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Roads, Geography, and Connectivity: Economic Impacts of Road Infrastructure in Georgia and Armenia

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Abstract

Adequate road infrastructure is considered one of the major factors for economic development. The improvement of connectivity has been crucial for the development agenda. This has resulted in rapid increase in infrastructure spending in low- and middle-income countries in the last decades. This thesis attempts to identify the economic impacts of road rehabilitation and construction projects by drawing evidence from Georgia and Armenia, middle income countries from the South Caucasus region.

Improved road infrastructure increases the urban perimeter, connecting people to jobs and markets. Chapter 2 studies this link. By drawing evidence from Armenia, the chapter examines how road quality affects rural employment. The analysis combines two different sets of data and two methodologies to study this question. A historical setting of roads during the Russian Empire is used for identifying exogenous variation of road quality in the country. The analysis show that proximity to better quality roads (one unit increase in log distance) results in a 5.7 percentage point increase in the probability of working in a non-agricultural sector, a 5.1 percentage point increase in the probability of having a skilled manual job, and 9.3 percentage points higher likelihood of women getting cash earnings.

Road infrastructure has linkages with other hard and soft infrastructure. Building on Hirschman's linkages and Christaller's Central Place Theory, the following chapter studies the impact of large-scale road rehabilitation projects on access to utility services and facilities by rural households in Georgia. Using Euclidean straight-line connector and least-cost path spanning tree instrumental variables, the results show that households living in settlements which happened to lie near rehabilitated roads were more likely to have access to different utility services and facilities in the house. The closer a household lives to an improved road (one unit increase in log distance or 2,7 times increase in km), the probability to have access to gas increases by 5.3 percentage points, waste disposal by 10.4 percentage points, and the Internet by 2 percentage points. Households closer to improved roads are shown to be 8.7 percentage points more likely to have running water inside house, 9.2 percentage points more likely to have shower at home, and 3.8 percentage points more likely to use electricity or gas as main source of heating.

Different types of roads serve different purposes. While major roads and highways are built to connect urban centers, access and local roads serve farmers to reach local markets. The last chapter examines the heterogeneous impacts of different types of rehabilitated roads by using a difference-in-difference estimation method on road improvement projects in Georgia. The analysis of the short-term impacts of road infrastructure projects found that rural households that received improved roads increased their overall spending on non-food items by 35%, and spending on education by 47%. The effects were stronger if the rehabilitated road was an access or a local road. Households in treated settlements have also seen their regular income increase by 36.6%.

These results call for goal oriented spatial transport network planning to improve connectivity of rural settlements to urban centers, markets and jobs, and highlight the linkages that improved connectivity brings to households.

Zusammenfassung

Eine funktionierende Straßeninfrastruktur ist ein entscheidender Faktor wirtschaftlicher Entwicklung. Die Verbesserung der Verkehrsanbindung ist daher auch ein zentraler Aspekt der Entwicklungsagenda. Dies hat in den letzten Jahrzehnten zu einem raschen Anstieg der Infrastrukturausgaben in Ländern mit niedrigem und mittlerem Einkommen geführt. In der vorliegenden Arbeit werden die wirtschaftlichen Auswirkungen von Straßeninstandsetzungs, und -bauprojekten in Georgien und Armenien untersucht, zwei Ländern mit mittlerem Einkommen in der Südkaukasusregion.

Eine verbesserte Straßeninfrastruktur erweitert das Stadteinzugsgebiet und verbindet Menschen mit Arbeitsplätzen und Märkten. Kapitel 2 untersucht diesen Zusammenhang. Anhand von Beispielen aus Armenien untersucht das Kapitel, wie sich die Qualität der Straßen auf die ländliche Beschäftigung auswirkt. Die Analyse kombiniert zwei verschiedene Datensätze sowie zwei Methoden, um diese Frage zu beantworten. Ein historisches Straßennetz aus der Zeit des Russischen Reiches wird hierbei herangezogen, um die exogene Variation der Straßenqualität im Land zu bestimmen. Die Analysen zeigen, dass die Nähe zu Straßen von besserer Qualität (eine Einheit Zunahme des logarithmischen Wertes der Entfernung oder 2,7-fache Zunahme der Kilometerzahl) zu einer um 5,7 Prozentpunkte höheren Wahrscheinlichkeit führt, im nicht-landwirtschaftlichen Sektor zu arbeiten, zu einer um 5,1 Prozentpunkte höheren Wahrscheinlichkeit, einen qualifizierten handwerklichen Beruf auszuüben, und zu einer um 9,3 Prozentpunkte höheren Wahrscheinlichkeit, dass Frauen einer bezahlten beruflichen Tätigkeit nachgehen.

Des Weiteren hat die Straßeninfrastruktur eine auf Wechselwirkungen beruhende Beziehung mit anderen harten und weichen Infrastrukturbereichen. Aufbauend auf Hirschmans Linkages und Christallers Central Place Theory untersucht das folgende Kapitel die Auswirkungen groß angelegter Straßensanierungsprojekte auf den Zugang ländlicher Haushalte zu Versorgungsdiensteinrichtungen, und -leistungen. Unter Verwendung des euklidischen Straight Line Connector und eines Least-Cost Path, der sich über drei instrumentelle Variablen erstreckt, zeigen die Ergebnisse, dass Haushalte in Orten, die zufällig in der Nähe instandgesetzter Straßen liegen, mit größerer Wahrscheinlichkeit Zugang zu Versorgungsdienstleistungen im eigenen Haus haben. Liegt ein Haushalt an einer sanierten Straße, steigt die Wahrscheinlichkeit des Zugangs (eine Einheit Zunahme des logarithmischen Wertes der Entfernung) zu Gas um 5,3 Prozentpunkte, zu Abfallentsorgung um 10,4 Prozentpunkte, zu Internet um 2 Prozentpunkte und zu fließenden Wasser um 8,7 Prozentpunkte. Die Wahrscheinlichkeit eine eigene Dusche nutzen zu können, stieg um 9,2 Prozentpunkte und Strom oder Gas als Hauptheizquelle zu nutzen, stieg um 3,8 Prozentpunkte.

Verschiedene Straßentypen dienen unterschiedlichen Zwecken. Dies ist ein letzter wichtiger Faktor, welcher in der vorliegenden Arbeit untersucht wird. Hauptstraßen und Autobahnen werden gebaut, um städtische Zentren miteinander zu verbinden. Zufahrts- und Gemeindestraßen dienen dagegen der Landbevölkerung, um Zugang zu lokalen Märkten zu erhalten. Im letzten Kapitel werden die heterogenen Auswirkungen verschiedenerer sanierter Straßentypen untersucht, indem eine Difference-in-Difference-Estimation Method für Straßenverbesserungsprojekte

in Georgien angewandt wird. Bei der Analyse der kurzfristigen Auswirkungen der Straßeninfrastrukturprojekte wird festgestellt, dass ländliche Haushalte, die von sanierten Straßen profitierten, ihre Gesamtausgaben für Nicht-Ernährungsgüter um 35% erhöhten und die Ausgaben für Bildung um 47%. Die Auswirkungen waren stärker, wenn es sich bei der instandgesetzten Straße um eine Zugangsstraße oder eine lokale Straße handelte. Die Haushalte in den untersuchten Ortschaften konnten ihr regelmäßiges Einkommen schließlich um 36,6% steigern.

Diese Ergebnisse legen für die Praxis eine zielgerichtete Planung der räumlichen Transportnetzwerke nahe, um die Anbindung ländlicher Ortschaften an städtische Zentren, Märkte und Arbeitsplätze zu verbessern. Dabei sollten Wechselwirkungen genutzt werden, die eine verbesserte Anbindung der Haushalte mit sich bringt.

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Abbreviations

ADB	Asian Development Bank
Armstat	National Statistical Service of the Republic of Armenia
DHS	Demographic and Health Survey
DID	Difference-in-Difference
EIB	European Investment Bank
ESRI	Environmental Systems Research Institute
FDG	Focus Group Discussion
GDP	Gross Domestic Product
GEL	Georgian Lari
Geostat	National Statistics Office of Georgia
GHSL	Global Human Settlement Layer
GIS	Geographic Information Systems
GMM	Generalized Method of Moments
GPS	Global Positioning System
GRIP	Global Roads Inventory Project
IDPs	Internally displaced persons
ILCS	Integrated Living Conditions Survey
ISET	International School of Economics at Tbilisi State University
IV	Instrumental Variable
LOP	Law of One Price
LRNIP	Lifeline Road Network Improvement Project
LSMS-ISA	Living Standards Measurement Study Integrated Surveys on Agriculture
MCC	Millennium Challenge Corporation
MDBs	Multilateral Development Banks

MDF	Municipal Development Fund of Georgia
METI	Ministry of Economy, Trade, and Industry
MRDI	Ministry of Regional Development and Infrastructure
NASA	National Aeronautics and Space Administration
N-S Corridor	North-South Corridor
OD	Origin-destination
OSM	Open Street Maps
RD	Regression Discontinuity
RRRP	Rural Roads Rehabilitation Project
SDGs	Sustainable Development Goals
SLRP	Secondary and Local Roads Project
TRACECA	Transport Corridor Europe-Caucasus-Asia
UNDP	United Nations Development Programme
UNICEF	The United Nations Children's Fund
USAID	The United States Agency for International Development
USD	U.S. Dollar
USGS	U.S. Geological Survey
WB	The World Bank
WDI	The World Development Indicators
WMS	Welfare Monitoring Survey

"Good roads, canals, and navigable rivers, by diminishing the expense of carriage, put the remote parts of the country more nearly upon a level with those in the neighboring town. They are upon that account the greatest of all improvements."

Adam Smith, *The Wealth of Nations, Chapter XI*, 1776.

Chapter 1

Introduction

1.1 Background and motivation

Adequate infrastructure is one of the key drivers of economic prosperity. However, in low- and middle-income countries infrastructure falls behind the actual needs to address economic prosperity, adequate public healthcare, welfare, and environmental factors. According to the World Bank, globally around 1 billion people live more than 2 kilometers away from an all-weather road, 663 million individuals lack access to improved sources of drinking water, 2.4 billion do not have access to improved sanitation facilities, 940 million live without electricity, and around 4 billion lack access to the Internet. In addition, millions cannot access work and education opportunities due to high transportation costs (Rozenberg and Fay, 2019).

Resilient infrastructure is one of the components of the Sustainable Development Goals (SDGs) adopted in 2015.[1] The achievement of many of the other SDGs might be highly dependent on well-functioning sets of infrastructure: schools, hospitals, roads, railways, water, electrification, and information and communications technology (ICT). Improved access to transport infrastructure can reduce poverty, decrease morbidity levels, increase educational outcomes and promote economic development in connected regions by easing mobility and trade, reducing price volatility, intensifying economic linkages and spreading economic activities through disperse of technologies and ideas.[2] However, road constructions may also have a negative impact on the environment through increased transportation emissions, logging for road construction, etc., and act as a most consistent determining factor of deforestation and forest frontier expansion, particularly in tropical frontier forests (Roberts et al., 2018; Asher et al., 2018; Busch and Ferretti-Gallon, 2017; Rudel et al., 2009).

[1]Goal 9: "Build resilient infrastructure, promote sustainable industrialization and foster innovation." Target 1: "Develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all." Sustainable Development Goals, the United Nations, 2015. `https://sustainabledevelopment.un.org/sdg9` (Reviewed: June, 2019).

[2]For example see Hirschman (1958, 1977); Bell and van Dillen (2018); Adukia et al. (2017); Faber (2014); Torero and Gulati (2004); Khandker and Koolwal (2010); Donaldson (2018) among others.

Considering the possible high economic benefits, investments in transport infrastructure projects are increasing annually, particularly in low- and middle-income countries. Yet, analysis on further investment needs urge for more investments and the discussion of infrastructure investment gaps. The Global Infrastructure Outlook estimated that the global infrastructure investment needs to be 94 trillion USD between 2016 and 2040. With the current spending trend, 19% higher than it will be achieved with the current spending trend. This means that on average 3.5% of global GDP needs to be invested on infrastructure to cover the needs. According to the report, investment needs are the highest in road infrastructure - requiring 31% more investments than predicted with current investment trends (Oxford Economics and Global Infrastructure Hub, 2017).

The response to this growing need is also reflected in the project portfolios of international organizations. For example, the World Bank had 178 active transportation projects overall, with total net commitments of USD 38.9 billion in 2018, representing over 16% of the total lending portfolio.[3] Transport accounted for 21% of the Asian Development Bank's (ADB) investments in 2017, making it one of the major sectors of ADB's lending operations (Raitzer et al., 2019).

The discourse on increasing infrastructure investment needs is not new, but it is changing. In recent years it seems to be slowly shifting from identifying amount of funds needed towards identifying investment goals and spending more efficiently while also taking climate change factors into account (Rozenberg and Fay, 2019). This seems intuitive. Ideally, projects should be implemented after prioritizing goals that they should achieve. However, in practice, transport infrastructure projects are not always prioritized considering social, economic and environmental factors (Burgess et al., 2015; Nguyen et al., 2011).

An empirical quantification of the effects of transport infrastructure projects is important for policymakers. Growing investments in road infrastructure requires analyzing the impacts on various economic, social, and environmental factors. In recent years improved data availability and transparency of projects have contributed to the rise of empirical literature that studies causal impacts of transport infrastructure projects. Large road infrastructure projects, for example, have quite often shown overall positive and significant effects on economic growth and trade integration, among others while also largely contributing to deforestation and CO_2 emissions (Roberts et al., 2018).

The literature addressing the rural-urban linkages finds that proximity to urban centers is one of the crucial determinants of rural settlement development. In addition to proximity, road quality plays an important role in travel time and cost. However, road quality factors often are not taken into account while analyzing the road projects, mostly due to the lack of data.

Improved roads also help increase the urban perimeter, by linking towns of different sizes to nearby villages. This can result in the diffusion of service accessibility and provision from urban to rural areas and improve the lives of urban households.

[3]Source: Transport Strategy, the World Bank `https://www.worldbank.org/en/topic/transport/overview`, Section 2: Strategy. (Reviewed: June, 2019).

Different types of roads fulfill different purposes. Major roads and highways connect cities and urban centers to each other and are the main drivers of the cross-border shipment of goods. Local and access roads on the other hand, provide last-mile connectivity, connecting farmers to markets and towns. Most of the literature evaluates specific large or rural road projects, but scarce attention has been paid to evaluating heterogeneous effects of different types of road infrastructure projects.

1.2 Research questions

Connecting households and businesses to markets and to social services is crucial to any development agenda. Given the gaps in the literature, this dissertation is motivated to contribute to the growing literature on the economic effects of road connectivity, one of the main key issues in development. This thesis aims to identify the impacts of improved road connectivity in three directions. Firstly, it identifies causal impact of road quality on rural employment. Secondly, it measures the impact of large road rehabilitation projects to evaluate the access to utility services by rural households. Lastly, it looks at the heterogeneous impacts of different types of road improvement projects to identify changes in household income and spending. Specifically, the following questions are addressed through the course of this thesis.

Research questions

- **Q1**. Does access to better quality roads have an impact on agricultural and non-agricultural employment of rural households?
- **Q2**. What are the impacts of improved roads on household accessibility to utility services and on living conditions?
- **Q3**. Do households' income and consumption change when settlements are better connected?

The research draws evidence from the road connectivity projects from Georgia and Armenia, countries in the South Caucasus region.

1.3 Conceptual framework

The seminal work of Johann Heinrich von Thünen (1826) has shown that spatial allocation of agricultural production systems is linked to proximity to urban markets and transportation costs. Farmers living closer to urban markets have lower transportation costs, receiving higher market prices for their products, which increases their land rent value (Von Thünen, 1826). Starting from von Thünen's land rent model, spatial economic theory argues that spatial access to consumer markets and urban centers, controlled by transportation costs, is an important factor for economic development. Walter Christaller developed the Central Place Theory in 1933 (Christaller, 1933; Christaller and Baskin, 1966) arguing how central places are formed in relation to each other and highlighted their importance for providing goods and services. The theory, later refined by Lösch (1940), attempts to explain the functional and spatial distribution of settlements and their inter-linkages. The literature on locations of economic activities was taken further by Paul Krugman by revisiting economic geography in the early 1990s (Krugman, 1991, 1999*b*). Transport costs condition where firms and workers are located.

Transportation plays an important role in economic linkages. Albert Otto Hirschman argued that transport infrastructure, as social overhead capital, has significant linkages that promote economic growth through growth in industries (Hirschman, 1958, 1977). He highlighted three types of linkages of infrastructural projects: forward linkages - promoting industries in need of roads and railways, backward linkages - promoting industries which supply materials for railway and road constructions, and lateral linkages - connecting industries to each other.[4]

Because of the availability of data on an aggregate level, linkages of infrastructure have been heavily studied at the regional or country level. The studies have looked at a hypothesized causal link between infrastructural spending and various outcomes, such as economic growth, production increase and manufacturing. The research has focused on historical, long-, medium- and short-term impacts of improved infrastructure. Cliometrics, or "new economic history" has been widely covering research on the impacts of transport infrastructure in historical settings. For example, by using counterfactuals, Fogel (1962) showed, that railway infrastructure by itself did not contribute much to the economic growth of the US during the industrialization period. Donaldson and Hornbeck (2016) argue that early railway transport in the US resulted in increased land prices - by 1890 agricultural land value would be decreased by 60% if there had been no railways.

