to:		
Buy food	-1.239	(0.472) ***
Buy goods	0.105	(0.167)
Go to work	0.785	(0.602)
Do business	-0.295	(0.469)
Visit friends/relatives	-0.156	(0.383)
Use of public bus to reach:		
Populated area	1.015	(0.712)
Municipal capital	1.298	(0.493) ***
Hospital	1.675	(0.521) ***
School		
Use of vehicle to reach:		
Populated area	1.365	(0.796) *
Municipal capital	0.170	(0.530)
Hospital	-0.427	(0.518)
School	1.707	(0.928) *
Transport equipment ownership		
Bicycle	0.366	(0.399)
Motorcycle	0.508	(0.398)
Vehicle	-0.168	(0.525)
Education		
No. of students		
All	1.003	(0.608) *
Boys	0.739	(0.533)
Girls	0.878	(0.535) *
Preschool	-1.191	(0.437) ***
Elementary	-0.261	(0.519)

Secondary	0.334	(0.458)
University	-0.007	(0.165)
Health		
No. of sick HH members	-0.613	(0.500)
Economic benefits		
No. of HH members engaged in:		
Agriculture	0.098	(0.671)
Industry	0.057	(0.062)
Commerce	0.109	(0.185)
Service	0.321	(0.151) **
Public sector	0.950	(0.371) ***
HH monthly income	0.290	(0.223)

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

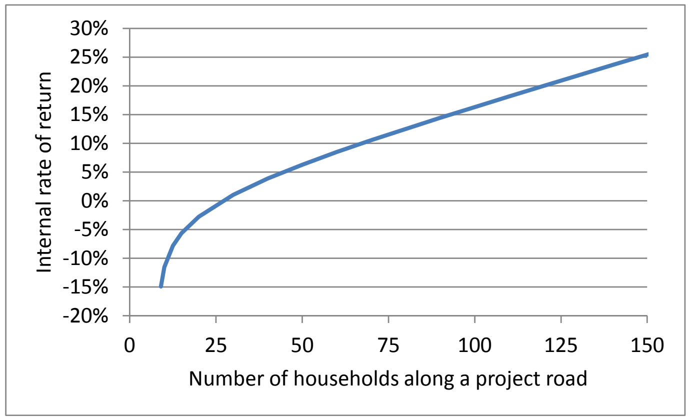
Investment policy implications

76. The above estimation results have several important policy implications. First, they indicate that improved rural roads have had a certain impact on development outcomes in some areas, as exemplified by the shift in transport modal choice or increased school attendance by girls. Meanwhile, economic impacts on households—such as job creation and household income—have proved to be weaker, although with an overall positive impact.

77. Furthermore, the impact evaluation results could be used for the cost–benefit analysis of rural road interventions, for which the suitability of the traditional evaluation approach with respect to road-user benefits is limited. In the case of Tocantins, household monthly income increased by an estimated US$40–$70 on average. At a US$40 increase per household and month, under a conservative approach and a reasonable economic assumption,[25] rural road investment becomes justified when it serves more than 80 households, reaching a 12 percent internal rate of return (IRR). The graph below (Figure 9) illustrates the IRR in relation to the number of beneficiaries along each road section. Although this finding is interesting, it should not be seen as the only driver for designing a policy on transport investments, because other elements—for instance, economic development and social benefits perspectives, which are often not measured quantitatively—can also be taken into account to justify particular investments.

25 The project life is assumed to be 30 years. The average investment cost is about US$267,000 per intervention road. Note that each road may have four to five civil works, including bridges and culverts. The maintenance cost is assumed to be 1.5 percent of the initial investment cost.

Figure 9: Predicted rate of return and number of beneficiaries



78. Finally, the impact evaluation results show that the improvement of transport should be coordinated with other sectoral policies. For example, the project was found to have increased the number of children attending school, with an estimated 300 children in 1,100 households surveyed[26] (with the DID matching result, the magnitude of the impact is estimated at 0.284 per household). School capacity should be increased accordingly, because without such adequate capacity, social benefits from improved rural roads would likely be offset by lower quality of education. Similarly, improved public transport policy should be coordinated: evidence shows that people's use of public buses increased following project completion. According to the simple DID matching estimates, the probability of using a bus to reach a populated area would increase by 3.2 percent.

Lessons learned for improving impact evaluation design

79. The implementation of this impact evaluation raised methodological and practical lessons. First, it is essential to define and maintain a representative control group to carry out a rigorous evaluation of a project or program. In the present exercise, household surveys have been carried out only where civil works were planned, for the reasons mentioned above. The retrofit pipeline comparison only worked partially, resulting in an unbalanced sample size between the treatment and control groups. In Jalapão and the Northeast, the control group had only 60 households, far fewer than the treatment group composed of 360.

80. Maintaining the comparability between the treatment and control groups is also essential to avoid bias in the comparison. At the design stage, each treatment community should be paired with one control community located within the same municipality and sharing similar characteristics, for the sake of comparability. Important loopholes may appear in the course of the evaluation if, as is likely to occur in such exercises over the long term, the control groups end up benefiting from road improvements. In addition, it is important to collect as many observables as possible in an effort to control the potential heterogeneity of the two groups. In the case of Tocantins, the data clearly show significant differences in household characteristics between the treatment and control groups, mainly because the sample of the control group was limited to one of the two regions in both the first and second groups. In the

26 With the DID regression result, the marginal effect is estimated at 0.147 per household.

present case, a matching DID method was used to control differences in characteristics between groups.

81. It is similarly important to ensure comparability between baseline and follow-up surveys. In theory, identical households or communities should have been interviewed before and after interventions to develop panel data. In the present evaluation, the follow-up surveys could not be implemented in the same households because the location of the households interviewed for the baseline was not documented. As a result, the evaluation is not based on panel data. This is considered a significant design flaw because it complicates intertemporal comparability. Improvements in future impact evaluations may be achieved by recording household identification and/or geo-references of surveyed households.

82. The timing of the follow-up survey(s) is also a critical aspect: although direct and physical outcomes, such as travel time to the nearest hospital, can be observed immediately after project completion, it may take some time to observe other indirect socioeconomic impacts, such as job creation and health outcomes. It would be useful to carry out multiple follow-up surveys over the long run, although longer-term evaluations also run the risk of losing part of the control group for the reasons mentioned above.

83. Coordination among the managers of the works and the team in charge of impact evaluation is essential to ensure appropriate timing and location of the surveys. In fact, the timing of the works must often adapt to particular field constraints (delays due to administrative procedures or weather conditions, relocation of works, etc.). In the present evaluation, even basic information, such as the works' location and schedule, have not always been made available on time.

84. The questionnaires used for the interviews must be extremely well conceived and customized to the project's particular design and context. For example, although questions about the transport distance or time traveled for a particular activity seemed pertinent a priori, with hindsight the questionnaire should rather have focused on the number of impediments to travel due to inclement weather over the past 6 to 12 months (to cover seasonality). This type of question would have been more effective in view of achieving spot improvement works on rural roads, thus allowing for year-round transport. Moreover, in retrospect, interviewees offered very subjective responses when asked about distances. Other questions, such as those related to illness, seem to have little bearing on the project. Alternatively, a question about the frequency of foregone medical care due to transport problems would have been more pertinent.

85. Finally, at the analytical stage, it is worthwhile to test several different estimation techniques to verify the robustness of the results. In certain cases, different techniques may potentially generate different results, whereas in other cases results may not differ regardless of the applied method. It is important to maintain flexibility in data collection to permit the application of several analytic techniques. In the case of Tocantins, it was worth the effort to find appropriate instruments to perform the IV estimation, which is based on completely different empirical settings from those of the DID estimators.

86. The present exercise demonstrated that impact evaluations of transport projects aimed at improving accessibility are feasible but difficult to implement. Looking ahead, the challenge of designing an impact evaluation methodology for

projects that seek to improve major existing road works (such as rehabilitation and/or upgrading of national roads, which constitute an important part of the Bank's portfolio in the transport sector) remains on the agenda.

VIII. Conclusion

87. Many rural residents still have only limited access to good road infrastructure in the developing world. A wide range of social and economic impacts can emerge from rural road development, from physical connectivity improvements (i.e., shorter distances and travel times) to long-term economic impacts, such as job creation and welfare improvement.

88. The current paper revisited the question of the economic and social benefits related to rural road development. Using household survey data from the State of Tocantins, Brazil, three different estimation techniques are applied to check the validity of the results: DID matching, DID regression, and IV estimators.

89. Overall, the analysis shows that improved rural road connectivity changed the population's choices with respect to modes of transportation. Following the rural road intervention, members of the impacted communities increasingly began to use public buses and individual cars. Furthermore, evidence indicates that the project increased school attendance, particularly by girls. Although statistically weak in relative terms, the evaluation indicates that the project contributed to increasing household income and creating more agricultural jobs in certain regions. Because some impacts require longer gestation periods, follow-up surveys and analyses will be required to more precisely capture the values of the entire set of impacts.

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X. Annex Tables

Table 15: DID Regression (1)

	Distance to: Populated area		Municipal capital		Hospital		School	
D	-0.215	(0.198)	0.454	(0.066) ***	0.338	(0.074) ***	-0.125	(0.113)
T	-0.967	(0.213) ***	-0.275	(0.111) **	-0.192	(0.124)	-0.112	(0.149)
D*T	-0.369	(0.289)	-0.357	(0.152) **	-0.184	(0.165)	0.600	(0.190) ***
lnHH size	-0.145	(0.192)	0.290	(0.114) **	0.207	(0.118) *	0.001	(0.131)
Adult share	0.408	(0.407)	0.251	(0.217)	0.122	(0.229)	0.682	(0.265) ***
HH head sex: Male	0.534	(0.211) **	-0.271	(0.133) **	-0.285	(0.142) **	-0.390	(0.147) ***
HH head education: Elementary	0.335	(0.170) **	0.139	(0.090)	-0.048	(0.092)	-0.149	(0.110)
HH head education: Secondary	0.011	(0.298)	0.108	(0.163)	0.041	(0.173)	0.093	(0.188)
HH head education: University	-0.054	(0.643)	0.411	(0.333)	0.110	(0.373)	0.101	(0.409)
Appliance ownership: Refrigerator	0.297	(0.243)	0.070	(0.138)	0.011	(0.132)	0.200	(0.153)
Appliance ownership: Color TV	0.086	(0.228)	0.001	(0.128)	-0.149	(0.127)	-0.300	(0.144) **
Appliance ownership: Radio	0.064	(0.153)	-0.005	(0.079)	-0.040	(0.085)	0.033	(0.097)
Appliance ownership: Gas stove	0.351	(0.216) *	0.074	(0.114)	-0.011	(0.107)	0.174	(0.136)
Appliance ownership: Washing machine	-0.441	(0.208) **	-0.322	(0.118) ***	-0.383	(0.138) ***	-0.070	(0.137)
Gas use for cooking	-0.339	(0.192) *	0.087	(0.104)	-0.102	(0.125)	-0.253	(0.124) **
Power use for lighting	-0.876	(0.242) ***	-0.377	(0.129) ***	-0.342	(0.130) ***	-0.575	(0.148) ***
Tap water for cooking	0.752	(0.158) ***	0.131	(0.087)	0.066	(0.093)	-0.557	(0.101) ***
Constant	-0.348	(0.608)	2.503	(0.335) ***	2.948	(0.370) ***	0.444	(0.415)
Obs.	2064		2064		2064		2064	
R-squared	0.063		0.059		0.054		0.075	
F-stat	8.85		9.09		7.91		10.37	

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectiv ely.

Table 16: DID regression (2)

	Travel time to: Populated area		Municipal capital		Hospital		School	
D	0.496	(0.066) ***	0.426	(0.050) ***	0.362	(0.053) ***	0.003	(0.072)
T	-0.204	(0.069) ***	0.020	(0.055)	0.088	(0.056)	0.194	(0.080) **
D*T	-0.009	(0.100)	-0.081	(0.071)	-0.109	(0.076)	0.416	(0.102) ***
lnHH size	0.060	(0.065)	0.079	(0.049) *	0.050	(0.053)	0.002	(0.070)
Adult share	0.099	(0.139)	-0.017	(0.100)	-0.056	(0.111)	0.307	(0.146) **
HH head sex: Male	0.222	(0.070) ***	0.066	(0.056)	0.028	(0.061)	-0.046	(0.083)
HH head education: Elementary	0.000	(0.061)	0.082	(0.042) **	0.001	(0.043)	-0.134	(0.060) **
HH head education: Secondary	-0.284	(0.105) ***	-0.077	(0.074)	-0.212	(0.087) **	-0.231	(0.097) **
HH head education: University	-0.417	(0.226) *	-0.113	(0.173)	-0.375	(0.196) *	-0.333	(0.228)
Appliance ownership: Refrigerator	-0.108	(0.085)	-0.061	(0.061)	-0.006	(0.067)	0.026	(0.089)
Appliance ownership: Color TV	-0.088	(0.078)	-0.120	(0.055) **	-0.203	(0.062) ***	-0.212	(0.077) ***
Appliance ownership: Radio	0.100	(0.053) **	-0.034	(0.037)	0.011	(0.042)	0.074	(0.053)
Appliance ownership: Gas stove	-0.154	(0.075) **	-0.167	(0.051) ***	-0.177	(0.055) ***	-0.140	(0.077) *
Appliance ownership: Washing machine	-0.062	(0.067)	-0.242	(0.052) ***	-0.178	(0.057) ***	-0.081	(0.069)
Gas use for cooking	-0.078	(0.062)	-0.011	(0.047)	0.027	(0.053)	-0.110	(0.063) *
Power use for lighting	-0.302	(0.080) ***	-0.287	(0.060) ***	-0.281	(0.067) ***	-0.372	(0.084) ***
Tap water for cooking	0.003	(0.052)	-0.099	(0.038) ***	-0.181	(0.043) ***	-0.439	(0.054) ***
Constant	3.384	(0.209) ***	4.068	(0.161) ***	4.171	(0.173) ***	2.861	(0.225) ***
Obs.	1,375		1,976		1,908		1,946	
R-squared	0.216		0.208		0.091		0.159	
F-stat	23.48		30.05		10.25		22.03	

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectiv ely.

Table 17: DID Regression (3)

	No. of trips to: Buy food			Buy goods			Go to work			Do business			Visit friends/relatives		
D	0.494	(0.129)	***	-0.036	(0.060)		-0.154	(0.163)		-0.109	(0.101)		0.063	(0.093)	
T	-0.155	(0.140)		-0.125	(0.053)	**	-0.926	(0.180)	***	0.109	(0.119)		-0.013	(0.097)	
D*T	-0.885	(0.169)	***	0.047	(0.069)		0.237	(0.213)		-0.031	(0.144)		0.035	(0.126)	
lnHH size	0.145	(0.111)		0.125	(0.043)	***	0.189	(0.133)		0.229	(0.093)	**	-0.054	(0.080)	
Adult share	0.258	(0.240)		0.281	(0.099)	***	-0.600	(0.278)	**	0.420	(0.208)	**	-0.002	(0.165)	
HH head sex: Male	0.245	(0.138)	*	0.050	(0.056)		-0.794	(0.129)	***	-0.155	(0.094)	*	0.001	(0.093)	
HH head education: Elementary	0.008	(0.094)		0.065	(0.034)	*	0.146	(0.111)		0.204	(0.074)	***	0.043	(0.071)	
HH head education: Secondary	0.032	(0.167)		0.046	(0.059)		0.804	(0.239)	***	0.269	(0.155)	*	0.142	(0.142)	
HH head education: University	0.263	(0.371)		0.121	(0.168)		0.415	(0.465)		0.497	(0.355)		0.651	(0.385)	*
Appliance ownership: Refrigerator	-0.183	(0.135)		0.016	(0.055)		0.267	(0.168)		0.017	(0.108)		-0.009	(0.107)	
Appliance ownership: Color TV	0.150	(0.128)		0.032	(0.049)		-0.082	(0.154)		0.129	(0.102)		-0.242	(0.100)	**
Appliance ownership: Radio	-0.129	(0.088)		0.059	(0.033)	*	0.102	(0.109)		-0.075	(0.071)		-0.036	(0.065)	
Appliance ownership: Gas stove	0.200	(0.120)	*	-0.048	(0.051)		-0.042	(0.142)		0.046	(0.095)		0.054	(0.092)	
Appliance ownership: Washing machine	0.064	(0.114)		-0.008	(0.047)		0.153	(0.150)		-0.220	(0.097)	**	0.049	(0.087)	
Gas use for cooking	0.029	(0.107)		-0.001	(0.042)		0.178	(0.140)		0.015	(0.096)		0.063	(0.083)	
Power use for lighting	0.013	(0.127)		-0.023	(0.051)		0.238	(0.159)		-0.133	(0.102)		0.044	(0.102)	
Tap water for cooking	-0.180	(0.089)	**	-0.013	(0.035)		-0.008	(0.115)		0.209	(0.075)	***	-0.015	(0.065)	
Constant	-4.252	(0.357)	***	-4.860	(0.140)	***	-2.299	(0.425)	***	-4.617	(0.294)	***	-4.098	(0.252)	***
Obs.	2,064			2,064			2,064			2,064			2,064		
R-squared	0.053			0.013			0.062			0.021			0.011		
F-stat	7.11			1.17			8.02			2.29			1.09		