However, results on the impact of road infrastructure on economic growth are mixed. Some studies identify a large effect of road infrastructure on economic performance and growth (Donaldson, 2018; Hornung, 2015; Demurger, 2001; Fremdling, 1977; Rephann and

[4]Considering Hirschman's proposed linkages (Hirschman, 1958, 1977), one of the most studied linkages with large-scale hard infrastructure development is manufacturing and firms (Datta, 2012; Ghani et al., 2016; Chandra and Thompson, 2000; Datta, 2012; Aschauer, 1989; Zhang and Fan, 2004; Khanna, 2014). In addition, better infrastructure has shown to affect technology diffusion (Hornung, 2014), urbanization or suburbanization Hornung (2015); Baum-Snow (2007), demand on high skilled labor Michaels (2008) through these linkages.

Isserman, 1994), while others find small or only short-term effect (Fogel, 1962; Banerjee et al., 2012; Khanna, 2014).[5]

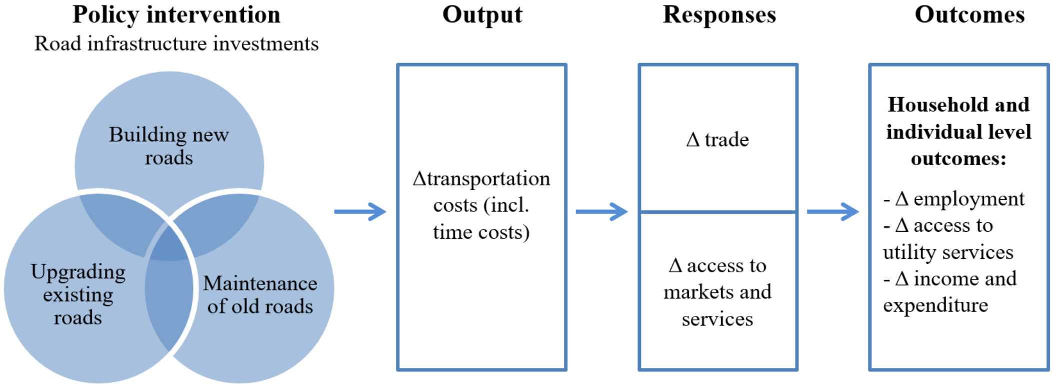

Figure 1.1: Conceptual framework: impacts of road infrastructure improvement. (Adapted from Laird and Venables (2017) and Berg et al. (2016)).

The conceptual framework on Figure 1.1 demonstrates the pathway from policy intervention to outcomes through output and responses. There are three main groups of policy interventions where road infrastructure investments are directed: building new roads, upgrading existing roads, and maintaining old road infrastructure. The immediate output to improved road infrastructure is decreased transportation and time costs. The responses to road infrastructure improvement are change in trade and access to markets and services.

The Law of One Price (LOP) from trade theory predicts price convergence in the absence of transportation costs and trade barriers. In a frictionless world of complete information, arbitrage would ensure that homogeneous goods are sold for one price. However, in the real world, the LOP might not hold due to several reasons such as incomplete information, transportation costs, search costs and trade barriers. Transportation costs play an important role in within-country trade. Let P_i be the price of some good X in market i and P_j be the price in market j. Let's assume that some fraction f of good X gets wasted in transit. In this setting, it is profitable to transit good X from market i to market j if $(1-f)P_j \succ P_i \rightarrow (1-f) \succ P_i/P_j$. Likewise, shipment in the other direction would occur only if $(1-f)P_i \succ P_j \rightarrow P_i/P_j \succ 1/(1-f)$. Therefore, there is a band within which relative prices of good X can fluctuate given by $(1-f) \prec P_i/P_j \prec 1/(1-f)$. If prices get outside the band, arbitrage will push them back within it. The simple logic behind this model is that by decreasing transportation costs, improved roads or highways will reduce price dispersion by narrowing the band (Andrabi and Kuehlwein, 2010).

[5]In terms of the theoretical literature, Barro (1990) analyzed economic growth effects of public infrastructure investments, followed by Glomm and Ravikumar (1997) and others. Later Rioja (2003*a*) introduced the role of infrastructure maintenance expenditure and its effect on depreciation rate of public infrastructure and Rioja (2003*b*) measured how maintenance expenditure affected the effectiveness of existing infrastructure. Both latter publications show that having higher maintenance expenditure rather than new infrastructure investment can lead to a positive impact on output.

The importance of transportation costs has also been tested in historical settings. Using historical data on colonial India, Donaldson (2018) shows that new railroad network across the country decreased trade costs, increased interregional trade, and increased real income levels. Andrabi and Kuehlwein (2010) showed that sharp price convergence of grain prices between 1861 to 1920 in British India was partly explained by newly built railway infrastructure. Overall, as the theory suggests, road infrastructure plays an important role in price decease and intensified trade.[6]

Another response to the immediate output in the conceptual framework is change in access to markets and services. Road infrastructure impacts on access to markets and services derives from Christaller's Central Place Theory (Christaller and Baskin, 1966). Improved connectivity facilitates movement of goods, services and ideas between central places and peripheral settlements. Later, Wanmali and Islam (1995, 1997) extended research in the context of developing countries context by building on Christaller's Central Place Theory. Wanmali and Islam (1995, 1997) highlight that improvement of hard infrastructure, like roads, also results in improvement in soft infrastructure, and services become more accessible to rural settlements through diffusion.

Finally, the responses of change in trade and access to markets and services result in individual and household level outcomes. The Alonso-Muth-Mills model predicts the urban perimeter beyond which agriculture would be the predominant employment sector (Brueckner, 1987). As the urban perimeter increases, employment in the non-agricultural sector increases. Urban perimeter increase improves access to markets and services, making public service implementation and provisioning in rural areas easier with improved road access. Lastly, decreased prices from intensified trade and additional employment opportunities lead to an increase in household income and spending (Aggarwal, 2018; Aggarwal et al., 2018; Iimi et al., 2018; Stifel et al., 2016).

1.4 Spatial data as a tool for development

In the last decade a large body of literature has emerged in economics using geographic information systems (GIS) data. There are three main reasons for this according to Donaldson and Storeygard (2016). The first is accessibility. Spatial or satellite data gives us the possibility to look at things that are hidden from official statistics due to illegality or failed state capacity to collect them or to provide them centralized (for example, see Henderson et al., 2012; Lessmann and Seidel, 2017; Kaczan, 2017).

Second, the long-time span of spatial data allows the identification of spatial patterns of development (Michalopoulos and Papaioannou, 2017). In this regard, data on nighttime light has been revolutionary. The main questions economists try to answer using the long-span of nighttime lights have been about economic growth, city growth and agglom-

[6] For example, see Faber (2014); Casaburi et al. (2013); Limão and Venables (2001); Aggarwal (2018); Andrabi and Kuehlwein (2010).

eration effects, regional inequality, conflicts, detecting urban markets, predicting poverty, detecting regional favoritism, and identifying spatial distribution of skills in cities, among others (Henderson et al., 2012; Dingel et al., 2019; Gonzalez-Navarro and Turner, 2018; Keola et al., 2015; Vogel et al., 2018; Gibson et al., 2017; Khanna, 2016; Lessmann and Seidel, 2017; Hodler and Raschky, 2014; Mellander et al., 2015; Witmer and O'Loughlin, 2011; Jean et al., 2016; Hodler and Raschky, 2014; Dingel et al., 2019).

The final major reason for increased usage of spatial data is identifying causal impacts of different policies (Kudamatsu, 2018). The problem of endogenous placement of infrastructure projects arises since infrastructural projects are not randomly placed. This challenges the way to look at causal effects: areas with better infrastructure have better economic outcomes due to the improved infrastructure, or since some areas have better economic potential they attract more road infrastructure, improving the economic outcomes. In order to identify causal impacts, quasi-experimental methods such as the difference-in-difference estimation methodology has often been used with propensity score matching and spatial data (Aggarwal, 2018; Kaczan, 2017; Mu and van de Walle, 2011; Bardaka et al., 2019; Datta, 2012).

To tackle endogeneity and reverse causality issues, others have used instrumental variable strategy (IV) based on spatial data or historical settings. Banerjee et al. (2012)[7] used Euclidean connectors or straight lines as proxies to predict the existence of transportation networks between Chinese cities. They used this method to estimate the impact of transport infrastructure on the economic performance in Chinese counties. This straight-line instrument was soon adopted by different studies for measuring various impacts of transport infrastructure interventions (Atack et al., 2010; Faber, 2014; Khanna, 2014; Ghani et al., 2016). Later, Faber (2014) combined the straight-line proxy with a spatial instrument based on the least-cost path of connectivity to study the effect of China's National Truck Highway System on trade integration. In order to construct the least-cost path instrument, he used remote sensing data on land cover and elevation and applied optimal route and minimum spanning tree algorithms to identify the least-cost spanning tree network.

The digitization of historical maps gave possibility of exploiting exogenous variation of transport infrastructure placement. The main idea is that transportation networks built a long time ago for different purposes, do not have a direct impact on current economic outcomes. Many studies have emerged studying the economic impacts using historical settings. For example,Garcia-López et al. (2015) and Holl (2016) use Roman roads and the 1760 Bourbon postal routes to study the impact of expanded highway network on city size and firm-level productivity in Spain, Möller and Zierer (2018) rely on historical maps of planned railroad and autobahn maps in Germany to study the impacts of autobahns on regional employment in Germany, Duranton and Turner (2012) use historical U.S. highway plan to estimate the impact of interstate highways on urban growth, Volpe Martincus et al. (2017) use historical Inca routes for Peru to identify the impact of expanded road network

[7]The first version of their paper is from 2004.

on firm-level export and employment, and Baum-Snow et al. (2012) use historical Chinese rail and road networks as a source of identifying variation to study the impacts of urban railroads and highways on central city industrial GDP.

There setting permitted, others have used Fuzzy Regression Discontinuity (RD) design considering the threshold determinant in receiving a rehabilitated road (Asher and Novosad, 2016; Casaburi et al., 2013). This quasi-experimental method provides a possibility to test the variable of interest on villages slightly above and below the threshold line. In addition, there are spatial regression discontinuity designs studying economic outcomes at state and regional boarders Michalopoulos and Papaioannou (2014).

1.5 Research setting

Georgia and Armenia are perceived as transit corridor countries from Asia to Europe. They might also play an important part in the Belt and Road Initiative (BRI) led by China. Therefore, these two countries have attracted huge amounts of investments and loans to build high speed highways and rehabilitate feeder roads. Since the early 2000s several multilateral development banks (MDBs) together with central governments have heavily co-financed road infrastructure improvement projects in the South Caucasus region.

The countries have similar economic and political histories. Both were part of the Soviet Union until 1991, enjoyed relatively good quality infrastructure, and experienced large drop in economy after the independence and conflicts in the early 1990s. The drop was higher for Georgia. The average GDP growth between 1990 to 2000 was -7.1% compared to -1.9% in Armenia. Georgia has higher rural population and share of people working in agriculture. 46.4% of people in 2015 lived in rural settlements, compared to 37.3% in Armenia. And 51% of employed in 2015 in Georgia were working in agriculture, compared to 35% in Armenia, as shown on Table 1.1.

Figure 1.2 demonstrates that both countries have high population density and high purchasing power within and around the capital cities. Armenia also has a very well-developed mining sector - accounting for high economic output in Syunik Marz - the south of the country.

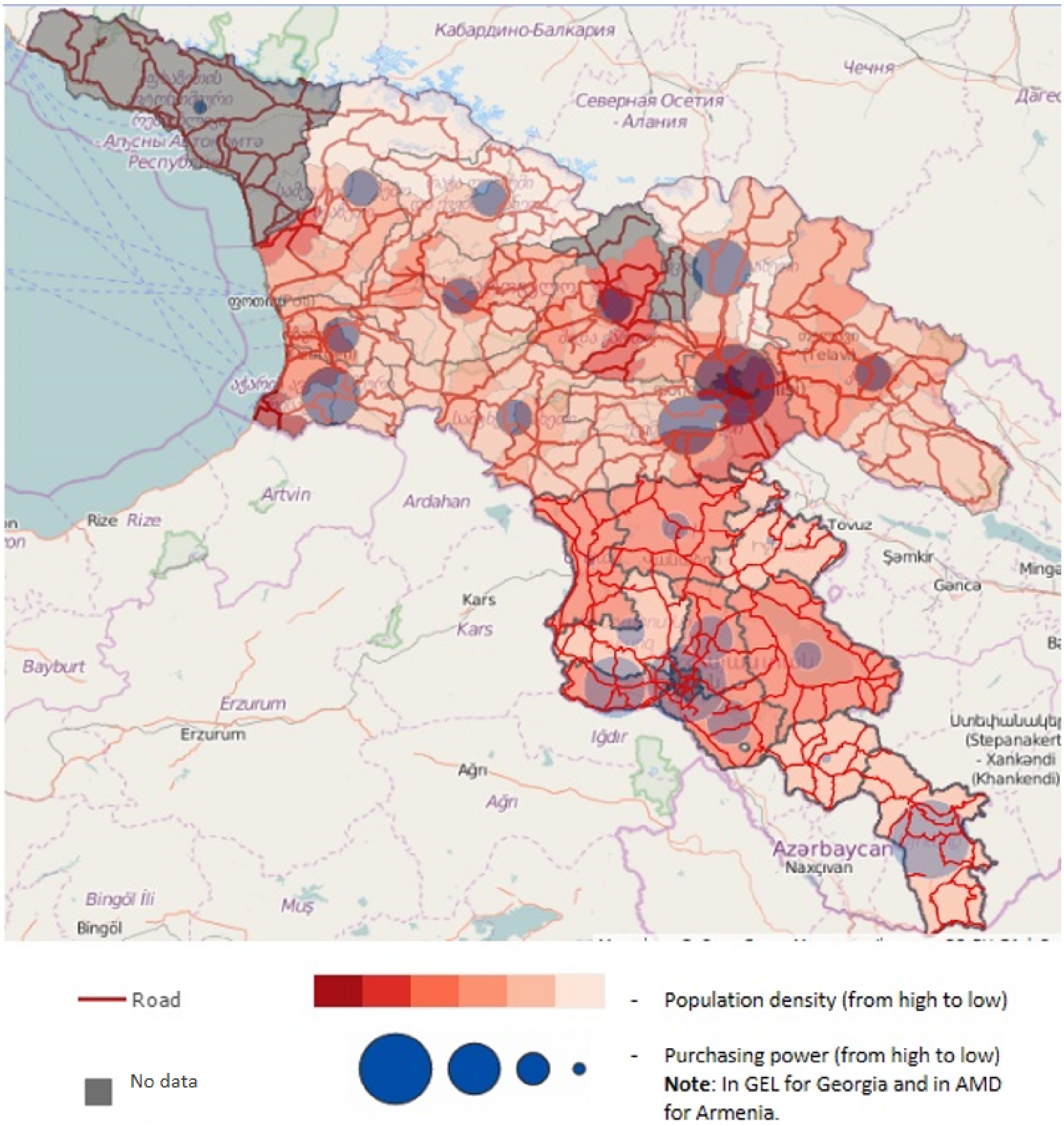

Figure 1.2: Map of Georgia and Armenia. Regions, Population, Purchasing Power and Roads of Georgia and Armenia.
Source: Author. The layers obtained from ArcGIS ESRI Online, Global Roads Open Access Dataset.

Table 1.1: Selected development indicators for Georgia and Armenia

	Georgia	**Armenia**
Surface area (sq. km thousands)[1]	69.7	29.7
Population, mln in 2015[1]	3.7	3.0
Rural population (% of total)[3]	46.4	37.3
Population growth rate, average 2000-2015 (% of total)[1]	-1.2	-0.1
Life expectancy at birth, total (years)[3]	75.0	74.9
Mean years of schooling, 2015[3]	13.9	12.7
Human Development Index value, 2015[3]	0.769	0.743
Human Development Rank, 2015[3]	70	84
GDP (current bln USD, 2015)[1]	14.0	10.5
GDP per capita PPP (current USD, 2015)[2]	9,599.5	8,418.7
GDP growth, average 2000-2015 (%)[1]	5.9	6.4
GDP growth, average 1990-2000 (%)[1]	-7.1	-1.9
Unemployment, 2015 (%)[3]	12.3	16.3
Employment in services, 2014 GEO, 2015 ARM (%)[2]	39.1	48.8
Employment in agriculture, 2014 GEO, 2015 ARM (%)[2]	50.9	35.3
Agriculture, value added (% of GDP), 2015[1]	9.0	19.0
Services, etc., value added (% of GDP), 2015[1]	66	52
Industry, value added (% of GDP), 2015[1]	25	29
Exports of goods and services (% of GDP), 2015[1]	45	30
Imports of goods and services (% of GDP), 2015[1]	65	42
Doing Business Index rank, 2015[4]	16	38

Source: [1]World Development Indicators, the World Bank; [2]The World Bank Databank (WDI); [3]Human Development Data, UNDP; [4]Doing Business, the World Bank.