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Table 18: DID Regression (4)

	Bus for populated area				Bus for municipal capital			
	Linear probability		Probit		Linear probability		Probit	
D	0.046	(0.017) ***	0.296	(0.120) **	0.071	(0.024) ***	0.265	(0.094) ***
T	-0.017	(0.015)	-0.322	(0.180) *	-0.046	(0.024) *	-0.311	(0.126) **
D*T	-0.0006	(0.0213)	0.238	(0.199)	0.081	(0.032) **	0.442	(0.144) ***
lnHH size	0.001	(0.016)	-0.003	(0.119)	0.009	(0.023)	0.036	(0.090)
Adult share	-0.017	(0.033)	-0.132	(0.254)	-0.071	(0.048)	-0.272	(0.190)
HH head sex: Male	0.000	(0.017)	0.016	(0.133)	-0.008	(0.027)	-0.004	(0.105)
HH head education: Elementary	0.010	(0.013)	0.073	(0.097)	-0.017	(0.020)	-0.075	(0.075)
HH head education: Secondary	-0.028	(0.020)	-0.286	(0.231)	-0.093	(0.031) ***	-0.422	(0.158) ***
HH head education: University	-0.063	(0.015) ***			-0.112	(0.052) **	-0.590	(0.371)
Appliance ownership: Refrigerator	0.004	(0.018)	0.053	(0.142)	-0.013	(0.029)	-0.042	(0.107)
Appliance ownership: Color TV	-0.040	(0.017) **	-0.334	(0.128) ***	-0.032	(0.027)	-0.121	(0.099)
Appliance ownership: Radio	-0.004	(0.012)	-0.028	(0.090)	-0.021	(0.018)	-0.077	(0.069)
Appliance ownership: Gas stove	0.003	(0.018)	0.025	(0.111)	-0.029	(0.026)	-0.102	(0.089)
Appliance ownership: Washing machine	-0.003	(0.014)	-0.031	(0.132)	-0.041	(0.021) *	-0.177	(0.099) *
Gas use for cooking	0.021	(0.014)	0.213	(0.117) *	0.018	(0.021)	0.080	(0.090)
Power use for lighting	-0.041	(0.017) **	-0.297	(0.114) ***	-0.018	(0.028)	-0.065	(0.101)
Tap water for cooking	0.034	(0.012) ***	0.285	(0.089) ***	0.042	(0.018) **	0.172	(0.071) **
Constant	0.088	(0.050) *	-1.411	(0.368) ***	0.264	(0.075) ***	-0.659	(0.288) **
Obs.	2,064		2,036		2,064		2,064	
R-squared	0.032				0.044			
F-stat	5.53				6.84			
Pseudo-R2			0.065				0.050	
Wald-stat			69.93				90.86	
Z-stat for interaction effect (mean & std. dev.)			0.604	(0.107)			2.761	(0.214)

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Table 19: DID Regression (5)

	Bus for hospital				Bus for school			
	Linear probability		Probit		Linear probability		Probit	
D	0.077	(0.023) ***	0.325	(0.098) ***	0.016	(0.009) *	0.362	(0.204) *
T	-0.010	(0.023)	-0.132	(0.130)	-0.005	(0.006)	-3.651	(0.182) ***
D*T	0.066	(0.031) **	0.342	(0.148) **	0.027	(0.012) **	3.969	(0.234) ***
lnHH size	0.014	(0.022)	0.063	(0.091)	0.004	(0.010)	0.076	(0.167)
Adult share	-0.040	(0.047)	-0.154	(0.193)	0.003	(0.017)	0.028	(0.333)
HH head sex: Male	-0.001	(0.026)	0.020	(0.106)	-0.002	(0.010)	-0.011	(0.212)
HH head education: Elementary	-0.011	(0.019)	-0.051	(0.076)	-0.012	(0.008)	-0.187	(0.126)
HH head education: Secondary	-0.080	(0.029) ***	-0.393	(0.159) **	-0.030	(0.008) ***		
HH head education: University	-0.134	(0.039) ***	-0.914	(0.451) **	-0.028	(0.008) ***		
Appliance ownership: Refrigerator	0.004	(0.027)	0.020	(0.110)	0.001	(0.012)	0.000	(0.203)
Appliance ownership: Color TV	-0.045	(0.026) *	-0.179	(0.101) *	-0.013	(0.012)	-0.208	(0.183)
Appliance ownership: Radio	-0.015	(0.017)	-0.058	(0.070)	0.010	(0.007)	0.199	(0.140)
Appliance ownership: Gas stove	-0.035	(0.025)	-0.126	(0.090)	0.009	(0.011)	0.186	(0.171)
Appliance ownership: Washing machine	-0.035	(0.021) *	-0.156	(0.101)	-0.013	(0.008)	-0.316	(0.209)
Gas use for cooking	0.028	(0.021)	0.128	(0.092)	-0.010	(0.006) *	-0.355	(0.217) *
Power use for lighting	-0.019	(0.026)	-0.069	(0.101)	0.012	(0.010)	0.260	(0.169)
Tap water for cooking	0.010	(0.017)	0.054	(0.072)	-0.008	(0.007)	-0.177	(0.136)
Constant	0.203	(0.070) ***	-0.917	(0.287) ***	0.009	(0.030)	-2.451	(0.555) ***
Obs.	2,064		2,064		2,064		1,882	
R-squared	0.043				0.020			
F-stat	6.35				2.91			
Pseudo-R2			0.050				0.102	
Wald-stat			85.74				3,361.7	
Z-stat for interaction effect (mean & std. dev.)			2.484	(0.178)			1.753	(0.355)

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Table 20: DID Regression (6)

	Car for populated area				Car for municipal capital			
	Linear probability		Probit		Linear probability		Probit	
D	0.002	(0.012)	0.092	(0.142)	0.013	(0.015)	0.100	(0.128)
T	-0.043	(0.014) ***	-0.524	(0.198) ***	-0.024	(0.018)	-0.158	(0.140)
D*T	0.050	(0.017) ***	0.527	(0.227) **	0.059	(0.023) **	0.363	(0.172) **
lnHH size	-0.007	(0.012)	-0.123	(0.153)	0.014	(0.016)	0.100	(0.112)
Adult share	0.055	(0.027) **	0.645	(0.337) *	0.110	(0.034) ***	0.804	(0.234) ***
HH head sex: Male	-0.012	(0.012)	-0.150	(0.173)	0.004	(0.020)	0.057	(0.133)
HH head education: Elementary	0.025	(0.009) ***	0.348	(0.139) **	-0.002	(0.014)	-0.049	(0.098)
HH head education: Secondary	0.044	(0.021) **	0.533	(0.216) **	0.053	(0.031) *	0.293	(0.160) *
HH head education: University	0.150	(0.072) **	1.028	(0.331) ***	0.117	(0.077)	0.489	(0.287) *
Appliance ownership: Refrigerator	0.010	(0.011)	0.113	(0.154)	0.003	(0.016)	0.015	(0.125)
Appliance ownership: Color TV	0.004	(0.012)	0.044	(0.142)	0.025	(0.016)	0.185	(0.120)
Appliance ownership: Radio	0.019	(0.009) **	0.236	(0.119) **	0.024	(0.012) **	0.181	(0.091) **
Appliance ownership: Gas stove	0.016	(0.009) *	0.303	(0.174) *	0.025	(0.014) *	0.247	(0.136) *
Appliance ownership: Washing machine	0.022	(0.015)	0.211	(0.132) *	0.042	(0.020) **	0.228	(0.104) **
Gas use for cooking	0.007	(0.012)	0.070	(0.122)	0.018	(0.017)	0.108	(0.100)
Power use for lighting	-0.009	(0.011)	-0.101	(0.143)	0.001	(0.015)	0.029	(0.124)
Tap water for cooking	0.026	(0.010) ***	0.305	(0.108) ***	-0.005	(0.013)	-0.051	(0.087)
Constant	-0.035	(0.040)	-2.852	(0.544) ***	-0.094	(0.053) *	-2.789	(0.385) ***
Obs.	2,064		2,064		2,064		2,064	
R-squared	0.037				0.035			
F-stat	2.83				3.88			
Pseudo-R2			0.100				0.068	
Wald-stat			65.20				79.30	
Z-stat for interaction effect (mean & std.dev.)			1.451	(0.230)			1.978	(0.164)

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Table 21: DID Regression (7)

	Car for hospital						Car for school					
	Linear probability			Probit			Linear probability			Probit		
D	-0.004	(0.016)		-0.023	(0.116)		-0.005	(0.008)		-0.116	(0.215)	
T	-0.028	(0.020)		-0.174	(0.134)		-0.018	(0.010)	*	-0.336	(0.238)	
D*T	0.076	(0.025)	***	0.447	(0.163)	***	0.040	(0.013)	***	0.717	(0.302)	**
lnHH size	0.016	(0.016)		0.107	(0.104)		0.002	(0.008)		-0.020	(0.178)	
Adult share	0.093	(0.034)	***	0.611	(0.220)	***	0.058	(0.021)	***	1.167	(0.459)	**
HH head sex: Male	-0.005	(0.020)		-0.002	(0.130)		0.002	(0.011)		0.092	(0.211)	
HH head education: Elementary	-0.007	(0.014)		-0.065	(0.093)		0.012	(0.007)	*	0.273	(0.173)	
HH head education: Secondary	0.057	(0.032)	*	0.286	(0.152)	*	0.026	(0.017)		0.495	(0.258)	*
HH head education: University	0.149	(0.081)	*	0.596	(0.273)	**	0.123	(0.065)	*	1.073	(0.347)	***
Appliance ownership: Refrigerator	0.005	(0.018)		0.023	(0.125)		0.008	(0.008)		0.210	(0.185)	
Appliance ownership: Color TV	0.011	(0.018)		0.074	(0.116)		-0.003	(0.008)		-0.062	(0.170)	
Appliance ownership: Radio	0.039	(0.012)	***	0.270	(0.088)	***	0.005	(0.007)		0.107	(0.153)	
Appliance ownership: Gas stove	0.000	(0.016)		0.003	(0.120)		0.016	(0.006)	***	0.716	(0.344)	**
Appliance ownership: Washing machine	0.038	(0.020)	*	0.203	(0.103)	**	0.009	(0.011)		0.137	(0.166)	
Gas use for cooking	0.016	(0.017)		0.090	(0.098)		0.009	(0.010)		0.133	(0.149)	
Power use for lighting	0.001	(0.017)		0.019	(0.117)		-0.007	(0.008)		-0.140	(0.182)	
Tap water for cooking	0.007	(0.014)		0.026	(0.085)		0.008	(0.008)		0.133	(0.151)	
Constant	-0.042	(0.053)		-2.271	(0.355)	***	-0.056	(0.029)	**	-4.114	(0.828)	***
Obs.	2,064			2,064			2,064			2,064		
R-squared	0.033						0.035					
F-stat	3.12						1.99					
Pseudo-R2				0.051						0.145		
Wald-stat				63.48						45.58		
Z-stat for interaction effect (mean & std.dev.)				2.522	(0.193)					1.496	(0.433)	

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Table 22: DID Regression (8)

	Bicycle ownership		Motorcycle ownership		Car ownership	
	Linear probability	Probit	Linear probability	Probit	Linear probability	Probit
D	-0.110 (0.031)***	-0.290 (0.082) ***	-0.001 (0.024)	-0.015 (0.098)	0.026 (0.018)	0.172 (0.121)
T	-0.284 (0.034)***	-0.767 (0.095) ***	0.089 (0.030) ***	0.305 (0.103)***	-0.037 (0.020) **	-0.211 (0.134)
D*T	0.070 (0.041)*	0.171 (0.119)	-0.008 (0.037)	-0.002 (0.130)	0.041 (0.025) *	0.224 (0.164)
lnHH size	0.102 (0.027)***	0.308 (0.080) ***	0.091 (0.023) ***	0.359 (0.088)***	0.045 (0.018) **	0.263 (0.112)**
Adult share	-0.100 (0.059)*	-0.255 (0.165)	0.100 (0.049) **	0.403 (0.177)**	0.156 (0.037) ***	0.945 (0.223)***
HH head sex: Male	-0.003 (0.030)	-0.025 (0.088)	-0.109 (0.022) ***	-0.480 (0.113)***	-0.025 (0.019)	-0.137 (0.137)
HH head education: Elementary	0.063 (0.023)***	0.182 (0.068) ***	0.074 (0.019) ***	0.298 (0.078)***	0.037 (0.013) ***	0.267 (0.097)***
HH head education: Secondary	0.090 (0.043)**	0.267 (0.123) **	0.210 (0.041) ***	0.702 (0.126)***	0.092 (0.031) ***	0.536 (0.154)***
HH head education: University	0.089 (0.085)	0.263 (0.252)	0.219 (0.092) **	0.743 (0.261)***	0.284 (0.085) ***	1.129 (0.249)***
Appliance ownership: Refrigerator	0.007 (0.032)	0.027 (0.093)	-0.038 (0.027)	-0.147 (0.099)	0.020 (0.018)	0.108 (0.127)
Appliance ownership: Color TV	0.023 (0.031)	0.071 (0.088)	0.045 (0.026) *	0.152 (0.094)*	0.013 (0.018)	0.084 (0.115)
Appliance ownership: Radio	0.072 (0.021)***	0.208 (0.062) ***	0.027 (0.018)	0.092 (0.067)	0.022 (0.013) *	0.141 (0.085)*
Appliance ownership: Gas stove	-0.051 (0.030)*	-0.146 (0.082) *	0.079 (0.022) ***	0.355 (0.100)***	0.008 (0.015)	0.091 (0.125)
Appliance ownership: Washing machine	-0.039 (0.029)	-0.107 (0.083)	0.054 (0.028) **	0.157 (0.084)*	0.033 (0.021)	0.156 (0.100)
Gas use for cooking	-0.055 (0.026)**	-0.166 (0.078) **	0.014 (0.025)	0.054 (0.081)	0.031 (0.018) *	0.152 (0.095)*
Power use for lighting	-0.002 (0.032)	-0.012 (0.091)	0.029 (0.024)	0.128 (0.098)	0.016 (0.016)	0.116 (0.122)
Tap water for cooking	-0.019 (0.022)	-0.056 (0.063)	-0.026 (0.019)	-0.100 (0.069)	0.019 (0.014)	0.109 (0.085)
Constant	0.504 (0.089)***	-0.041 (0.254)	-0.041 (0.072)	-1.806 (0.299)***	-0.153 (0.056) ***	-2.954 (0.382)***
Obs.	2,064	2,064	2,064	2,064	2,064	2,064
R-squared	0.128		0.076		0.050	
F-stat	21.38		11.16		4.27	
Pseudo-R2		0.100		0.076		0.072
Wald-stat		262.54		148.35		79.86
Z-stat for interaction effect (mean & std.dev.)		1.692 (0.331)		-0.048 (0.014)		1.093 (0.096)