The transit potential of both countries has been actively utilized. In recent years, the number of freights shipped by motor-roads has been increasing in Georgia and Armenia as shown on Figure 1.3. This could be the result of improved road infrastructure, and the growing trend creates more demand for improved infrastructure.

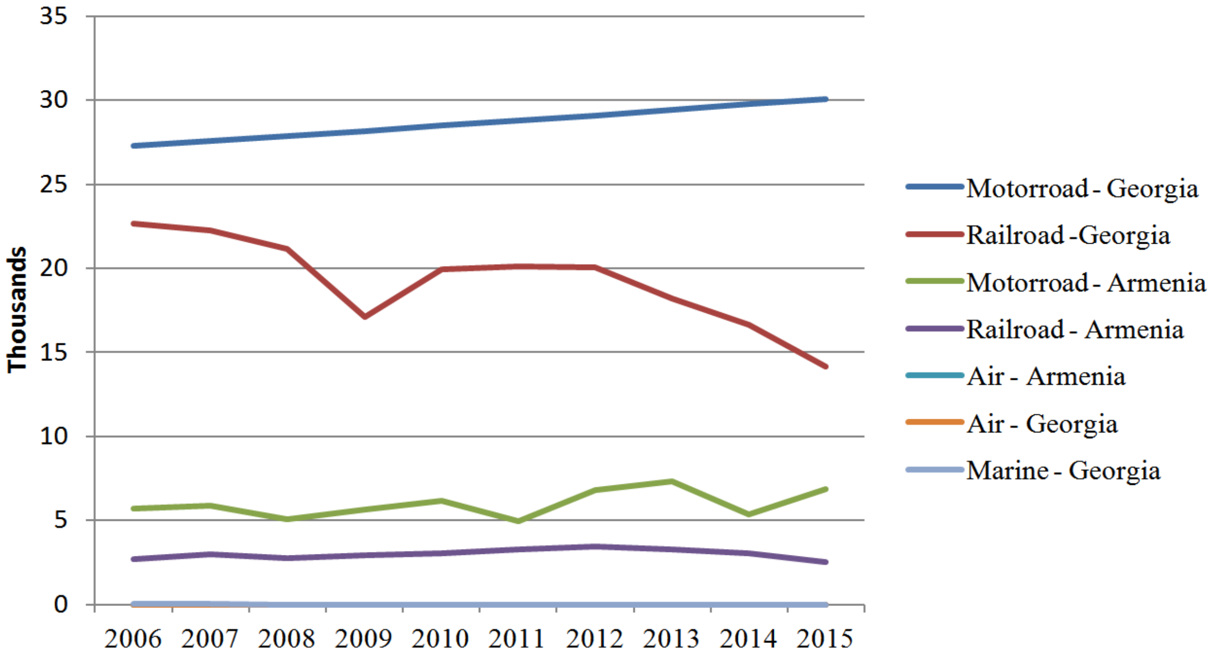

Figure 1.3: Freight shipped (thsd. tons) by means of transport.
Source: Statistical Yearbook of Georgia 2016, p.191, Statistical Yearbook of Armenia 2016, p.328, Statistical Yearbook of Armenia 2011, p.332.

1.5.1 Overview of road infrastructure in Georgia

The Georgian road network consists of 13 international road routes - a total of 1,603 kilometers and 202 national road routes - a total of 5,298 kilometers (Government of Georgia, 2014). The international and national roads are generally considered as major roads. The international roads connect Georgian cities and towns to the neighboring countries, while national roads connect different cities and municipal centers to each other. The international roads are heavily used for freight. Even before the large infrastructural projects began, while most of the national roads were in poor condition, the international roads were largely kept in fair or good condition. According to World Bank (2013), in 2006 70% of the international roads were in fair to good condition and more than 60% of the national roads were in poor condition. Since then, the Georgian government has been actively attracting funding from international organizations to finance the rehabilitation of the deteriorated infrastructure. Currently the country is building its first four lane highway and is rehabilitating secondary and local roads.

The East-West highway is considered as the central piece in transforming Georgia into a logistics and transportation hub for trade between Asia and Europe by the Georgian government. The highway is part of the E-60 European route, running from Brest, France (the Atlantic coast), to Irkeshtam, Kyrgyzstan (the border with China). The main highway project in Georgia - East-West Highway (E-60 and E-70 highways), brings east and west of Georgia together by connecting the three biggest cities in-between. The planned project implementation period is 2006-2022, and in total around 400 km of roads are planned to be built. Some part of the highway has been planned to be newly built segments; however, a large part of the construction constitutes of expanding the existing two-lane major roads into four-lane ones. Georgia had constructed or reconstructed about one third, or around 130 km of roads by the end of 2016.

In addition to the highway construction project, the government has also been investing in secondary and local roads. The main road infrastructure projects include Secondary and Local Roads Project (SLRP) and Regional Development Project - both co-funded by the World Bank and Samtskhe-Javakheti Rural Roads Rehabilitation Project - co-funded by the Millennium Challenge Corporation (MCC).

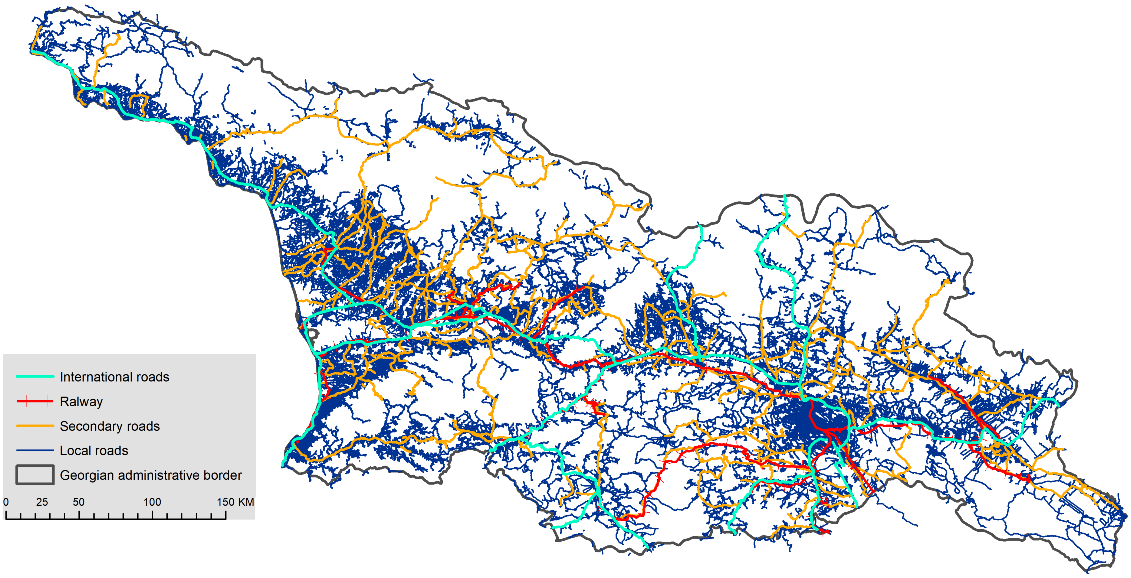

Figure 1.4: Roads in Georgia.
Source: Author. Local roads obtained from Openstreetmaps.

1.5.2 Overview of road infrastructure in Armenia

The total length of the classified road network of Armenia is 7700 km long, from which around interstate roads account for 1400 km, regional roads for 2520 km, and local roads for the remaining 3780 km of classified roads. Most of the roads were built during the Soviet Union times in the 1960s and 1970s, and have deteriorated since independence in

1991 due to the low maintenance (Farji Weiss et al., 2017). During the last two decades Armenia has been receiving increasing funding for road construction and maintenance.

In Armenia, the main highway - North-South Road Corridor, goes from the north of the country to the south by connecting five big cities. Most of the highway is being built by expanding the already existing two-lane major roads into four lanes. The project was planned to be implemented during 2009-2019, but it has been delayed. The total length of the road is planned to be 556 km (Source: North-South Road Corridor Investment Program). Most of the highway is built on already existing main roads, but in some areas where roads had been built going through small towns or villages, the new highway has been re-routed. By the end of 2015 only small part of this highway had been completed.

The Rural Road Rehabilitation Project[8] started in 2007 with a loan from the Millennium Challenge Corporation (MCC) (completed 24 km) and continued by the World Bank loan from 2009 to 2013. The MCC funds have covered the rehabilitation of 24 km of roads, the World Bank covered 446 km, and approximately 50km of rural roads were improvement from the Armenian government funds Fortson et al. (2015). The project is still ongoing, receiving major funding from Asian Development Bank (ADB)[9] as well as from the World Bank for Lifeline Road Network Improvement Project (LRNIP).[10]

Figure 1.5: North-South Road Corridor
Source: N-S Road Corridor Investment Program

[8]Source: Evaluation of a Rural Road Rehabilitation Project in Armenia, March 12, 2015. Millennium Challenge Corporation. Reference Number: 06916

[9]Source: Armenia: Rural Road Sector Project, ADB. `http://www.adb.org/documents/armenia-rural-road-sector-project`

[10]Source: World Bank Supports Further Improvement of Armenia's Rural Roads Network, July 31, 2015. The World Bank `http://www.worldbank.org/en/news/press-release/2015/07/31/world-bank-supports-further-improvement-of-armenias-rural-roads-network`

1.6 Impact of roads on settlements - qualitative research

This thesis builds on interdisciplinary research. Focusing on economic questions, using econometric methods, qualitative survey from sociology, and spatial data and tools from geography also play an important role in the analysis. Although heavily using economic methods, the thesis echoes the importance of the interaction of different fields and methodologies (Bathelt et al., 2017). In this regard, this thesis attempts to contribute to bridging the divide between quantitative and qualitative research by supporting the results from complex quantitative analysis - combining economics and geography - with results from qualitative surveys with households and stakeholders.

Quantitative research combined with qualitative research provides a complete picture in the social sciences (Onwuegbuzie and Leech, 2005). During the course of preparing the thesis, qualitative research has helped understand the context of the research setting and what variables to use in the analysis. It has also supported me in testing out the research questions. In addition to collecting the secondary data, I have conducted expert interviews, focus group discussions and interviews with village heads.

Expert interviews

The main goal of the expert interviews was to identify all road projects in both countries, obtain administrative and survey data, and identify planned policies for spatial development. In total, I have conducted 27 interviews with experts. The experts were from central governments, ministries, and specialized departments responsible for road construction and rehabilitation projects from international organizations which are the biggest funders of road infrastructure projects in Georgia and Armenia, research organizations which have done research on road projects, and different departments of national statistical offices.

Focus group discussions with communities

The main goals of the focus group discussions (FGDs) were to understand the impacts of road projects on households - benefits and co-benefits as well as challenges accompanying them. The semi-structured FGDs were conducted with three types of communities. First, communities which had received road rehabilitation or a construction project within the settlement; Second, communities which had received an access road to the village; And third, settlements that were in process or were expecting to receive one in the near future.

The FGDs were done in two waves. In total, 12 FGDs were conducted in both countries - six in each. Six FGDs were conducted during the first wave in the fall of 2016, and four repeated FGDs during the summer of 2017. The FGDs were conducted in four locations in Georgia: Khashuri, Akhalkalaki, Telavi and Gori, and in four locations in Armenia: Amasia, Dashtadem, Nor Yerznka and Karmirgyugh. The focus group locations were selected according to research interests to cover as many different cases as possible. In

Georgia, mainly towns were selected for the interviews as a large number of secondary road rehabilitation projects had been implemented there in recent years. In Armenia, mostly villages were selected as most infrastructure projects had a strong rural focus.

The questions asked to the communities were about their economic activities, infrastructure development projects within or nearby their settlements - with the particular emphasis on road rehabilitation projects, existing challenges and opportunities that improved roads had brought, and the issues that settlements were experiencing. The participants were also asked to rank the projects they had received by importance, and provide reasoning. The focus groups in the repeated survey were presented with the results from previous FGDs, and participants were asked to discuss their preferences over the road rehabilitation projects and opportunities and challenges associated with them.

Interviews with village heads

In addition to the FDGs with local communities, village heads were also interviewed in Armenia. Village heads are officially appointed bureaucrats of each village. They are usually the most informed people in villages about past, ongoing, or future public works. The village heads were also asked about the implemented projects in the village, existing problems, and possible solutions. This information was later used to complement the responses from the FGDs.

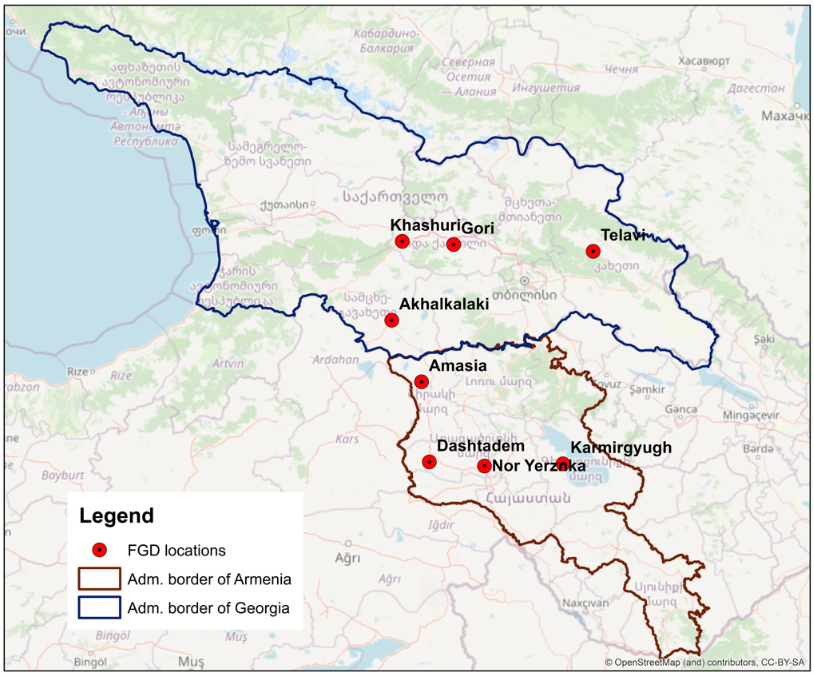

Figure 1.6: Focus group locations in Georgia and Armenia

Results

Below, I briefly present the major results related to the scope of this thesis. For maximizing the participants' anonymity, I have used profession or the FGD location to refer to the participants (Saunders et al., 2015).

Accessibility and employment

The participants were asked to report how accessibility to different areas had changed and what it had brought to them in terms of economic opportunities. Almost all focus group participants reported decreased travel time to nearby towns and cities, and some also reported decreased travel costs.

"Before it used to be more expensive to go to the university, going there would cost you 1500 Drams, now it is possible to reach there with only 200 Drams", - says a student from Karmirgyugh, Armenia.

Improved transportation has also benefited workers. FDG participants from Gori, a town in 80 kilometers from the capital city of Georgia, report halved travel time to Tbilisi and availability of frequent transport. However, size of benefits also depends on the proximity to cities. The villages which were already close to the urban centers only saw little benefit. This was the case for the workers from Nor Yerznka, Armenia. Since the village is only 20 kilometers far from the capital city Yerevan, with good condition roads leading there, the new highway only slightly reduced the travel time.

Improved roads bring more trade. Barter is still often used in Armenian villages, buyers come to the villages with flour, sugar, or different vegetables, and villagers exchange their agricultural products with them. *"Since the road rehabilitation, buyers started coming more often"*, - says a farmer from Karmirgyugh, Armenia. Others report selling more to agricultural markets since the improvement of roads, which was the case in Nor Yerznka, Armenia. Some farmers report increased agricultural productivity and increased involvement in non-agricultural employment sector. This was the case in Gori, Georgia.

Income and consumption

The FGD participants reported better access to local markets and increased visits from intermediary buyers. Although, they do not report significant changes in their income since the roads were improved. In terms of changes in consumption, they reported buying more clothing and other non-food items in markets since the roads have been improved.

Complementary infrastructure

The FGD participants and village heads were asked about the complementary infrastructure that had accompanied road improvement works or were missing. In terms of transportation related complementary infrastructure, some communities expressed concern with lacking infrastructure. For example, while interviewees from some communities reported increased frequency of transport services that came with improved roads, others still lacked this complementary infrastructure. Participants from Telavi, Georgia reported that there is no bus or mini-bus transport going to the nearby villages after 6 p.m. Therefore, they cannot work in the town unless they have a car.