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Table 23: DID Regression (9)

	No. of students Total		Boys		Girls		Preschool	
D	0.104	(0.131)	0.143	(0.132)	-0.234	(0.130) *	-0.007	(0.099)
T	-1.201	(0.157) ***	-0.719	(0.147) ***	-0.924	(0.142) ***	-0.105	(0.104)
D*T	0.430	(0.190) **	0.163	(0.179)	0.588	(0.176) ***	0.154	(0.131)
lnHH size	1.044	(0.124) ***	0.861	(0.111) ***	0.786	(0.108) ***	0.292	(0.072) ***
Adult share	-3.885	(0.278) ***	-2.938	(0.245) ***	-2.837	(0.237) ***	-1.420	(0.156) ***
HH head sex: Male	-0.188	(0.148)	-0.281	(0.134) **	-0.058	(0.134)	0.129	(0.102)
HH head education: Elementary	-0.032	(0.100)	-0.012	(0.096)	-0.026	(0.094)	0.069	(0.066)
HH head education: Secondary	-0.655	(0.213) ***	-0.432	(0.188) **	-0.411	(0.185) **	0.230	(0.147) *
HH head education: University	-0.694	(0.367) *	-0.617	(0.304) **	-0.317	(0.355)	0.406	(0.330)
Appliance ownership: Refrigerator	-0.052	(0.146)	-0.075	(0.144)	0.014	(0.142)	-0.140	(0.113)
Appliance ownership: Color TV	0.113	(0.132)	-0.031	(0.131)	0.110	(0.130)	-0.006	(0.100)
Appliance ownership: Radio	-0.028	(0.097)	0.106	(0.091)	-0.087	(0.091)	0.003	(0.067)
Appliance ownership: Gas stove	0.272	(0.129) **	0.237	(0.122) **	0.042	(0.120)	0.019	(0.095)
Appliance ownership: Washing machine	0.072	(0.135)	0.149	(0.127)	-0.009	(0.125)	0.031	(0.091)
Gas use for cooking	0.263	(0.123) **	0.088	(0.116)	0.151	(0.114)	0.057	(0.084)
Power use for lighting	0.232	(0.141) *	-0.003	(0.134)	0.264	(0.135) **	0.060	(0.103)
Tap water for cooking	-0.093	(0.098)	0.006	(0.094)	-0.206	(0.095) **	0.028	(0.071)
Constant	-0.692	(0.414) *	-1.705	(0.371) ***	-1.808	(0.360) ***	-3.639	(0.245) ***
Obs.	2,064		2,064		2,064		2,064	
R-squared	0.391		0.298		0.278		0.114	
F-stat	116.01		66.91		58.63		15.05	

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Table 24: DID Regression (10)

	No. of students						No. of sick HH members	
	Elementary		Secondary		University			
D	-0.007	(0.132)	-0.194	(0.092) **	-0.004	(0.032)	0.085	(0.140)
T	-0.161	(0.140)	-0.009	(0.117)	-0.009	(0.043)	-0.808	(0.143) ***
D*T	0.143	(0.175)	0.237	(0.137) *	0.001	(0.049)	0.076	(0.178)
lnHH size	1.151	(0.118) ***	0.455	(0.087) ***	0.119	(0.040) ***	0.547	(0.116) ***
Adult share	-4.475	(0.257) ***	-0.471	(0.181) ***	0.193	(0.096) **	0.274	(0.252)
HH head sex: Male	-0.294	(0.140) **	-0.143	(0.086) *	0.103	(0.050) **	0.107	(0.140)
HH head education: Elementary	-0.127	(0.094)	-0.095	(0.072)	0.031	(0.021)	-0.200	(0.104) **
HH head education: Secondary	-0.857	(0.188) ***	0.271	(0.169) *	0.076	(0.062)	-0.352	(0.175) **
HH head education: University	-0.523	(0.340)	-0.206	(0.248)	0.617	(0.316) *	-1.006	(0.214) ***
Appliance ownership: Refrigerator	0.033	(0.139)	0.155	(0.102)	0.023	(0.030)	-0.227	(0.149)
Appliance ownership: Color TV	0.253	(0.126) **	0.162	(0.099) *	0.006	(0.043)	-0.100	(0.138)
Appliance ownership: Radio	0.043	(0.091)	-0.030	(0.067)	0.035	(0.023)	0.035	(0.093)
Appliance ownership: Gas stove	-0.079	(0.124)	0.144	(0.073) **	0.001	(0.017)	0.201	(0.127)
Appliance ownership: Washing machine	-0.023	(0.122)	0.102	(0.107)	0.059	(0.048)	0.171	(0.127)
Gas use for cooking	0.036	(0.114)	0.096	(0.092)	0.080	(0.039) **	0.026	(0.114)
Power use for lighting	0.014	(0.138)	-0.114	(0.098)	-0.004	(0.035)	0.416	(0.137) ***
Tap water for cooking	0.221	(0.093) **	-0.104	(0.070)	-0.011	(0.026)	-0.084	(0.097)
Constant	-0.416	(0.401)	-4.251	(0.267) ***	-5.016	(0.144) ***	-4.181	(0.381) ***
Obs.	2,064		2,064		2,064		2,064	
R-squared	0.445		0.082		0.038		0.065	
F-stat	165.58		10.48		1.44		9.84	

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Table 25: DID Regression (11)

	No. of HH members engaged										HH Monthly income	
	Agriculture		Industry		Commerce		Service		Public sector			
D	-0.201	(0.117) *	0.001	(0.012)	-0.014	(0.036)	0.037	(0.026)	0.221	(0.089) **	-0.018	(0.091)
T	-1.563	(0.157)	-0.022	(0.013) *	-0.076	(0.051)	0.018	(0.027)	-0.355	(0.092) ***	0.246	(0.075) ***
D*T	0.304	(0.191)	0.023	(0.017)	0.067	(0.055)	-0.010	(0.041)	0.114	(0.119)	0.170	(0.101) *
lnHH size	0.923	(0.126) ***	-0.008	(0.017)	0.026	(0.035)	0.052	(0.034)	0.217	(0.071) ***	0.352	(0.062) ***
Adult share	1.148	(0.264) ***	0.014	(0.030)	0.015	(0.066)	0.016	(0.060)	0.044	(0.164)	1.372	(0.130) ***
HH head sex: Male	-0.925	(0.158) ***	0.007	(0.013)	-0.048	(0.028) *	0.023	(0.037)	0.074	(0.094)	-0.038	(0.074)
HH head education: Elementary	0.097	(0.107)	0.012	(0.007) *	0.052	(0.021) **	0.027	(0.017) *	0.228	(0.056) ***	-0.050	(0.056)
HH head education: Secondary	-0.614	(0.211) ***	-0.006	(0.006)	0.265	(0.096) ***	0.053	(0.051)	1.083	(0.179) ***	0.188	(0.098) **
HH head education: University	-1.066	(0.349) ***	0.154	(0.156)	-0.075	(0.034) **	-0.041	(0.025) *	2.098	(0.457) ***	0.979	(0.142) ***
Appliance ownership: Refrigerator	-0.097	(0.155)	-0.017	(0.019)	0.067	(0.037) *	0.037	(0.032)	0.119	(0.104)	0.096	(0.083)
Appliance ownership: Color TV	-0.042	(0.144)	0.019	(0.011) *	-0.002	(0.038)	-0.050	(0.040)	0.077	(0.096)	-0.005	(0.075)
Appliance ownership: Radio	-0.114	(0.098)	0.015	(0.007) **	-0.012	(0.029)	-0.013	(0.022)	-0.078	(0.066)	0.022	(0.050)
Appliance ownership: Gas stove	-0.035	(0.124)	0.002	(0.003)	-0.015	(0.023)	0.028	(0.012) **	0.154	(0.075) **	0.136	(0.089)
Appliance ownership: Washing machine	-0.223	(0.143)	-0.006	(0.015)	0.088	(0.056)	0.003	(0.035)	0.164	(0.097) *	0.176	(0.055) ***
Gas use for cooking	-0.411	(0.132) ***	0.021	(0.016)	0.138	(0.051) ***	0.043	(0.031)	0.312	(0.093) ***	0.365	(0.049) ***
Power use for lighting	-0.167	(0.145)	0.010	(0.010)	-0.003	(0.030)	0.065	(0.024) ***	-0.115	(0.098)	-0.005	(0.078)
Tap water for cooking	0.024	(0.103)	0.006	(0.010)	0.020	(0.030)	-0.028	(0.025)	-0.003	(0.067)	0.071	(0.048)
Constant	-1.215	(0.408) ***	-4.635	(0.049) ***	-4.609	(0.100) ***	-4.758	(0.101) ***	-4.930	(0.253) ***	3.906	(0.209) ***
Obs.	2,064		2,064		2,064		2,064		2,058		1,797	
R-squared	0.201		0.017		0.036		0.014		0.097		0.227	
F-stat	36.72		0.24		1.87		1.19		8.42		29.16	

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Table 26: IV Estimation (1)

	Distance to: Populated area		Municipal capital		Hospital		School	
D	-2.414	(1.004) **	-0.536	(0.628)	-0.631	(0.671)	2.550	(0.727) ***
lnHH size	-0.334	(0.313)	0.361	(0.196) *	0.286	(0.209)	-0.141	(0.227)
Adult share	0.072	(0.657)	0.270	(0.411)	0.220	(0.439)	0.069	(0.475)
HH head sex: Male	-0.605	(0.378) *	-0.655	(0.236) ***	-0.680	(0.252) ***	-0.484	(0.274) *
HH head education: Elementary	0.035	(0.271)	0.103	(0.169)	-0.171	(0.181)	-0.117	(0.196)
HH head education: Secondary	-0.483	(0.442)	0.194	(0.276)	0.153	(0.295)	-0.278	(0.320)
HH head education: University	-0.927	(0.894)	0.552	(0.559)	0.086	(0.598)	-0.823	(0.647)
Appliance ownership: Refrigerator	-0.195	(0.410)	-0.288	(0.256)	-0.299	(0.274)	0.097	(0.296)
Appliance ownership: Color TV	0.129	(0.407)	0.473	(0.254) *	0.038	(0.272)	0.133	(0.294)
Appliance ownership: Radio	0.096	(0.252)	-0.194	(0.158)	-0.232	(0.168)	-0.106	(0.182)
Appliance ownership: Gas stove	0.520	(0.423)	0.334	(0.265)	0.133	(0.283)	0.637	(0.306) **
Appliance ownership: Washing machine	-0.580	(0.295) **	-0.410	(0.184) **	-0.470	(0.197) **	-0.187	(0.214)
Gas use for cooking	-0.601	(0.285) **	-0.127	(0.178)	-0.458	(0.190) **	0.082	(0.206)
Power use for lighting	-0.878	(0.432) **	-0.330	(0.270)	-0.316	(0.289)	-0.495	(0.313)
Tap water for cooking	0.666	(0.274) **	0.074	(0.171)	0.193	(0.183)	-0.237	(0.198)
Constant	2.228	(1.499)	2.834	(0.937) ***	3.685	(1.002) ***	-1.159	(1.085)
Obs.	911		911		911		911	
R-squared			0.016		0.017			
Wald-stat	2.90		2.14		2.49		3.75	
Sargan overidentifying restriction test	0.75		0.05		2.03		0.93	
Hausman exogeneity test	21.79 ***		23.78 ***		10.40 ***		45.83 ***	

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Table 27: IV Estimation (2)

	Travel time to: Populated area		Municipal capital		Hospital		School	
D	0.274	(0.417)	-0.146	(0.242)	-0.438	(0.281)	1.007	(0.297) ***
lnHH size	0.058	(0.106)	0.096	(0.076)	0.075	(0.089)	-0.044	(0.103)
Adult share	-0.045	(0.229)	-0.051	(0.159)	-0.084	(0.185)	0.029	(0.216)
HH head sex: Male	0.041	(0.141)	-0.062	(0.096)	-0.098	(0.110)	-0.015	(0.132)
HH head education: Elementary	0.146	(0.090) *	0.080	(0.065)	-0.002	(0.076)	-0.105	(0.088)
HH head education: Secondary	-0.113	(0.162)	-0.045	(0.106)	-0.100	(0.123)	-0.354	(0.143) **
HH head education: University	-0.373	(0.331)	0.070	(0.214)	-0.265	(0.248)	-0.834	(0.287) ***
Appliance ownership: Refrigerator	-0.255	(0.149) *	-0.138	(0.101)	-0.019	(0.114)	-0.146	(0.137)
Appliance ownership: Color TV	-0.335	(0.159) **	-0.291	(0.100) ***	-0.408	(0.114) ***	-0.287	(0.137) **
Appliance ownership: Radio	0.173	(0.086) **	-0.172	(0.061) ***	-0.086	(0.070)	0.030	(0.082)
Appliance ownership: Gas stove	0.044	(0.151)	-0.011	(0.105)	-0.101	(0.119)	0.028	(0.144)
Appliance ownership: Washing machine	0.018	(0.109)	-0.144	(0.072) **	-0.096	(0.084)	-0.051	(0.097)
Gas use for cooking	-0.177	(0.111) *	-0.096	(0.069)	-0.031	(0.082)	0.041	(0.093)
Power use for lighting	-0.294	(0.171) *	-0.251	(0.108) **	-0.299	(0.121) **	-0.155	(0.142)
Tap water for cooking	0.072	(0.091)	-0.140	(0.065) **	-0.170	(0.076) **	-0.323	(0.087) ***
Constant	3.543	(0.607) ***	4.644	(0.367) ***	4.940	(0.428) ***	2.623	(0.478) ***
Obs.	551		841		833		816	
R-squared	0.169		0.096				0.118	
Wald-stat	5.88		8.07		5.07		9.77	
Sargan overidentifying restriction test	0.56		0.72		1.65		2.98 *	
Hausman exogeneity test	12.76 ***		15.60 ***		16.95 ***		56.32 ***	

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Table 28: IV Estimation (3)

	No. of trips to: Buy food	Buy goods	Go to work	Do business	Visit friends/relatives
D	-1.239 (0.472) ***	0.105 (0.167)	0.785 (0.602)	-0.295 (0.469)	-0.156 (0.383)
lnHH size	0.238 (0.147) *	0.068 (0.052)	0.129 (0.188)	0.184 (0.146)	-0.112 (0.119)
Adult share	0.243 (0.309)	0.147 (0.110)	-0.492 (0.394)	0.265 (0.307)	-0.214 (0.250)
HH head sex: Male	0.060 (0.178)	0.038 (0.063)	-0.378 (0.226) *	-0.198 (0.177)	-0.074 (0.144)
HH head education: Elementary	-0.107 (0.127)	0.065 (0.045)	0.215 (0.162)	0.241 (0.126) *	0.123 (0.103)
HH head education: Secondary	0.038 (0.208)	0.063 (0.074)	0.920 (0.265) ***	0.591 (0.206) ***	0.179 (0.168)
HH head education: University	0.112 (0.421)	-0.022 (0.149)	0.771 (0.536)	0.265 (0.418)	0.331 (0.341)
Appliance ownership: Refrigerator	0.252 (0.193)	0.043 (0.068)	-0.069 (0.245)	0.101 (0.191)	0.015 (0.156)
Appliance ownership: Color TV	-0.312 (0.191) *	0.055 (0.068)	0.478 (0.244) **	0.110 (0.190)	-0.223 (0.155)
Appliance ownership: Radio	-0.320 (0.119) ***	0.028 (0.042)	0.125 (0.151)	-0.143 (0.118)	-0.123 (0.096)
Appliance ownership: Gas stove	-0.394 (0.199) **	-0.061 (0.071)	0.208 (0.254)	0.211 (0.198)	0.026 (0.161)
Appliance ownership: Washing machine	-0.024 (0.139)	-0.009 (0.049)	0.107 (0.177)	-0.267 (0.138) **	0.063 (0.113)
Gas use for cooking	0.028 (0.134)	0.025 (0.048)	0.136 (0.171)	-0.002 (0.133)	-0.119 (0.109)
Power use for lighting	0.345 (0.203) *	0.010 (0.072)	0.089 (0.259)	-0.139 (0.202)	0.075 (0.165)
Tap water for cooking	-0.112 (0.129)	0.022 (0.046)	0.167 (0.164)	0.242 (0.128) *	0.080 (0.104)
Constant	3.346 (0.706) ***	4.926 (0.250) ***	4.551 (0.898) ***	4.394 (0.701) ***	3.733 ().572) ***
Obs.	911	911	911	911	911
R-squared		0.003	0.026	0.028	0.005
Wald-stat	2.26	0.54	3.12	1.94	0.65
Sargan overidentifying restriction test	1.87	0.25	4.60 **	0.13	2.51 *
Hausman exogeneity test	8.56 ***	10.16 ***	28.99 ***	5.35 **	45.70 ***