While some report the lack of complementary transport services, others highlight the need of complementary physical infrastructure. *"Highways should also be built for people"*, - says a participant from Nor Yerznka, Armenia. The village lies nearby a major road which has been expanded into a highway. If before they could have easily crossed the road to get to the village opposite side of the road before, now they cannot as there is no bridge.

In many settlements roads brought some complementary infrastructure. Many communities where inner roads have been rehabilitated, the FGD participants report having new streetlights, waste disposal service, and natural gas supply in their communities.

However, the issue of inadequate road maintenance remains. *"Even after roads are improved, inner village roads are rarely maintained"*, - reports a participant from Amasia, Armenia.

Negative externalities

Safety has been the main concern with the upgraded roads. The interviewed communities often reported that sidewalks either had not been built or had been used for parking cars. Better roads mean cars can drive faster, increasing danger for people living along the roadside. *"It is dangerous for my children, because the door of our house opens directly on the road"*, - says a participant from Karmirgyugh, Armenia. Some participants reported that the number of accidents had increased since the roads had been improved and no proper sidewalks had been built. In Telavi, Georgia, participants reported that often they have to walk on the main road, especially when they have baby carts, because the sidewalks are occupied by parked cars and they cannot pass. There also report the lack of designated parking areas.

Concerns are different in Khashuri, Georgia. Currently the major traffic going from the east to the west of the country is going though the middle of the town of Khashuri. However, with building and expanding the new highway - East-West Highway of Georgia - the plan is to bypass the town. The construction of the bypass road has already begun. The participants expressed their concern that this might result in decrease in retail business, restaurants and service areas in the town and increase unemployment.

1.7 Organization of the thesis

Following the preceding introduction to the topic and the research questions, the thesis is structured into three main chapters and a general conclusion chapter. Although the three chapters are related, they are self-contained papers, each specifically addressing each of the above proposed research questions and objectives.

Chapter 2 studies the impact of road quality on agricultural and non-agricultural employment by analyzing the evidence from Armenia. The study uses different sets of data and different methodological approaches to study the research question. Another distinctive feature of the chapter is that I use a unique road quality dataset and exploit a historical setting of roads to address the endogeneity and reverse causation problems. The study uses a historical instrumental variable obtained by georeferencing and digitizing a military-topographic map of the Caucasus created during the Russian Empire in 1903.

Chapter 3 examines the relationship between large scale road rehabilitation projects and utility services. The rehabilitation projects studied in this chapter have been implemented in Georgia between 2006-2015. The projects were designed to improve the connectivity of municipal district centers to each other. As a side effect, a large number of peripheral settlements also appeared better connected, creating an interesting setting to study the impact of rehabilitated roads. In order to address the non-random selection of improved roads between the targeted district center nodes, I use an instrumental variable strategy based on Euclidean distance and the least cost path spanning tree network from the transport engineering literature.

Chapter 4 focuses on studying the economic effects of different types of roads rehabilitated in Georgia and evaluates their short-term impacts on household income and expenditure. The combination of household and settlement surveys, administrative and spatial data with a difference-in-difference methodology is used to study the causal effects of improved roads at the household level in 135 settlements.

Chapter 2

Connectivity, road quality and rural employment: evidence from Armenia

2.1 Introduction

Poor transportation infrastructure restricts accessibility to markets and jobs for the rural population in low- and middle-income countries (World Bank, 2009). In recent years, governments, with the help of international organizations, have been intensively investing in building new infrastructure and improving or maintaining old infrastructure. Improved roads tend to decrease travel time and costs, and promote mobility. Hence, better transportation infrastructure might stimulate mobility of goods and labor, connecting people to jobs.

Proximity to urban areas has always been considered an important aspect to rural households for access to goods and services and it is widely studied in the literature. The studies show that living closer to urban areas improves the economic well-being and nutrition of rural households (Stifel and Minten, 2017; Sharma, 2016), increases non-farm employment and market-oriented activities (Deichmann et al., 2009; Fafchamps and Shilpi, 2005, 2003), and overall, positively affects spatial dimensions of development (Sharma, 2016). However, proximity alone cannot be a good measure of accessibility because it does not take road condition into account - which can have a large impact on travel time to urban centers.

A large majority of households in low- and middle-income countries are still mainly involved in agriculture, often employed in self-subsistence farming. According to the accounts data, in low-income countries labor productivity in non-agricultural employment is 4.5 times higher than in agricultural employment, it is 3.2 times higher in middle-income countries, 2.2 higher in high-income countries (McCullough, 2017). Structural transformation has been a key policy issue in low- and middle-income countries in recent decades. One of the ways to address this problem is to give rural households opportunities to get employed in more productive sectors. Proximity to cities and access to adequate road infrastructure could play an important role in increasing non-agricultural employment among rural individuals (Aggarwal, 2018; Asher and Novosad, 2018).

This paper analyzes the impact of road quality on agricultural and non-agricultural employment, studying evidence from Armenia. Empirical studies on the relationship between road infrastructure and labor outcomes often suffer from endogeneity and reverse causation problems. Road quality is usually not exogenous. Other than topographic characteristics, it is often driven by economic, social, or political factors (Banerjee et al., 2012; Datta, 2012; Nguyen et al., 2011; Burgess et al., 2015). To address the endogeneity and reverse causation issues, this study uses a (historical) instrumental variable strategy. The instrumental variable has been obtained by georeferencing and digitizing a military-topographic map of the Caucasus region printed by the Russian Empire in 1903. The study uses historical, primary military and post roads to instrument the existing road quality a century later.

The results show that a shorter distance to the nearest good quality road has statistically significant positive impact on overall non-agricultural employment, on skilled manual employment for rural men, and non-agricultural employment and cash earnings for rural women. People are more likely to work outside of their villages if they have access to good quality roads, and also tend to work for more hours. The analysis has been carried out on two different datasets, the Demographic and Health Survey and the Integrated Living Conditions Survey of Armenia, using different estimation methods. The results are similar and robust from both datasets.

This paper contributes to three groups of literature: (1) estimating impact of road infrastructure improvement, (2) examining rural employment and structural transformation, and (3) using historical setting for causal inference. There is a growing number of literature evaluating road construction or improvement programs in various countries, like in India (Aggarwal, 2018; Asher and Novosad, 2018; Bell and van Dillen, 2014; Duranton et al., 2014; Datta, 2012; Ghani et al., 2016), Bangladesh (Khandker et al., 2009; Khandker and Koolwal, 2011), Papua New Guinea (Gibson and Rozelle, 2003; Wiegand et al., 2017), Ethiopia (Dercon et al., 2009), Indonesia (Gibson and Olivia, 2010), Vietnam (Mu and van de Walle, 2011), China (Banerjee et al., 2012; Wang et al., 2016; Fan and Chan-Kang, 2005; Faber, 2014), and Georgia (Lokshin and Yemtsov, 2005), among others. Overall, improved connectivity causes travel time and cost reduction. The cost and time saving stimulates mobility, connecting rural areas to urban centers, people to markets and services. Easier mobility quite often is a key factor in trading, as a result reducing product prices (Donaldson, 2018; Andrabi and Kuehlwein, 2010; Aggarwal, 2018), it also shows to reduce poverty (Khandker et al., 2009), and contributes to local market development (Mu and van de Walle, 2011).[1]

The second area of contribution is to the literature on rural employment and structural

[1]For an overview on the impacts of infrastructure improvements on various economic outcomes, please see Redding and Turner (2015).

transformation. Road improvement and travel time reduction contributes to easing access to jobs. High transportation costs show to increase the size of the agricultural workforce and employment in subsistence farming (Gollin and Rogerson, 2014; Adamopoulos, 2011). On the other hand, improved accessibility to jobs through improved roads benefits structural transformation. Asher and Novosad (2016) and Mu and van de Walle (2011) find that the rural roads programs in India and Vietnam respectively, increase wage labor participation and the share of households mainly relying on the service sector as their main source of income. While existing literature has largely been concerned with recently built or paved roads, this paper studies the variation of road quality using a unique dataset on the condition of roads.

Finally, the paper also contributes to the growing body of literature that uses historical settings to account for endogeneity. Duranton and Turner (2012) use a historical highway plan of the US highway to estimate a structural model of city growth and transportation, Baum-Snow et al. (2012) use Chinese rail and road networks from 1962 as a source of identifying variation in rail and road networks after 2000, Volpe Martincus et al. (2017) use historical Inca routes for Peru, Garcia-López et al. (2015) and Holl (2016) use Roman roads and the 1760 Bourbon postal routes as sources of exogenous variation of highway extension in Spain, and Möller and Zierer (2018) rely on a 1890 plan of railroad network in Germany and a 1937 map of planned autobahns to study regional employment. This paper uses the historical military routes of Armenia during the Russian Empire times to account for the endogeneity of modern-day road quality.

The research focuses on Armenia to fill the gap in the literature for several reasons. In Armenia, agricultural employment rate is still high, though it has reduced from 40.4% in 1991 to only 33.6% in 2016[2]. Moreover, most people engaged in agriculture in Armenia, like in many other low- and middle-income countries, are best characterized as engaging in subsistence or quasi-subsistence agriculture, meaning that they consume most of the goods they produce. Given this, identifying mechanisms of structural change is very important. In addition, Armenia has been receiving large loans for rehabilitating and improving existing deteriorated roads, as well as for building new ones. Therefore, it is policy relevant to study the impacts of these road projects. And lastly, the unique dataset on road quality and the historical setting of Armenia provides an opportunity to identify impacts of road quality on rural employment outcomes.

2.2 Conceptual framework

In regional research, the importance of transportation costs has long been recognized as one of the major factors of economic development. Von Thünen's land rent model and its subsequent modifications predict concentric circles of specialization in agriculture surrounding cities (Von Thünen, 1826). Building on this, regional economic models

[2]Source: International Labor Organization (ILO), Key Indicators of the Labor Market `https://www.ilo.org/ilostat`. Accessed April, 2019.

predict that improving rural connectivity would facilitate moving from agricultural to non-agricultural employment. For example, the Alonso-Muth-Mills model predicts an urban perimeter beyond which agriculture would be the primary employment sector. The urban perimeter takes into account that urban wages, deduced with transportation costs, would be lower than agricultural wages (Brueckner, 1987). Therefore, if we consider road quality improvements as a source of decreasing commuting costs in a given location, we expect improved road quality to expand the urban perimeter.

Starting from the Lewis (1954) model, researchers have argued that labor market imperfections prevent people employed in the agricultural sector from relocating to higher productivity sectors.[3] Since labor productivity is 4.5 and 3.2 times higher in non-agricultural employment than in agriculture in low- and middle-income countries respectively (McCullough, 2017), it is important to study the transition channels from agricultural to non-agricultural employment. A multi-sector multi-region model developed by Gollin and Rogerson (2014) shows that higher transport costs increase the size of agricultural workforce and self-subsistence farming. Deichmann et al. (2009) study rural-urban linkages in Bangladesh and find that households living closer to urban centers are more likely to be employed or self-employed in non-farm sector, and Asher and Novosad (2018) find that newly paved rural roads in India increase non-farm employment by stimulating easier access to outside-village labor markets.

There are two channels linking road infrastructure and rural employment. The first channel is through agricultural productivity. Improved roads decreasing transportation costs might decrease the costs of agricultural inputs as shown in (Aggarwal, 2018), and help individuals move to non-agricultural employment by increasing agricultural productivity. For example, Sotelo (2015) estimates on average a 14% increase in agricultural productivity because of paving existing roads, by increasing access to inputs and increasing output prices.

The second channel works through decreased job search and commuting costs. Decreased transportation costs likely decrease costs of job search or commuting to a job, reducing barriers to working outside the village. It is an important issue, considering possible underemployment in the agricultural sector. The studies show that agricultural work is less productive than non-agricultural work. However, by looking at actual reported hours worked in different sectors in several Sub-Saharan countries, McCullough (2017) has shown that the productivity gap is not as high as it was previously considered. She observes that agricultural workers are working far fewer hours than non-agricultural workers, and therefore can be considered underemployed. The underemployment might be due to the seasonality of agricultural work, as some seasons require far more work than others. On the other hand, if farmers have limited access to farm inputs, they might need to work more hours in agricultural sector.

[3] The literature has also suggested that barriers to the reallocation of labor could result from insurance networks that discourage movement out of rural areas (Munshi and Rosenzweig, 2016), and informational frictions (Banerjee and Newman, 1998), among others.

Improved accessibility to jobs could help farmers to take non-agricultural work during agricultural off-season. Commuting might be particularly hard not only due to the long distance to urban areas, but also due to poor road quality and transportation infrastructure. Improved roads and transportation infrastructure therefore, are expected to increase the probability of household members engaging in work outside their village.

2.3 Background

The paper focuses on Armenia to study the relationship between road quality and rural employment. Armenia is a low-middle-income country (GDP per capita USD 3,917 in 2016 (constant 2010 US$)) with a population of 2.9 million people.[4] The country has quite a well developed road network; Figure 2.1 shows that most of the settlements in the country are connected to roads. However, the quality of roads is still a matter of concern. The railroad network is not very well developed in the country mainly due to the rough terrain. Therefore, road network is vital for passenger and freight transportation.

The classified road network of Armenia is 7700 km long, from which around 1400 km are interstate roads, 2520 km are regional roads, and 3780 km are local roads. Most of the roads have been built in the 1960s and 1970s, and have deteriorated since the independence in 1991 due to poor maintenance (Farji Weiss et al., 2017). Since the early 2000s, the country has received funding from different international organizations, such as the Millennium Challenge Corporation (MCC), the World Bank (WB), and the Asian Development Bank (ADB) to rehabilitate the lifeline roads[5] in the country and expand the major interstate road into a highway, connecting the south to the north of the country. There have been several ongoing projects since then: the Rural Roads Rehabilitation Project, which was started by the MCC and taken over and expanded by the World Bank as Lifeline Road Network Improvement Project (LRNIP), and two projects by the ADB: North-South Highway and Rural Roads Sector Project. The projects have been improving road quality and rural-urban connectivity.

A large share of Armenians are employed in agriculture. Structural transformation has been slow: as of 2016, 33.6% of Armenians were working in agriculture, just 6.8 percentage points lower than in 1991.[6] Agriculture accounted for 16.4% of GDP in 2016.[7] Like in most low- and middle-income countries, the majority of people employed in agriculture in Armenia are rural individuals employed in self-subsistence or semi-self-subsistence farming. Therefore, it is crucial to understand the link between improved road quality and rural employment, and what role improved roads could play in structural transformation.

[4]Source: Databank, the World Bank `https://data.worldbank.org/indicator` Accessed: June, 2019.

[5]The roads connecting villages to major roads are often called "lifeline roads" in Armenia (Farji Weiss et al., 2017).

[6]Source: International Labor Organization (ILO), Key Indicators of the Labor Market `https://www.ilo.org/ilostat`. Accessed April, 2019.

[7]Source: Statistical Committee of the Republic of Armenia, ArmStatBank `http://armstatbank.am/pxweb/hy/ArmStatBank/?rxid=602c2fcf-531f-4ed9-b9ad-42a1c546a1b6` Accessed April, 2019.

Finally, the historical setting and available data for Armenia allow me to employ instrumental variable strategy to study the causal impacts of road quality. In particular, this paper uses historical roads from the times of the Russian Empire as a conditionally exogenous source of variation in quality of transport infrastructure.

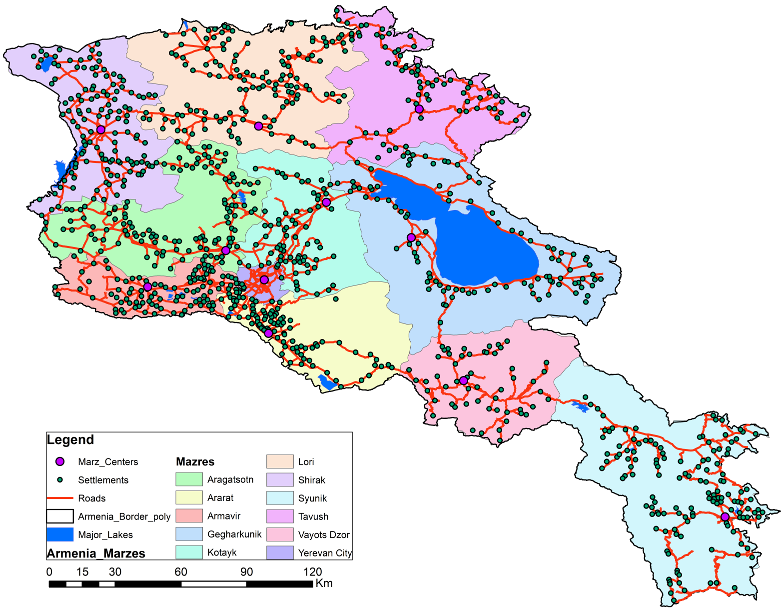

Figure 2.1: Roads and settlements.
Source: Author's compilation based on WB data on roads, and administrative data from Acopian Center for the Environment.