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Table 29: IV Estimation (4)

	Bus for populated area IV Probit			Bus for municipal capital IV Probit			Bus for hospital IV Probit		
D	1.015	(0.712)		1.298	(0.493)	***	1.675	(0.521)	***
lnHH size	-0.235	(0.195)		-0.008	(0.144)		0.034	(0.147)	
Adult share	-0.659	(0.419)		-0.430	(0.302)		-0.252	(0.308)	
HH head sex: Male	0.064	(0.245)		0.252	(0.165)		0.233	(0.175)	
HH head education: Elementary	-0.066	(0.163)		-0.193	(0.120)	*	-0.143	(0.124)	
HH head education: Secondary	-0.437	(0.323)		-0.406	(0.211)	*	-0.325	(0.218)	
HH head education: University				-0.311	(0.430)		-0.602	(0.542)	
Appliance ownership: Refrigerator	-0.228	(0.236)		-0.073	(0.177)		-0.044	(0.184)	
Appliance ownership: Color TV	-0.059	(0.251)		0.032	(0.179)		-0.045	(0.183)	
Appliance ownership: Radio	0.146	(0.159)		-0.165	(0.113)		-0.120	(0.117)	
Appliance ownership: Gas stove	0.084	(0.228)		-0.016	(0.172)		0.055	(0.179)	
Appliance ownership: Washing machine	-0.293	(0.222)		-0.201	(0.144)		-0.237	(0.148)	*
Gas use for cooking	0.204	(0.190)		0.028	(0.136)		0.035	(0.141)	
Power use for lighting	-0.390	(0.239)	*	-0.296	(0.182)	*	-0.022	(0.192)	
Tap water for cooking	-0.017	(0.178)		-0.061	(0.125)		-0.169	(0.127)	
Constant	-1.189	(0.987)		-1.146	(0.694)	*	-1.781	(0.731)	**
Obs.	911			911			911		
Wald-stat	37.69			59.34			57.71		
Amemiya-Lee-Newey overidentifying restriction test	1.39			9.36 ***			14.89 ***		
Hausman exogeneity test	4.81 **			12.22 ***			9.77 ***		

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Table 30: IV Estimation (5)

	Car for populated area IV Probit	Car for municipal capital IV Probit	Car for hospital IV Probit	Car for school IV Probit
D	1.365 (0.796) *	0.170 (0.530)	-0.427 (0.518)	1.707 (0.928) *
lnHH size	-0.016 (0.219)	0.124 (0.164)	0.094 (0.164)	0.145 (0.245)
Adult share	0.599 (0.457)	0.929 (0.344) ***	0.570 (0.342) *	1.543 (0.561) ***
HH head sex: Male		-0.136 (0.206)	-0.071 (0.198)	0.120 (0.299)
HH head education: Elementary	0.414 (0.206) **	0.138 (0.148)	0.068 (0.143)	0.132 (0.229)
HH head education: Secondary	0.473 (0.299)	0.440 (0.215) **	0.426 (0.213) **	0.196 (0.352)
HH head education: University	0.893 (0.474) *	0.409 (0.419)	0.349 (0.423)	1.034 (0.491) **
Appliance ownership: Refrigerator	0.275 (0.341)	0.124 (0.237)	-0.018 (0.218)	0.482 (0.393)
Appliance ownership: Color TV	-0.240 (0.282)	0.025 (0.217)	-0.111 (0.211)	-0.003 (0.328)
Appliance ownership: Radio	0.344 (0.185) *	0.153 (0.135)	0.214 (0.134)	0.058 (0.207)
Appliance ownership: Gas stove	0.719 (0.439) *	0.127 (0.256)	-0.058 (0.231)	
Appliance ownership: Washing machine	-0.025 (0.191)	0.307 (0.141) **	0.252 (0.143) *	0.073 (0.225)
Gas use for cooking	0.164 (0.183)	0.172 (0.141)	0.049 (0.141)	0.205 (0.227)
Power use for lighting	0.061 (0.327)	0.303 (0.261)	0.205 (0.243)	0.142 (0.386)
Tap water for cooking	0.521 (0.201) ***	0.031 (0.143)	0.104 (0.141)	0.338 (0.233)
Constant	-4.742 (1.061) ***	-3.046 (0.818) ***	-1.910 (0.777) **	-5.486 (1.334) ***
Obs.	921	911	911	911
Wald-stat	22.77	32.23	19.91	18.40
Amemiya-Lee-Newey overidentifying restriction test	3.30 *	0.97	0.18	1.06
Hausman exogeneity test	11.56 ***	19.33 ***	12.90 ***	8.55 ***

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Table 31: IV Estimation (6)

	Bicycle ownership IV Probit	Motorcycle ownership IV Probit	Car ownership IV Probit
D	0.366 (0.399)	0.508 (0.398)	-0.168 (0.525)
lnHH size	0.410 (0.127) ***	0.397 (0.129) ***	0.369 (0.156) **
Adult share	0.051 (0.256)	0.405 (0.263)	1.421 (0.340) ***
HH head sex: Male	-0.181 (0.160)	-0.514 (0.172) ***	-0.457 (0.229) **
HH head education: Elementary	0.004 (0.108)	0.420 (0.113) ***	0.106 (0.143)
HH head education: Secondary	0.023 (0.175)	0.964 (0.172) ***	0.373 (0.216) *
HH head education: University	0.077 (0.360)	0.917 (0.332) ***	0.896 (0.388) **
Appliance ownership: Refrigerator	0.313 (0.172) *	-0.203 (0.166)	0.013 (0.224)
Appliance ownership: Color TV	0.007 (0.163)	0.157 (0.167)	0.134 (0.220)
Appliance ownership: Radio	0.212 (0.101) **	0.079 (0.101)	0.210 (0.134) *
Appliance ownership: Gas stove	-0.177 (0.165)	0.427 (0.182) **	-0.340 (0.219)
Appliance ownership: Washing machine	-0.096 (0.116)	-0.026 (0.114)	0.164 (0.144)
Gas use for cooking	-0.102 (0.115)	0.054 (0.112)	0.264 (0.141) *
Power use for lighting	-0.231 (0.171)	0.480 (0.184) ***	0.016 (0.239)
Tap water for cooking	-0.148 (0.107)	-0.036 (0.108)	0.048 (0.143)
Constant	-1.063 (0.601) *	-2.219 (0.617) ***	-2.411 (0.788) ***
Obs.	911	911	911
Wald-stat	42.05	76.06	41.37
Amemiya-Lee-Newey overidentifying restriction test	0.62	0.85	0.98
Hausman exogeneity test	14.94 ***	7.10 ***	13.85 ***

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Table 32: IV Estimation (7)

	No. of students Total		Boys		Girls		Preschool	
D	1.003	(0.608) *	0.739	(0.533)	0.878	(0.535) *	-1.191	(0.437) ***
lnHH size	0.860	(0.190) ***	0.584	(0.166) ***	0.649	(0.167) ***	0.040	(0.136)
Adult share	-3.082	(0.398) ***	-2.593	(0.348) ***	-2.161	(0.350) ***	-1.829	(0.286) ***
HH head sex: Male	0.016	(0.229)	-0.042	(0.200)	0.169	(0.201)	0.056	(0.164)
HH head education: Elementary	0.018	(0.164)	0.099	(0.144)	-0.074	(0.144)	0.010	(0.118)
HH head education: Secondary	-0.587	(0.268) **	-0.393	(0.234) *	-0.405	(0.235) *	0.313	(0.192) *
HH head education: University	-0.466	(0.542)	-0.422	(0.474)	-0.429	(0.477)	0.215	(0.389)
Appliance ownership: Refrigerator	-0.245	(0.248)	-0.369	(0.217) *	-0.107	(0.218)	-0.124	(0.178)
Appliance ownership: Color TV	0.309	(0.247)	0.083	(0.216)	0.428	(0.217) **	-0.305	(0.177) *
Appliance ownership: Radio	-0.409	(0.153) ***	-0.149	(0.134)	-0.265	(0.134) **	-0.171	(0.110)
Appliance ownership: Gas stove	-0.149	(0.257)	-0.009	(0.225)	-0.240	(0.226)	0.030	(0.184)
Appliance ownership: Washing machine	0.228	(0.179)	0.318	(0.157) **	-0.042	(0.157)	0.232	(0.128) *
Gas use for cooking	0.499	(0.173) ***	0.246	(0.151) *	0.275	(0.152) *	-0.053	(0.124)
Power use for lighting	0.551	(0.262) **	0.440	(0.229) *	0.458	(0.230) **	-0.054	(0.188)
Tap water for cooking	-0.136	(0.166)	0.021	(0.145)	-0.305	(0.146) **	-0.007	(0.119)
Constant	-2.566	(0.909) ***	-2.932	(0.795) ***	-3.513	(0.799) ***	-1.846	(0.652) ***
Obs.	911		911		911		911	
R-squared	0.259		0.213		0.184			
Wald stat	21.30		16.93		14.69		7.71	
Sargan overidentifying restriction test	0.24		0.29		0.22		0.01	
Hausman exogeneity test	14.57 ***		16.58 ***		11.52 ***		22.74 ***	

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Table 33: IV Estimation (8)

	No. of students						No. of sick HH members	
	Elementary		Secondary		University			
D	-0.261	(0.519)	0.334	(0.458)	-0.007	(0.165)	-0.613	(0.500)
lnHH size	1.206	(0.162) ***	0.441	(0.143) ***	0.133	(0.052) ***	0.279	(0.156) *
Adult share	-4.644	(0.340) ***	-0.869	(0.300) ***	0.210	(0.108) *	0.086	(0.327)
HH head sex: Male	-0.017	(0.195)	-0.157	(0.172)	0.214	(0.062) ***	0.230	(0.188)
HH head education: Elementary	-0.022	(0.140)	-0.082	(0.123)	0.035	(0.045)	-0.255	(0.135) *
HH head education: Secondary	-0.698	(0.228) ***	0.106	(0.201)	0.101	(0.073)	-0.131	(0.220)
HH head education: University	-0.257	(0.463)	-0.086	(0.408)	0.480	(0.147) ***	-0.712	(0.445) *
Appliance ownership: Refrigerator	0.016	(0.212)	0.133	(0.187)	0.053	(0.067)	-0.030	(0.204)
Appliance ownership: Color TV	0.190	(0.210)	0.298	(0.186) *	0.025	(0.067)	-0.313	(0.202)
Appliance ownership: Radio	0.029	(0.130)	-0.205	(0.115) *	0.015	(0.041)	-0.137	(0.125)
Appliance ownership: Gas stove	-0.596	(0.219) ***	0.275	(0.193)	0.010	(0.070)	0.147	(0.211)
Appliance ownership: Washing machine	0.069	(0.153)	0.138	(0.135)	-0.029	(0.049)	0.321	(0.147) **
Gas use for cooking	0.145	(0.147)	-0.084	(0.130)	0.079	(0.047) *	-0.147	(0.142)
Power use for lighting	-0.110	(0.223)	-0.133	(0.197)	-0.034	(0.071)	0.395	(0.215) *
Tap water for cooking	0.209	(0.142)	-0.134	(0.125)	-0.006	(0.045)	-0.128	(0.136)
Constant	-0.124	(0.775)	-4.108	(0.684) ***	-5.167	(0.247) ***	-4.027	(0.746) ***
Obs.	911		911		911		911	
R-squared	0.497		0.090		0.040			
Wald stat	59.54		6.40		2.50		1.81	
Sargan overidentifying restriction test	0.75		3.23 *		2.61		1.26	
Hausman exogeneity test	21.17 ***		8.13 ***		9.20 ***		15.96 ***	

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.

Table 34: IV Estimation (9)

	No. of HH members engaged: Agriculture	Industry	Commerce	Service	Public sector	HH Monthly income
D	0.098 (0.671)	0.057 (0.062)	0.109 (0.185)	0.321 (0.151) **	0.950 (0.371) ***	0.290 (0.223)
lnHH size	0.765 (0.209) ***	-0.002 (0.019)	0.022 (0.058)	0.059 (0.047)	0.276 (0.116) **	0.395 (0.068) ***
Adult share	1.145 (0.439) ***	0.046 (0.040)	-0.032 (0.121)	0.029 (0.099)	0.316 (0.242)	1.323 (0.142) ***
HH head sex: Male	-0.530 (0.252) **	-0.007 (0.023)	0.005 (0.070)	0.065 (0.057)	-0.049 (0.139)	0.005 (0.080)
HH head education: Elementary	0.168 (0.181)	0.021 (0.017)	0.068 (0.050)	0.027 (0.041)	0.224 (0.100) **	0.026 (0.058)
HH head education: Secondary	-0.484 (0.295) *	0.000 (0.027)	0.288 (0.081) ***	0.021 (0.066)	0.619 (0.163) ***	0.074 (0.096)
HH head education: University	-1.344 (0.598) **	0.002 (0.055)	-0.075 (0.165)	-0.077 (0.134)	2.583 (0.330) ***	0.907 (0.187) ***
Appliance ownership: Refrigerator	0.149 (0.274)	0.001 (0.025)	-0.036 (0.075)	0.049 (0.062)	0.083 (0.151)	-0.012 (0.089)
Appliance ownership: Color TV	0.145 (0.272)	0.017 (0.025)	0.053 (0.075)	0.020 (0.061)	0.138 (0.150)	0.046 (0.090)
Appliance ownership: Radio	-0.192 (0.168)	0.015 (0.016)	0.000 (0.046)	-0.026 (0.038)	-0.272 (0.093) ***	0.048 (0.054)
Appliance ownership: Gas stove	0.295 (0.283)	0.007 (0.026)	0.019 (0.078)	0.057 (0.064)	0.258 (0.156) *	0.018 (0.095)
Appliance ownership: Washing machine	-0.088 (0.197)	0.001 (0.018)	0.008 (0.054)	0.000 (0.044)	0.123 (0.109)	0.153 (0.063) **
Gas use for cooking	-0.216 (0.190)	0.007 (0.018)	0.128 (0.052) **	0.112 (0.043) ***	0.283 (0.105) ***	0.285 (0.061) ***
Power use for lighting	-0.561 (0.289) **	0.007 (0.027)	0.049 (0.080)	0.084 (0.065)	0.134 (0.159)	-0.099 (0.093)
Tap water for cooking	0.053 (0.183)	0.022 (0.017)	0.027 (0.050)	-0.008 (0.041)	0.142 (0.101)	0.118 (0.059) **
Constant	-3.426 (1.002) ***	-4.714 (0.092) ***	-4.780 (0.276) ***	-5.106 (0.225) ***	-6.021 (0.553) ***	4.180 (0.331) ***
Obs.	911	911	911	911	911	859
R-squared	0.051	0.006	0.032		0.081	0.159
F-stat	3.15	0.59	1.94	1.19	8.00	11.02
Sargan overidentifying restriction test	0.54	1.06	0.06	1.00	0.23	0.35
Hausman exogeneity test	23.07 ***	1.07	15.32 ***	8.51 ***	28.80 ***	13.83 ***

Note: Standard errors are shown in parentheses. *, **, *** indicate the statistical significance at 10%, 5% and 1%, respectively.