2.4 Data

In order to estimate the economic impacts of road quality, it is necessary to construct a unique settlement-level data combining aggregate and micro-data from multiple sources. This paper uses household and individual level surveys, road quality data, administrative, and geospatial data. This section describes the data sources and some summary statistics.[8]

2.4.1 Integrated Living Conditions Survey

Integrated Living Conditions Survey (ILCS) is a nation-wide survey conducted annually by the National Statistical Service of the Republic of Armenia (Armstat). The survey is representative at country, village/town and Marz[9] levels.[10] The survey includes rural and urban households and monitors the living standards of households. The questionnaires are asked on household as well as the individual level. The survey has been conducted

[8]For more detailed summary statistics please see Appendix 2.8.
[9]Administrative unit in Armenia, equivalent to a region.
[10]Source: Quality declaration Integrated Living Conditions Survey of Households, Armstat. `https://www.armstat.am/file/Qualitydec/eng/11.1.pdf` Accessed April, 2019.

since 2001, however, this study uses data starting from 2007 since questions on individual employment were not asked before the 2007 survey. The repeated cross-sectional data have been adjusted and appended for this study for each year from 2007 to 2016.

The main strengths of the data are rich details on individual employment, long time span, and questions about the perception on road and transport quality. However, the main disadvantage of the survey for this study is that no approximate location of households is known, except for the region (Marz) where the household lives and whether the location is rural or urban. The survey contains questions on distances to markets, hospitals, banks, and other service centers since 2009, making it possible to control for these characteristics while estimating the impact of road quality.

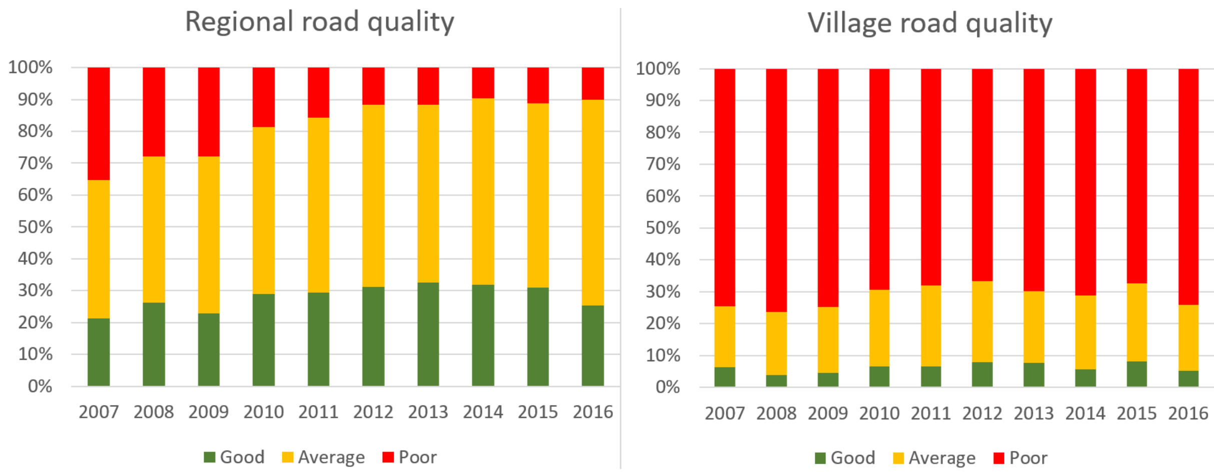

Figure 2.2: Road quality reported by HHs in 2007-2015

The data on road quality has been collected by asking households in rural areas how would they rate the quality of roads, from "Poor" to "Excellent" condition. The respondents had to evaluate the quality of roads within their settlement or community, and roads to regional towns or markets. Figure 2.2 shows road quality reported by the households from 2007 to 2016. While roads that lead to towns and markets seem to have improved over time, internal village roads remained in poor quality.

2.4.2 Demographic and Health Survey (DHS)

The Armenia Demographic and Health Survey (DHS) 2015-2016 is a nationally representative sample survey, designed to provide information on population and health issues in Armenia. The data have been collected by the National Statistical Service and the Ministry of Health of the Republic of Armenia and is co-funded by the United States Agency for International Development (USAID). The main goal of the survey is to collect demographic and health indicators, particularly from women of reproductive age, and in some questions from men as well. In total, the 2015-2016 survey has collected data on 6,116 women and 2,755 men of the age range of 15 to 49. The data is representative of the national and rural-urban areas. The 2015-2016 survey has 313 clusters in total, from which 121 are rural.

One of the advantages of the DHS survey is that the program collects the GPS location data of surveyed clusters. In order to protect the confidentiality of the respondents, the locations have been displaced. Each urban cluster has been displaced from the actual location up to 2 kilometers, and each rural cluster up to 10 kilometers.[11] The survey also provides a wide range of geospatial covariates, very useful for the purpose of the study.

Table 2.1: Rural employment by gender (DHS)

Occupation	Men	Women	Total
Not working	27%	62%	50%
Professional/technical	9%	25%	17%
Clerical	1%	2%	1%
Sales	6%	9%	8%
Agricultural	26%	45%	36%
Services	16%	6%	11%
Skilled manual	30%	6%	18%
Unskilled manual	9%	7%	8%
Other	4%	0%	2%
Total	1,233	2,571	3,804
Working	904	981	1,885

Rural respondents report lower labor activity. 43% of DHS respondents report living in rural areas, from which half indicate that they have not worked in last 12 months. The difference is very high between men and women, more than double the women report not working than men - 62% and 27% respectively.[12] Table 2.1 reports rural employment indicators. From those working, women are overwhelmingly employed in agriculture - 45% compared to 26% of men, and in professional employment - 25% compared to 9% of men. The employment groups are more varied for men, majority of them reported working in skilled manual employment, 30% compared to only 6% of women.

2.4.3 Road quality data

As in most of the low- and middle-income countries, there was no comprehensive road network quality data available for Armenia. To fill this gap, the World Bank financed the data collection of geo-referenced data on the Armenian road network, road quality, surface type and category. The data were collected in early 2017 using a smartphone application RoadLabPro - created by the World Bank as a data collection tool with accelerometers to

[11] For more information please see Mayala et al. (2018).

[12] Unfortunately, limited employment variables do not fully allow the calculation of the proportion of unemployed people versus the ones who do not work for other reasons.

map a road network, evaluate road condition, detect major road bumps, travel speed and report road safety hazards.[13]

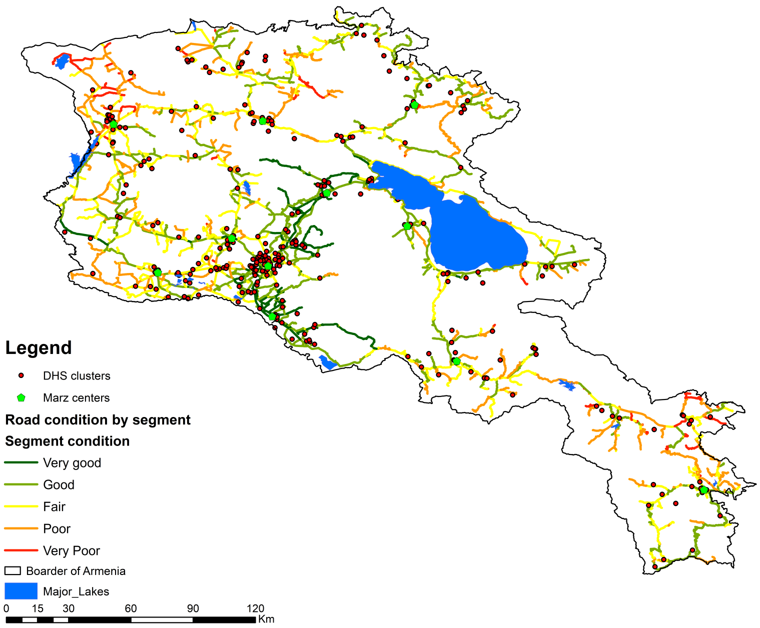

Figure 2.3: Road quality by road segment

Road quality categories: Very good (IRI range between 1.0 and 2.0), Good (2.0 - 4.0), Fair (4.0 - 6.0), Poor (6.0 - 10.0), Very poor (10.0 - 16.0). Source: Author's compilation based on data on road quality from the World Bank, and administrative data from the Acopian Center for the Environment.

In total, the data were collected on 8,286 km of roads, including major (international and national) and feeder roads. The road quality was divided into five categories according to the International Roughness Index (IRI): very good, good, fair, poor, and very poor.[14] The data shows that the road quality substantially differs between different regions (Marzs). For example, as Figure 2.7 shows, Yerevan - the region of the capital city has only 4% of its roads in poor or very poor quality, the reported road quality is better in in Kotayk and Ararat Marzs - surrounding Yerevan - more than 85% of primary and feeder roads are in good or very good condition, while Lori and Shirak regions have only around one-fifth of the primary and feeder roads in good condition.

2.5 Methodology

2.5.1 Empirical strategy

The impacts of infrastructure are often challenging to capture. This paper studies the questions using several datasets and estimation methods.

[13]For more information please see Farji Weiss et al. (2017) p.56.

[14]Road quality categories: Very good (IRI range between 1.0 and 2.0), Good (2.0 - 4.0), Fair (4.0 - 6.0), Poor (6.0 - 10.0), Very poor (10.0 - 16.0).

The first method studies the association between regional road quality and different employment outcomes. It uses the Integrated Living Conditions Survey - 10 years of repeated cross-sectional data - to answer the research questions. The survey has collected rich data on various employment outcomes, which is not usually the case in other surveys, making it possible to look at more variables of interest.[15]

The first part of the analysis studies the association of reported road quality leading to towns and markets, and binary employment outcomes: whether a person is employed in non-agricultural sector, in seasonal employment, and whether at least one member of the household works outside of the village. The second part of the analysis studies the relationship between hours worked, agricultural employment, and road quality.

The second method utilizes the opportunity of GPS location information collected by the surveys to answer the research questions. It combines the georeferenced data on quality of roads in Armenia collected by the World Bank, matching the geographic coordinates of household cluster locations collected by the DHS. The combined dataset with geographic locations provides an opportunity to calculate the proximity to good quality roads from each cluster where the household is, and then estimates the impact of the distance on various employment outcomes. In addition, the availability of georeferenced information allows to control for additional geospatial variables which could also be influencing employment outcomes. The idea of quality of roads and employment probability is captured in a simple reduced form specification:

$$Pr(Y_i = 1|x_{is}) = \varphi(\alpha + \beta LogDistGR_s + \varsigma I_{is} + \delta H_{is} + \tau S_s + \mu R_s + \varepsilon_{is}) \quad (2.1)$$

The outcome variable Y_i of an individual i living in settlement s shows the probability of being employed in the non-agricultural sector, skilled manual employment, seasonal employment, or likelihood of obtaining cash earnings. The main independent variable is $LogDistGR_s$ - log distance to the nearest good/very good quality road. The additional controls include individual level characteristics I_{is}, household level characteristics H_{is}, a vector of settlement (cluster) level geospatial covariates S_s, and region fixed-effects R_s.

2.5.2 Identification strategy

The question of endogeneity usually arises while studying the economic impacts of infrastructure. Initial conditions are likely to determine where new roads are to be built or which old roads receive maintenance (Banerjee et al., 2012; Datta, 2012). Roads might be built and kept in good condition in areas with high economic potential. Reverse causality might also be in play: areas with non-agricultural employment potential might require better roads, or better roads might lead to higher non-agricultural employment. Therefore, the question could be summed up as follows: do areas with better roads show better

[15]The questionnaires had been slightly modified over the period of 10 years, therefore, the variables have been adjusted accordingly to ensure the comparability over the years.

non-agricultural employment outcomes because of good road quality, or are better roads attracted by (potentially) higher non-agricultural employment? For example, if areas with good quality roads show higher non-agricultural employment, it could be because the roads were built and well-maintained in areas with higher economic potential. Therefore, simple correlation between road quality and non-agricultural employment would overestimate the impact of roads quality.

Another concern on road quality placement is political or ethnic favoritism. Burgess et al. (2015) shows evidence of mis-targeted infrastructure projects in Kenya due to ethnic favoritism; Nguyen et al. (2011) shows nepotism of public officials in their communes in Vietnam, mis-targeting infrastructural projects. Studying the long timespan from 1960 to 2010, Jedwab and Storeygard (2017) show that cities around the leader's place of origin in sub-Saharan Africa were growing faster than other cities because the leaders favored their cities of origin to target road infrastructure projects. Hodler and Raschky (2014) measured regional favoritism from outer space: they found that subnational regions, where current political leaders were born have more intense nighttime lights.

This paper uses an instrumental variable (IV) strategy to account for endogeneity.[16] The IV is based on a map of historical road networks of Armenia obtained from a Military-topographic map of the Caucasus region - shown in Figure 2.8 - prepared under the Russian Empire in 1903. The argument of exogeneity of the historical setting of roads can be motivated by several reasons. At the beginning of the 20th century, Armenia was under the rule of the Russian Empire. The southernmost state of the empire, situated on the border of Ottoman and Persian empires, Armenia was an important territory for military defense. The roads maintained by the Russian Empire were mainly used to transport armies. Even though the roads could also be used for trade and economic reasons, we can argue that the government of the Russian Empire would invest in building, rehabilitating, and maintaining the roads necessary for military reasons. The second argument is that since the historical roads were mapped before the industrialization of the region, when the large majority of people were employed in agriculture, we can argue that the roads would not have been built and maintained to promote non-agricultural employment. It is very unlikely that any decisions made in different settings far back in history, motivated mainly by non-economic reasons, could have anticipated rural employment development a century later.[17]

[16]The literature using similar method includes: Duranton and Turner (2012), Baum-Snow et al. (2012), Volpe Martincus et al. (2017), Garcia-López et al. (2015), Holl (2016) and Möller and Zierer (2018), among others.

[17]In the section of robustness checks the paper also addresses the factor of mine locations in the region, and shows that it is highly unlikely that mines would have influenced the historical primary road placement.

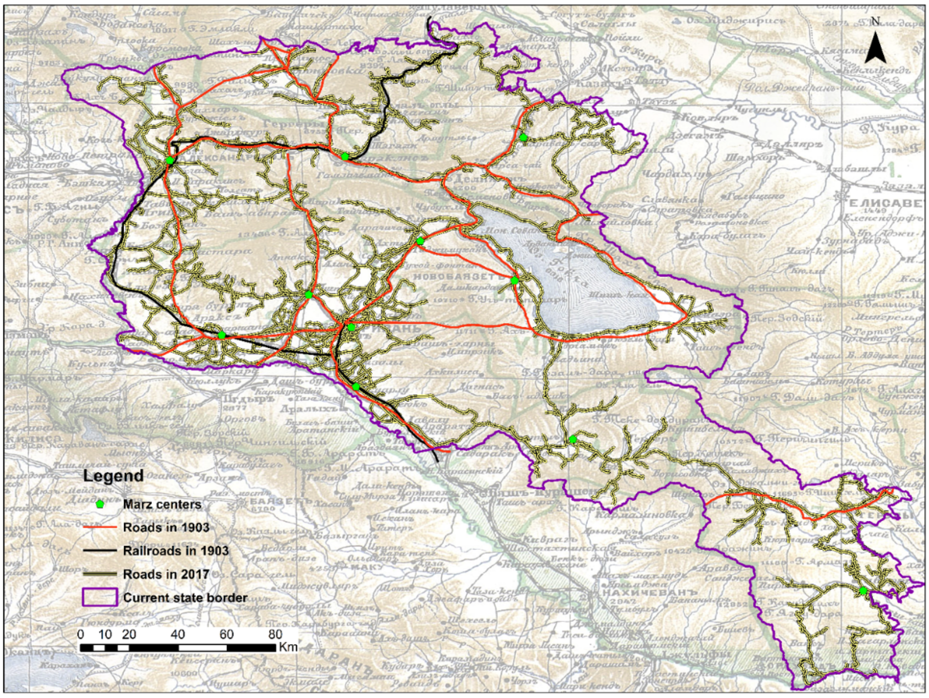

Figure 2.4: Digitized Military-topographic map of the Caucasus, 1903, fragment on Armenia.
Source: Author's compilation based on data from the Russian State Library, the World Bank, the Acopian Center for the Environment. Digitization by the author.

The historical map was georeferenced and the fragment of the map, containing Armenia, was digitized. The original map on Figure 2.8 shows four types of roads: primary roads, post roads (well developed cart road), cart roads, and drover's roads. Since drover's roads are mainly pathways, and would not have been actively used for transporting armies and maintained by the government, they were excluded from the analysis. Figure 2.4 shows a georeferenced and digitized road map of Armenia. The red lines depict the primary military and post roads of Armenia in 1903.

For the instrumental variable, Probit regression logarithmic distance to good roads is instrumented by logarithmic distance to primary military and post roads in 1903.

$$LogDistGR_s = \gamma LogDistRoads1903_s + \tau S_s + \delta H_{is} + \mu R_s + \varepsilon_{is} \tag{2.2}$$

$$Pr(Y_i = 1|x_{is}) = \Phi(\alpha + \beta \widehat{LogDist}GR_s + \iota I_{is} + \ \delta H_{is} + \tau S_s + \mu R_s + \varepsilon_{is}) \tag{2.3}$$

The instrumental variable $LogDistRoads1903_s$ is assumed to be correlated with the endogenous regressor $LogDistGR_s$ but independent from the error ε_s. We can argue that old main roads would have been maintained to transport armies, and later on these roads would also have higher quality.

2.6 Results

The results of the two separate datasets and methods are summarized in different subsections below.

2.6.1 ILCS

First, I show the results of the analysis of the repeated cross-sectional data of Integrated Living Conditions Survey (ILCS). The survey has collected information on perception of respondents on road quality in the region and locally - within the village. The road quality indicators include “good”, “average”, and “poor” (“good” is a reference category in the following results tables).

Table 2.2 shows the marginal effects of Probit regression. It shows the probability of a respondent being employed in non-agricultural sector (columns (1) and (2)), doing seasonal work (columns (3) and (4)), and whether there is anyone from the household working outside of the village (column (5)). Since the distance variables were not included in the questionnaires in 2007 and 2008, the regression is done with and without the distance variables. The first column shows a clear negative association between the household living in a region with average or poor road quality and non-agricultural employment. Individuals reporting poor road quality are 5,4 percentage points less likely to be working in the non-agricultural sector than the individuals reporting good quality roads in their regions. Controlling for the distance to the nearest market, kindergarten, and health center lowers the marginal effects, but still holds a statistically significant 3,5 percentage points lower probability of working in the non-agricultural sector (column (2)). As expected, average roads show lower marginal effects; individuals reporting quality of roads in their region leading to towns and markets as average, are 1,9 percentage points less likely to work in the non-agricultural sector than the individuals reporting good quality roads in their region. The marginal effect changes slightly to 1,4 percentage points (column (2)) when distance variables are included (hence, excluding 2007-2008 datasets because of the lack of the distance variables).

Columns (3) and (4) report the probability of working in seasonal employment given different regional road quality leading to towns and markets. Respondents who report average and poor road quality in their regions are, respectively, 1,5 and 5,2 percentage points less likely to work in seasonal employment. Considering that 66% of the respondents employed in agriculture report working whole year round and only 1,3% of them or 370 people report having a second job, this could mean that people living in areas with poor roads are less likely to take seasonal jobs during low agricultural seasons. Lastly, column (5) shows that households are less likely to report any household member working outside of the village if they report having poor or average roads quality leading to towns and markets.[18]

[18] Column (5) is reporting analysis on household level.

Table 2.3 reports the relationship between hours worked, agricultural employment, and reported road quality. The first column shows that people who work in agriculture tend to work less, estimated at 16.5 less hours worked the week before the survey, holding all other variables constant and controlling for the survey month. Descriptive statistics show that non-agricultural workers had worked on average 23 hours the week before the interview, while the non-agricultural workers had worked for 41 hours on average. This result is in line with the study done by McCullough (2017). By analyzing the Living Standards Measurement Study Integrated Surveys on Agriculture (LSMS-ISA) for four African countries - Ethiopia, Malawi, Tanzania and Uganda - she found that each agricultural worker was working on average 700 hours per year compared to the 1850 hours per non-agricultural worker. Our estimates are higher than those of McCullough (2017) but still show significantly large differences between the working hours of agricultural and non-agricultural workers. Column (2) shows that individuals reporting average or poor quality of roads leading to towns and markets, work slightly less than people reporting good regional road quality. Column (3) shows how the inclusion of the interaction terms affects the results. Respondents working in agriculture who report average quality of regional roads are estimated to have worked 1.7 hours less in the previous week than people reporting good roads. Interestingly, people employed in agriculture who report poor regional roads are estimated to work slightly more than agricultural employees who report good regional roads. They are estimated to have worked 3.5 hours more the week before. These results suggest that while people employed in agriculture indeed work for fewer hours, they work more if they have poor connectivity with towns and markets. The reasons could be that people with inadequate access have difficulties accessing agricultural inputs and extension services, and therefore are less productive and need to do more manual work.

Table 2.2: Marginal effects - probability of positive outcome.

	Non-agricultural employment		Seasonal employment		Job outside village
	(1)	(2)	(3)	(4)	(5)
Poor reg. road quality	-0.054***	-0.035***	-0.054***	-0.052***	-0.028*
	(0.006)	(0.008)	(0.007)	(0.009)	(0.015)
Average reg. road quality	-0.019***	-0.014**	-0.015***	-0.015**	-0.033***
	(0.005)	(0.006)	(0.006)	(0.007)	(0.011)
Log distance to market		-0.013***		-0.023***	-0.015***
		(0.003)		(0.003)	(0.005)
Log distance to kindergarten		-0.008***		-0.009***	-0.007**
		(0.002)		(0.002)	(0.003)
Log distance health center		-0.006**		0.012***	-0.006
		(0.003)		(0.003)	(0.005)
Individual controls	Yes	Yes	Yes	Yes	Yes
Household controls	Yes	Yes	Yes	Yes	Yes
Region-year FE	Yes	Yes	Yes	Yes	Yes
Survey month FE	Yes	Yes	Yes	Yes	Yes
Observations	49,443	37,245	49,442	37,244	7,228

Individual controls include: *gender, age, age squared, household head, marital status, education categories.*
Household controls include: *family size, number of children, family member abroad as an immigrant.*
Robust standard errors in parentheses clustered on household level. ***p<0.01, **p<0.05, *p<0.1

Table 2.3: OLS estimates on number of hours worked in previous week

	(1)	(2)	(3)
Agriculture	-16.51***		-16.06***
	(0.220)		(0.368)
Average reg. road quality		-0.995***	0.444
		(0.242)	(0.379)
Poor reg. road quality		-0.653**	-2.902***
		(0.318)	(0.561)
Agriculture x Average reg. road quality			-1.717***
			(0.438)
Agriculture x Poor reg. road quality			3.533***
			(0.638)
Individual controls	Yes	Yes	Yes
Household controls	Yes	Yes	Yes
Geographic controls	Yes	Yes	Yes
Region-year FE	Yes	Yes	Yes
Survey month FE	Yes	Yes	Yes
Const.	14.47	0.87	14.95
Observations	37,245	37,245	37,245
R-squared	0.372	0.213	0.375

Individual controls include: *gender, age, age squared, hh head, marital status, education categories.* HH controls include: *family size, number of children, family member abroad as an immigrant.* Geographic controls include: *log distance to market, log distance to kindergarten, log distance to health center.*

Robust standard errors in parentheses clustered on household level. ***p<0.01, **p<0.05, *p<0.1

2.6.2 DHS

This section reports the results of the analysis performed on the combination of DHS survey and the road survey. I mapped the GPS locations of DHS survey clusters together with the road survey vector dataset and other geographic raster data layers.

Table 2.4 shows the estimates of the first-stage regression - following the equation (2). The dependent variable is the endogenous variable $LogDistGR_s$ - log of distance to the nearest road in good condition. It is instrumented with $LogDistRoads1903_s$ - log distance to the nearest primary military and postal road in 1903.

Table 2.4: First-stage regression.

	Coeff. Logdist. good road	s.e
Logdist. Road 1903	0.421***	(0.0252)
Logdist. regional center	-2.602***	-0.408
Logdist. capital city	0.588***	(0.0839)
Altitude	0.000995***	(0.0001)
Slope	-0.0687***	(0.0197)
Population Density 2015	0.00437***	-0.00025
Nightlights Composite	-1.654***	-0.0971
Aridity	-0.00825	-0.00665
Individual controls	Yes	
Household controls	Yes	
Region dummies	Yes	
Observations	3,801	
R-squared	0.348	
First stage F-stat	276.76	

Individual controls include: age, age squared, gender, years of education, individual weights. Household controls include: owns land usable for agriculture, wealth index, number of children of age 5 and lower, number of family members.
Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1

Table 2.4 shows that $LogDistRoads1903_s$ has a strong, statistically significant correlation with the endogenous variable $LogDistGR_s$. The First-stage F-statistics also prove that $LogDistRoads1903_s$ is a strong instrument.

The coefficients in Table 2.5 represent the average marginal effects on the probability of non-agricultural employment and skilled manual employment. The marginal effects are estimated on the whole sample as well as on the samples of only women and only men. Column (1) shows the average marginal effects of the probability to be employed in the non-agricultural sector. The relationship between the distance to the nearest road in good condition and non-agricultural employment, as expected, is negative: 1 unit increase in log distance to the nearest good quality road, or approximately 2.7-fold increase ($e \approx 2.71828$), decreases the probability of being employed in non-agricultural sector by 5.7 percentage points. The effects are consistent for women and men, showing, respectively, -5.8 and-6.2 percentage points likelihood of being employed in the non-agricultural sector.

Next, I estimate the average marginal effects of the probability of being employed in skilled manual employment, given distance to the nearest good quality road. The results are reported in columns (4), (5), and (6). Overall, one unit increase in log distance (or approximately 2.7-fold increase) decreases the probability of having a skilled manual job by 5.1 percentage points. When the estimations are performed on men and women separately, we see that average marginal effects for women are still negative but lose statistical significance, while the coefficient for men still holds at statistically significant at negative 6.6 percentage points. This could be explained by the distribution of men and women in skilled employment shown in Figure 2.6. Only 6% of surveyed working women are employed in skilled manual employment, compared to 31% of men.

Table 2.6 shows the average marginal effects of the probability of being employed in seasonal employment, and the probability of receiving cash earnings. Overall, living further from a road in good condition is negatively associated with seasonal employment, 1 log increase in distance from a good road decreases the probability of working seasonally overall by 5.5 percentage points. These findings are in line with the results of the analysis done on the ILCS data, presented in Table 2.2. When marginal effects are calculated separately for women and men, the coefficient of the average marginal effect of women having seasonal jobs becomes positive but statistically insignificant. However, the marginal effect of the probability of seasonal employment on men is statistically highly significant - one unit increase in log distance decreases the probability of having a seasonal job by 10,7 percentage points. Unfortunately, limitations of the employment data in DHS surveys do not allow me to study the seasonality outcomes in depth. The descriptive statistics show that almost half (47%) of agricultural workers regard their employment as non-seasonal, working whole year round. These results could indicate that going further from a good quality road increases the probability that people regard their agricultural employment as non-seasonal. This could be because of lower probability of getting off-season employment.

Lastly, I estimate the probability of getting cash earnings given distance to a road in good condition. The results suggest that one unit increase in log distance to a good quality road decreases the probability of getting cash earnings by 5.6 percentage points. When I estimate average marginal effects separately for men and women, the effect on men is low and statistically insignificant. On the other hand, being close to good quality road seems very important for women - 1 log - or approximately 2.7 fold increase in distance to a good quality road - decreases the probability of getting cash earnings by 9.3 percentage points.

Overall, shorter distance to a good quality road seems to be decreasing agricultural employment, increasing skilled manual and seasonal employment, and seems to provide outside village job opportunities. Proximity to good quality roads is particularly important for women - living closer to roads in good condition increases their likelihood to be employed in the non-agricultural sector and obtain cash earnings for their work.

Table 2.5: Marginal effects of distance to roads in good condition on non-agricultural and skilled manual employment

	Non-agricultural employment			Skilled manual employment		
	(1)	(2)	(3)	(4)	(5)	(6)
	All	Women	Men	All	Women	Men
Logdist. good road	-0.057**	-0.058*	-0.062**	-0.051**	-0.027	-0.066**
	(0.024)	(0.033)	(0.029)	(0.021)	(0.029)	(0.029)
Age	0.022**	-0.003	0.036***	0.006	-0.001	0.019
	(0.010)	(0.013)	(0.013)	(0.009)	(0.008)	(0.015)
Gender (woman=1)	-0.177***			-0.198***		
	(0.019)			(0.018)		
Education in years	0.045***	0.062***	0.019***	-0.019***	-0.017***	-0.018***
	(0.005)	(0.007)	(0.007)	(0.004)	(0.005)	(0.007)
Number of children under 5	0.029*	-0.025	0.066***	0.004	0.020	-0.015
	(0.016)	(0.023)	(0.022)	(0.014)	(0.014)	(0.023)
Owns agricultural land	-0.171***	-0.216***	-0.093*	-0.016	0.008	-0.041
	(0.043)	(0.064)	(0.052)	(0.030)	(0.042)	(0.050)
Other individual controls	Yes	Yes	Yes	Yes	Yes	Yes
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,885	981	904	1,885	968	904

Geographical controls include: Distance to Marz center, Distance to Yerevan, Altitude, Slope, Population density, Nightlights composite, Aridity.

Additional individual and household controls include: Age squared, individual weights, HH wealth categories, family size.

Robust standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2.6: Marginal effects of distance to roads in good condition on seasonal employment and cash earnings

	Seasonal employment			Cash earnings		
	(1)	(2)	(3)	(4)	(5)	(6)
	All	Women	Men	All	Women	Men
Logdist. good road	-0.055**	0.010	-0.107***	-0.056**	-0.093***	-0.016
	(0.024)	(0.038)	(0.025)	(0.024)	(0.029)	(0.033)
Age	-0.035***	-0.032**	-0.034**	0.030***	-0.011	0.065***
	(0.010)	(0.015)	(0.013)	(0.010)	(0.013)	(0.014)
Gender (woman=1)	-0.063***			-0.245***		
	(0.020)			(0.020)		
Education in years	-0.034***	-0.038***	-0.024***	0.066***	0.073***	0.035***
	(0.005)	(0.007)	(0.006)	(0.005)	(0.008)	(0.007)
Number of children under 5	-0.032*	-0.019	-0.033	0.017	-0.042*	0.046**
	(0.017)	(0.025)	(0.022)	(0.017)	(0.022)	(0.024)
Owns agricultural land	0.015	-0.090	0.039	-0.171***	-0.239***	-0.083
	(0.040)	(0.063)	(0.050)	(0.044)	(0.059)	(0.056)
Other individual controls	Yes	Yes	Yes	Yes	Yes	Yes
Geographical controls	Yes	Yes	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,869	966	890	1,884	981	903

Geographical controls include: Distance to Marz center, Distance to Yerevan, Altitude, Slope, Population density, Nightlights composite, Aridity.

Additional individual and HH controls include: Age squared, individual weights, HH wealth categories, family size.

Robust standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

2.6.3 Robustness checks

Primary and secondary roads

Road quality might be related to the type of road, whether it is a major international road or a local road. Testing the distance to a primary road poses several challenges. First, no complete dataset exists on primary and secondary roads on Armenia. The latest complete dataset that could be obtained was from the Global Roads Inventory Project (GRIP), gathered, harmonized and integrated from almost 60 different geospatial datasets by the team of Meijer et al. (2018). However, the data on the South Caucasus, as well as other post-Soviet states, still remain incomplete. This could explain the high correlation (0.46) between primary roads from the GRIP dataset and historical roads from 1903, meaning that mostly old major roads might be captured in the GRIP dataset. This view is also supported by the low correlation between primary roads from the GRIP dataset and good quality roads (-0.02). The second problem is that, since the dataset has only a few roads, including them in the regression with the instrumental variable $LogDistRoads1903_s$ will result in multicollinearity. Multicollinearity might cause two basic problems: first, coefficient estimates become more sensitive to small change and might swing highly, and second, multicollinearity reduces the precision of the estimate coefficients, weakening statistical power. These problems are evident from the regression results once I integrate the incomplete roads dataset in the analysis: while coefficients keep the same sign, the coefficient value and statistical power fluctuate highly.

Location of mines

Location of historical roads might be influenced by factors other than geography and military strategies. For instance, roads could have been built in areas with greater economic potential. During the period that the historical map is depicting, the main non-agricultural sector with economic potential in Armenia was mining. Armenia has a long history of metal mining and is accounting a large part of the economy. According to the UN Comtrade, metals and ore concentrates accounted for more than half of Armenia's exports in 2017[19].

Copper mining first started in the Alaverdi area of Lori Marz in the 1770s. Later, it started in Kapan in Syunik Marz in the 1840s and by the mid-20th century the Kajaran copper-molybdenum mine in Syunik Marz had started production. The Kajaran mine is the largest operating mine in Armenia, accounting for 60% of the total mining turnover in the country (World Bank, 2016). Despite the historical importance of the mining sector in Armenia, it is unlikely that by the end of the 19th century primary road placement would have been influenced by mine locations. There are two main reasons to argue this. First, most of the historical mines were operated in the Lori (in north Armenia) and Syunik (in south Armenia) regions of the country. In both regions, as 2.5 shows, large mines are located very far from the historical routes. However, they are connected by railway lines. The only mine which seems to be on the primary historical road route is the Ararat

[19]UN Comtrade Database `https://comtrade.un.org/data/` (Reviewed: December, 2020).

mine. However, the operation of the Ararat mine had been relatively small until 1975. Additionally, it is not an active mine but rather a processing plant.[20]

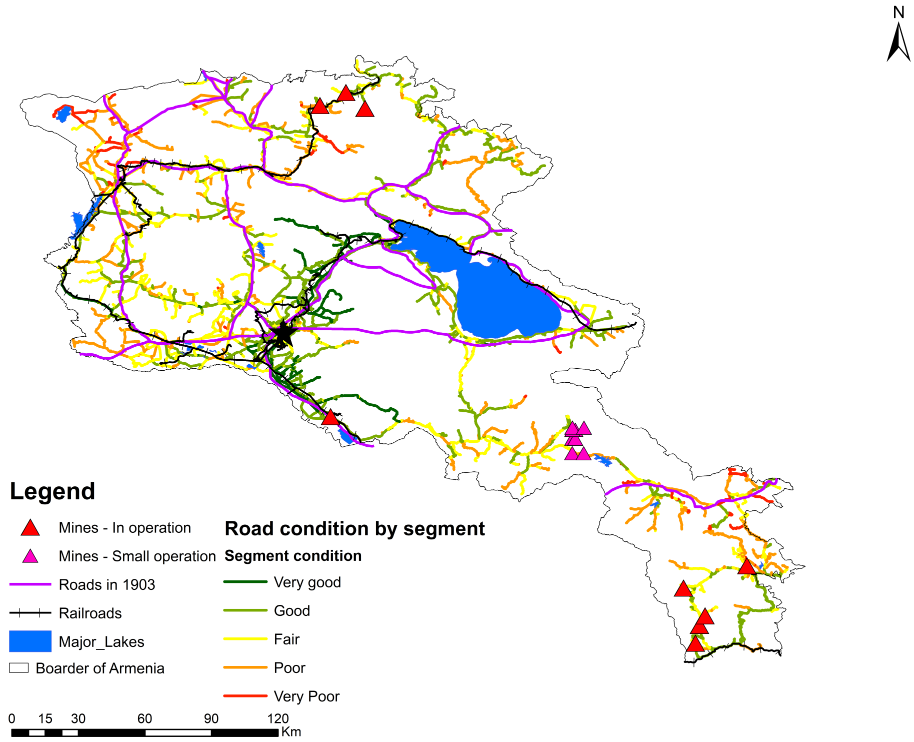

Figure 2.5: Mine locations in Armenia
Source: Author's compilation based on data on road quality from the World Bank, administrative data and mine location from the Acopian Center for the Environment, historical roads from Military-topographic map of the Caucasus, 1903 Archives of the Russian State Library.

[20]Source: State Committee of Real Estate Cadastre of Armenia.

2.7 Discussion and conclusion

Investing in improvement and maintenance of roads is widely believed to be vital for economic development. As a result, there is an increasing pressure of investing in road infrastructure, especially in low- and middle-income countries. There is growing literature, studying the link between road improvement, reduced transportation cost, and different economic outcomes. Nevertheless, there is a gap in identifying strong evidence on the linkage between road quality and economic outcomes. Moreover, evidence has been lacking on how road infrastructure quality affects the urban perimeter and impacts the employment of rural populations and affects structural transformation. This paper attempts to study these relationships.

In this analysis, I use two different sets of data and two different estimation methods to illustrate the link between road quality and rural employment. In the first method I use 10 years of repeated cross sectional Integrated Living Conditions Survey of individuals from 2007 to 2016, where respondents answer a set of questions about local infrastructure quality. In the second method I use Demographic and Health Survey from 2015-2016. Since DHS allows for approximate household location identification, I match the locations with a unique road quality dataset and use topographic control variables. In order to address the problem of endogeneity and reverse causation, I use the instrumental variable strategy based on historical military and postal routes of Armenia from the 1903 map, when Armenia was part of the Russian Empire.

The analysis with both datasets and methods shows that road quality is positively associated with non-agricultural employment in rural areas. Households living further from good quality roads are more likely to be employed in agriculture and less likely to be employed in seasonal employment. The DHS analysis shows negative association between distance to good quality roads and employment outcomes. People are 5.7 percentage points less likely to work in the non-agricultural sector and 5.1 percentage points less likely to be engaged in skilled manual employment with 1 log increase in distance (or approximately 2.7-fold increase in distance). Women are particularly affected on the type of pay they receive for work. The results show that 1 log increase in distance decreases the probability of getting cash earnings for work by 9.3 percentage points. These results are particularly interesting in the prism of women's empowerment, where financial independence is one of the key factors.

The results on seasonal employment are particularly interesting for their unexpected opposite sign. The analysis from both datasets shows a positive association of seasonal employment with better quality roads. The analysis on ILCS shows that people reporting poor road quality leading to towns and markets are 5.2 percentage points less likely to engage in seasonal work. The analysis on DHS shows 5.5 percentage points less likelihood of seasonal employment with one unit increase in log distance from good quality roads (approximately 2.7-fold increase). These results could be explained by the outcome that people living near improved roads are more likely to work outside the village. Better quality road infrastructure stimulates mobility and commuting through two main channels: increased productivity, and reduced job search and commuting costs. Therefore, people living closer to better roads might be more likely to find additional jobs during less active agricultural seasons.

The results are in line with the literature on agricultural productivity in terms of hours worked. Similar to McCullough (2017), this chapter finds that agricultural workers work fewer hours on average than non-agricultural workers - 16.5 hours less per week. The results are highly relevant to policy. People living further away from good quality roads tend to be underemployed (working fewer hours), and are less likely to work outside of village, and to find a seasonal job during inactive agricultural seasons. People who report average road quality in their region tend to work less hours in agricultural jobs than people living closer to good quality roads; however, respondents reporting poor quality roads work for more hours in agriculture. This result could be related to access to agricultural inputs and productivity. People with an access to average quality roads still have relatively adequate access to agricultural inputs, while poor quality roads hinder access to inputs, requiring more manual work.

While many low- and middle-income countries are investing heavily in new road construction projects, keeping local roads in good condition should also be their priority. The literature shows that having higher maintenance expenditure rather than new infrastructure investment can lead to a positive impact on output (Rioja, 2003*a*,*b*).

Access to better quality road infrastructure is positively associated with rural employment. The results are very policy relevant in the sense of structural transformation, providing non-agricultural jobs and new or additional work opportunities to people living in rural areas.

2.8 Appendix

Table 2.7: Summary statistics of variables used - ILCS Survey

Variable	Variable description	Obs.	Mean	Sd.	Min.	Max.
Outcome						
nagr	Dummy: respondent is employed in non-agricultural employment	49,442	0.28	0.45	0	1
season	Dummy: respondent is employed in seasonal employment	49,442	0.27	0.44	0	1
outjobdum	Dummy: household member works outside village	46,661	0.14	0.34	0	1
hours	Hours worked during previous week	49,209	28.42	16.45	0	168
Controls						
rqreg	Road quality categories: 1 - good, 2 - average, 3 - poor	49,442	1.93	0.68	1	3
sex	Gender of a respondent	49,442	0.51	0.50	0	1
hhhead	Dummy: respondent is a household head	49,442	0.30	0.46	0	1
age	Respondent's age	49,442	44.00	14.08	16	85
agesq	Age squared	49,442	2134	1272	256	7225
marstatus	Marital status of a respondent	49,442	1.35	0.73	1	5
edu	Highest education achieved by a respondent	49,442	3.32	0.51	1	4
members	Number of family members	49,442	4.94	1.82	1	16
fammigrwork	Dummy: household member is working abroad	49,442	0.17	0.38	0	1
childcount	Number of children in the family (under the age of 16)	49,442	1.03	1.12	0	7
eldercount	Number of elderly people age 65 and higher in the family	49,442	0.47	0.69	0	4
market	Distance to the nearest market	37,250	16.28	12.32	0.01	100
kinder	Distance to the nearest kindergarten	37,269	4.46	7.04	0	52
healthc	Distance to the nearest health center	37,272	1.10	5.07	0.002	500

Table 2.8: Summary statistics of variables used - DHS Survey

Variable	Variable description	Obs.	Mean	Sd.	Min.	Max.
Outcome						
nagr	Dummy: respondent works in the non-agricultural sector	1,885	0.64	0.48	0	1
smanual	Dummy: respondent has skilled manual employment	1,885	0.18	0.38	0	1
season	Dummy: respondent works seasonally	1,869	0.34	0.47	0	1
cash	Dummy: respondent has cash earnings	1,884	0.57	0.50	0	1
Treatment						
DistGR	Distance to the nearest good/very good quality road	1,885	2.03	2.11	0.00	13.28
IV						
DistRoad1903	Distance to the nearest 1903 year primary road	1,885	8.31	10.82	0.08	59.01
Controls						
age	Respondent's age	1,885	34.89	8.46	16	49
agesq	Age squared	1,885	1289	591	256	2401
edu	Respondent's years of education	1,885	10.95	2.29	0	20
gender	Dummy: Gender of a respondent	1,885	0.52	0.50	0	1
weights	Individual survey weights (in thsd.)	1,885	992	33	262	1998
wealth	Wealth index categories	1,885	1.98	1.00	1	5
familysize	Number of family members	1,885	4.90	1.66	1	11
child5	Number of children in the family of 5 years old and below	1,885	0.40	0.70	0	4
agland	Dummy: household holds an agricultural land	1,885	0.92	0.27	0	1
dist_marz	Distance to the regional (Marz) center	1,885	18.30	12.19	0.99	63.63
dist_yerevan	Distance to the capital city	1,885	58.66	43.12	6.85	209.15
ALT_DEM	Elevation of a settlement	1,885	1320	461	594	2331
slope	Slope of a settlement	1,885	3.41	2.70	0.10	12.40
pop_dens	Population density	1,885	234	454	23	2522
nightlight	Night-time light composite over the settlement	1,885	0.60	1.21	0	5.81
aridity	Aridity of land (measured in 2015)	1,885	18.56	4.65	11.23	29.38

Note: *DistGR*, *DistRoad*1903, *Dist_marz*, and *dist_yerevan* are calculated in ArcGIS using NEAR function, and are used in log form in estimations.

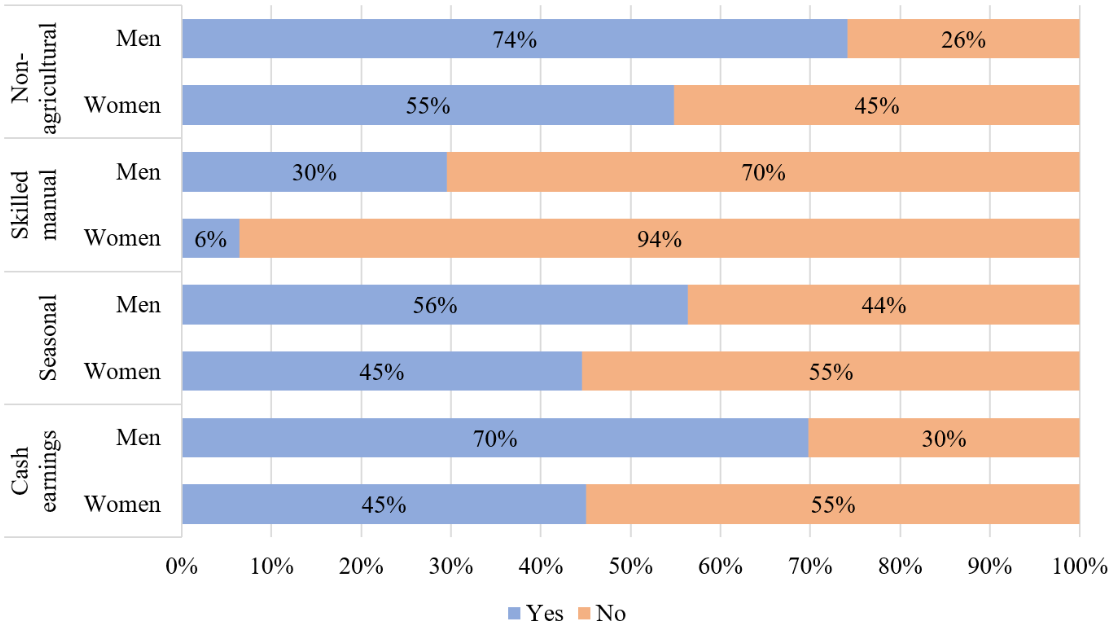

Figure 2.6: Rural employment indicators by Gender (DHS)

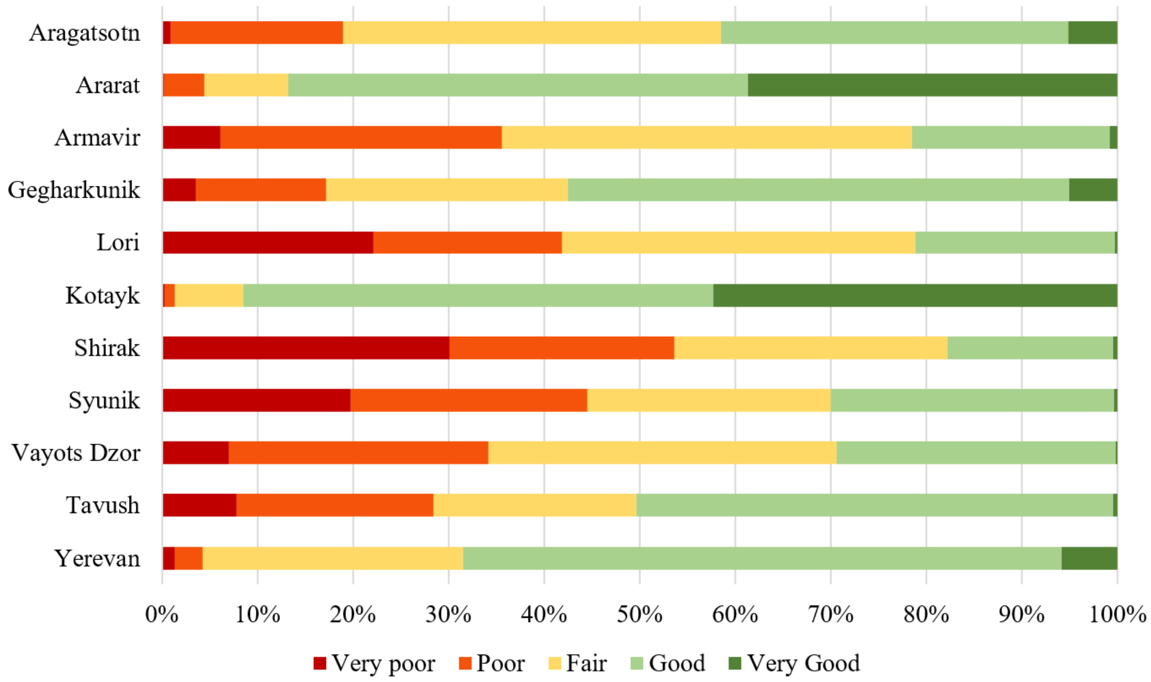

Figure 2.7:
Distribution of road network quality by region (Marz).
Calculated based on the WB RoadLabPro data on road quality.

Figure 2.8: Military-topographic map of the Caucasus, 1903
Source: Archives of the Russian State Library. (Map reprinted in 1914.)

Chapter 3

Linkages of road infrastructure: impact of rehabilitated roads on access to utility services - evidence from Georgia

3.1 Introduction

Access to utility services is one of the key components of the UN's 2015 Sustainable Development Goals (SDGs). Access to clean water, sanitation, waste management, as well as affordable energy and utilities for an effective learning environment constitute a large part of the sustainable development goals and might play a crucial part to end poverty and inequality in the coming decades. Utility services play an important role. Access to energy, water, waste disposal, and the Internet shows improvement of health outcomes and educational attainment and improvement of employment outcomes (Bell and van Dillen, 2014; Prüss-Ustün et al., 2014; Zhang, 2012). However, low- and middle-income countries still struggle to provide households with adequate utility services.

This problem is usually particularly severe in rural settlements. Cost and accessibility are the two main reasons why governments and private companies fail to provide rural households with utility services. Since rural settlements are usually more sparsely inhabited than urban areas, it is more costly per household to provide them with water, gas, or other utility services. Accessibility is also a problem; rural settlements are often in more remote areas or are only accessible by poor quality roads. This burden is especially problematic for building proper infrastructure of utilities, such as water and gas pipes since it requires settlements to be accessible by transportation. Providing waste disposal services also requires passable roads to collect garbage from rural settlements. Therefore good quality roads might play a crucial role in providing rural settlements with these services.

Large-scale infrastructure construction or rehabilitation projects improve connectivity between urban areas as well as between urban and peripheral settlements along the road. This case is especially common in low- and middle-income countries where spatial disparities are particularly visible (Kanbur and Venables, 2005). Improved roads improve travel time, reduce travel cost, and intensify the trade and mobility of goods and services (Faber, 2014; Andrabi and Kuehlwein, 2010; Donaldson, 2018; van de Walle, 2009). Considering these reasons, road infrastructure projects have been under a major spotlight in recent decades from governments and international organizations. Construction and rehabilitation of transportation networks constitute a major part of public spending, especially in low- and middle-income countries. The acceleration of spending on public infrastructure in low- and middle-income countries has drastically increased the stock of infrastructure during the last 15 years; and the trend is increasing (Gurara et al., 2017).

Improved accessibility has shown to improve various economic or social outcomes; however, its linkage with providing access to other infrastructure services, up to my knowledge, has not been studied. Does improved connectivity through rehabilitated roads improve households' accessibility to utility services? Despite the policy importance of this question, our existing empirical knowledge is limited. The growing body of empirical literature on impacts of road construction and rehabilitation projects so far has paid little attention on its effects on utility services. The policy question on how peripheral settlements in middle-income countries are affected when they have better connection to major roads, is not well studied either.

This chapter studies large-scale road rehabilitation projects in Georgia to contribute to our understanding in these questions. This chapter builds on Hirschman's proposed forward linkages (Hirschman, 1958, 1977) and Cristaller's Central Place Theory (Christaller and Baskin, 1966), and hypothesizes that improved roads reduce access barriers and decrease travel time to settlements, therefore making it easier for necessary machinery or transport providing services to access the settlements better.

The large-scale road rehabilitation projects covered in this chapter were implemented between 2006-2015. One of the major purposes of these road rehabilitation works was to improve connectivity between district (municipal) centers in the country. The projects were co-funded by the central government and different international organizations, such as the World Bank, Asian Development Bank (ADB), European Investment Bank (EIB), and Millennium Challenge Corporation (MCC), among others.

The analysis builds on the identification strategy pioneered by Faber (2014) to account for non-random placement of improved roads. Even though the non-nodal settlements (settlements which are not district centers)[1] were not necessarily specifically targeted by the rehabilitation projects, to assume that the rehabilitated routes were randomly chosen would still be a strong assumption. To address these concerns, I use an instrumental variable strategy based on the least cost path spanning tree network. Building the instru-

[1]Nodal settlements refer to district centers (which were specifically targeted by the road construction/rehabilitation projects), while non-nodal settlements refer to the settlements in-between the district centers (which were not necessarily targeted by the projects).

mental variable consists of two steps. First, I use remote sensing data on elevation, water cover and built-up areas to build a cost surface raster. Second, after creating the least cost raster, I apply Dijkstra's and Kruskal's algorithms to get the least cost path spanning tree network. Basically, considering the topographic and geographical characteristics and built-up areas, I calculate what the "least-cost" or easiest route to construct roads connecting the nodal towns would be.

The baseline identifying assumption is that the location of the non-nodal settlements along the least cost spanning tree network affects the accessibility to utility services only through the improved connection from the rehabilitated roads, conditional on regional fixed effects, distance to the nearest district center and other settlement and household control variables.

The results show that households closer to the rehabilitated roads have better access and use more utility services. The probability of having access to one of the utility services decreases from 2 to 10 percentage points by 1 log or 2.7-fold increase in distance from the nearest rehabilitated road. In addition, households closer to the rehabilitated roads are 33 percentage points more likely to have access to non-basic utility services.

The research contributes to the growing literature on estimating the effects of road infrastructure improvements. Improved transport infrastructure has shown to decrease trade costs and inter-regional price gaps (Donaldson, 2018; Faber, 2014; Casaburi et al., 2013; Andrabi and Kuehlwein, 2010), and contribute to local market development (Mu and van de Walle, 2011). In terms of household welfare, road infrastructure improvements have shown to increase wage labor market participation (Asher and Novosad, 2016), increase the variety of goods in the household consumption basket (Aggarwal, 2018), have shown consumption growth (Dercon et al., 2009; Gonzalez-Navarro and Quintana-Domeque, 2015), and reduced poverty rate (Warr, 2010; Dercon et al., 2009; Fan et al., 2000). The literature shows that roads also play a positive role in growth of economic activities: increase in non-agricultural small and medium sized enterprises (Lokshin and Yemtsov, 2005), facilitating high skilled teamwork (Dong et al., 2018), increase outcomes of (manufacturing) firms (Datta, 2012; Ghani et al., 2016; Chandra and Thompson, 2000; Zhang and Fan, 2004), and contribute to spatial spillover of economic development (Khanna, 2016). The impacts are also apparent on the urbanization and sub-urbanization of cities (Hornung, 2015), and have shown to cause decentralization and reduction of population in cities (Baum-Snow et al., 2017; Baum-Snow, 2007), as well as showing very small or no economic gains (Banerjee et al., 2012).

The chapter also contributes to the limited academic research on impacts of road infrastructure projects in Georgia. Lokshin and Yemtsov (2005) studied impacts of projects on road, schools, and water supply systems - implemented between 1998 and 2001 in rural Georgia. Using a propensity score matching difference-in-difference estimation method, the paper finds that road improvements led to an increase in small and medium-size enterprises, and decreased barter trade. Another group of literature has studied economy-wide and trade effects of East-West Highway project in Georgia. Demir and Monsalve (2016) predict that an increase in upgraded highway length would increase exports transported by road. ISET Policy Institute (2015) predicts that the East-West Highway would contribute in medium- and long-term overall GDP growth of the country, and increase household welfare. The paper reports higher expected gains for rural households than urban ones, but lower growth of households in the lowest two quantiles of income distribution.

Up to my knowledge, there is a gap in the literature on how improved road infrastructure contributes to improving other types of infrastructure, namely access to utility services. Studying this research question is interesting for several reasons. First, it is policy relevant: there is an increasing trend of large-scale infrastructure projects in low- and middle-income countries. It is necessary to know how these road rehabilitation projects support further infrastructure development. Second, improved accessibility has synergies with achieving other SDGs as well, such as healthcare and education. Third, this chapter studies the collection of all types of road rehabilitation works. While other papers study either highways or secondary roads, this research combines construction and rehabilitation of all types of international and national roads.

The rest of the chapter is organized as follows. Section 2 looks at the research setting and reviews the road rehabilitation projects used in this chapter. Section 3 reviews theoretical and empirical framework, proposing reduced form regression using instrumental variable strategy. Section 4 describes the data and data sources used for the research. Section 5 shows the results of the empirical analysis. Section 6 concludes.

3.2 Research setting

Poor road infrastructure is widely believed to limit access to economic opportunities. Therefore, governments try to direct funds to building and improving infrastructure. This is particularly apparent in low- and middle-income countries which quite often lack good quality road infrastructure. Most of the post-Soviet countries had been characterized with relatively good road infrastructure. Accessibility was not a major problem in Georgia either. However, since the collapse of the Soviet Union, a massive drop in economic output left infrastructure in a very deteriorated condition. This was particularly apparent in Georgia, which enjoyed a relatively high standard of living compared to its neighboring countries during the Soviet Union and had the highest drop in the economic output among all post-Soviet countries in the 1990s (World Bank, 2003).

Georgia is a low-middle income country (GDP per capita USD 4,084 in 2016 (constant 2010 US$)). Its population is 3.7 million people[2], with 43% of labor the force employed in agriculture.[3] Since the mid-2000s, the Georgian government has been heavily investing in improvement of deteriorated infrastructure and building new ones. Most of the funding comes from loans from multilateral development banks (MDBs).

[2]Census 2014, excluding population in the conflicted territories of Abkhazia and South Ossetia.
[3]National Statistics Office of Georgia, Distribution of employed by economic activity, 2017.

According to the 2014 Government Decree, the Georgian road network consists of 13 international road routes - a total of 1,603 kilometers, and 202 national road routes - a total of 5,298 kilometers - (Government of Georgia, 2014). The international and national roads are generally considered as major roads, with international roads connecting Georgian cities to the neighboring countries. National roads connect various Georgian towns and municipal centers to each other. In 2006, 70% of the international roads were in fair to good condition and more than 60% of the national roads were in poor condition. The budget of the Road Fund was enough for only about the one third of necessary road maintenance (World Bank, 2013). During this time, the Government of Georgia actively started attracting funding from MDBs to finance rehabilitation of the deteriorated infrastructure.

This chapter is studying the impacts of large-scale road infrastructure projects which were implemented during 2006-2015, namely, the East-West Highway (World Bank, ADB, EIB), Secondary and Local Roads Project (World Bank), Samtskhe-Javakheti Rural Roads Rehabilitation Project (Millennium Challenge Corporation).[4] The East-West Highway and part of the Secondary and Local Roads Project are still ongoing. This chapter takes only the parts of the rehabilitated and constructed roads into account, which were finished by the end of the year 2015.

3.2.1 Road rehabilitation projects

The government of Georgia has been involved in road rehabilitation projects through two main institutions, the Road Department (RD), and the Municipal Development Fund of Georgia (MDF), both under the Ministry of Regional Development and Infrastructure (MRDI). The Roads Department has been generally administering major road construction and rehabilitation projects, while MDF has been responsible for secondary (national) and local roads, with some exceptions.

The main purpose of the projects has been to improve connectivity between different district (municipal) centers to each other, and upgrade infrastructure to stimulate both connectivity and trade between regions and with neighboring countries.

East-West Highway

The main highway project in Georgia, the East-West Highway Project (E-60 and E-70 highways), brings together the east and the west of the country. The East-West Highway is considered by the Georgian government as a central piece in transforming Georgia into a logistics and transportation hub for trade between Asia and Europe. The highway is a part of the E-60 European route, running from Brest, France (the Atlantic coast), to Irkeshtam, Kyrgyzstan (the border with China). The project implementation period is 2006-2022 and the planned total length of the highway is around 400 kilometers. By

[4]The main purpose of the projects studied in this chapter was to rehabilitate already existing roads or construct the new ones (including, bridges and under-road canal pipes).

the end of the year 2016, Georgia had constructed or reconstructed about one third, or around 130 kilometers of road. The project is co-funded by the government of Georgia, the World Bank, Asian Development Bank and the European Investment Bank (ISET Policy Institute, 2015).

Secondary and Local Roads Project (SLRP)

The World Bank funded Secondary and Local Roads Project (SLRP) has been rolled out in several phases. The first phase was signed in 2004, finalizing the first rehabilitated road in 2006. In total, around 250 kilometers of roads had been rehabilitated. After successful completion of the first phase Phase 1 (SLRP I), in 2009 additional financing was approved. The goal of this financing was to rehabilitate an additional 450 kilometers of roads, which in the end increased to around 590 kilometers. In 2012, second phase of the program (SLRP II) was approved to rehabilitate another 250 kilometers, followed by the third phase of funding (SLRP III) in 2014 to rehabilitate an additional 147 kilometers. According to the data from the Roads Department of Georgia, in total around 1130 kilometers of roads had been rehabilitated under the World Bank SLRP projects by the end of 2015.

Samtskhe-Javakheti Rural Roads Rehabilitation Project

The Samtskhe-Javakheti Rural Roads Rehabilitation Project (RRRP) was a five-year project funded by the Millennium Challenge Corporation (MCC). The main goal of the project was to rehabilitate 220 kilometers of major roads in the Samtskhe-Javakheti region of Georgia. The construction started in 2006 and finished in 2010. In total 68.5 kilometers of international roads (near borders with Turkey and Armenia) and 151 kilometers of national roads were rehabilitated (NORC, University of Chicago, 2013).

Kakheti Regional Development Project

The Kakheti Regional Development Project is part of the World Bank funded Regional Development Project. One of the main goals of the project was to improve the connectivity of Kakheti region by rehabilitating roads and improving infrastructure in touristic areas of the region. By the end of 2015, around 72 kilometers of roads had been rehabilitated.

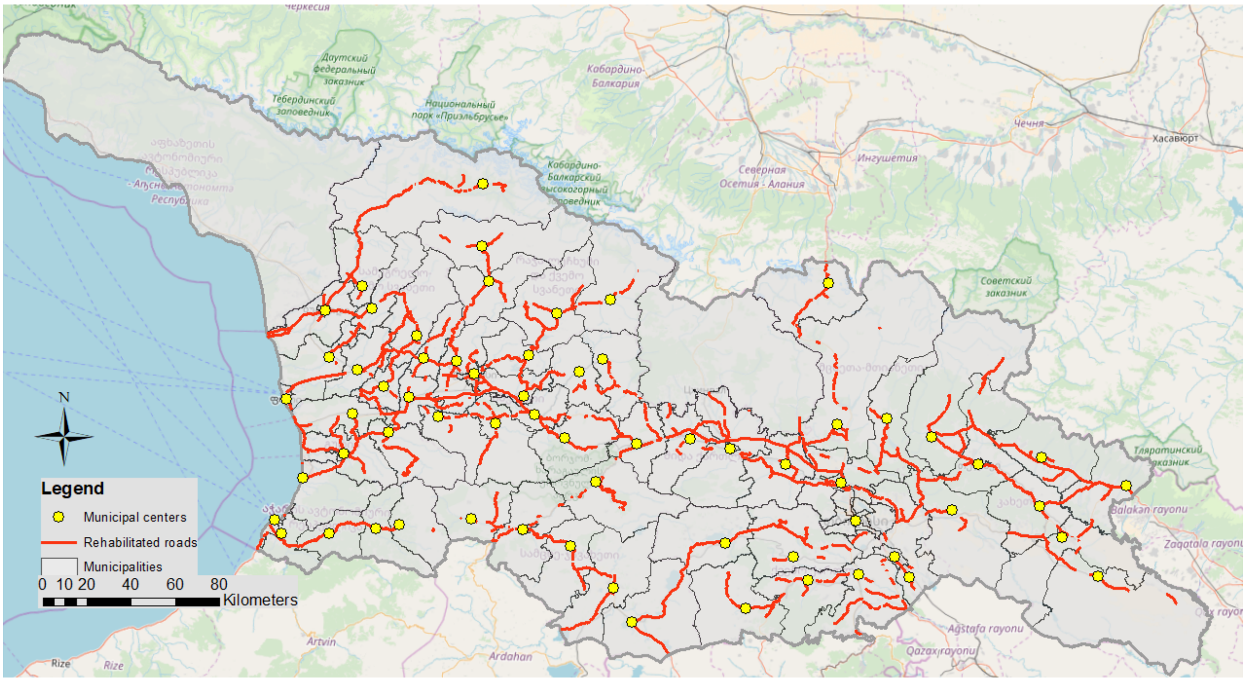

Figure 3.1: Rehabilitated major roads in Georgia in 2006-2015 (digitized and mapped in ArcGIS by the author)

3.3 Methodology

3.3.1 Theoretical framework

Spatial economic theory highlights the importance of transportation costs in spatial access to markets and service since Johann Heinrich von Thünen's land rent model in "The Isolated State" (Von Thünen, 1826). The impact of accessibility and transportation infrastructure on economic performance has been heavily studied ever since (Fogel, 1962; Hirschman, 1958, 1977; Krugman, 1991, 1999*a*; Fujita and Krugman, 2004).

Hirschman (1958) highlighted three types of linkages of infrastructural projects. Transport infrastructure, as social overhead capital - has forward, backward and latent linkages. Forward linkages - promoting industries in need of roads and railways, backward linkages - promoting industries which supply materials for railway and road constructions, and lateral linkages - connecting industries together. This chapter builds on Hirschman's linkages of transportation infrastructure. Namely, hypothesizing the importance of roads in linking urban and rural settlements and providing them with additional infrastructure.

Connectivity between smaller settlements and urban centers also interested geographers. Walter Christaller developed the Central Place Theory in 1933 (Christaller, 1933; Christaller and Baskin, 1966) after he observed the distribution patterns, number of towns and cities and their sizes. In the flat landscape of southern Germany Christaller noticed that towns of a certain size were roughly equidistant and central places were for people to gather and share goods and ideas. In other words, the Central Place Theory attempts to explain the functional and spatial distribution of settlements and their inter-linkages. The theory recognizes the importance of services as central functions as the driving force of emergence of service provider central places and the importance of accessibility to these centers. The Central Place Theory has three main elements: urban centers, their hexagonal market areas and transportation networks. Transportation networks are important for accessibility to central places. In the end, a hierarchy of central functions emerges, which underlines and explains the hierarchy of service centers (central places). There are different orders of service centers, with central ones providing most services.

Wanmali and Islam (1995) built on Christaller's Central Place Theory to explain rural infrastructure and rural services in India. Hard infrastructure investments, according to the paper, also facilitate the growth of "soft infrastructure", particularly the ones relevant to transportation. Over time, the services also become accessible to smaller settlements through diffusion. Related to Christaller's hierarchy of central places, with improved transportation network, nearby settlements also get access to services.

This chapter extends on the hypothesis of Wanmali and Islam (1995) on linkages of hard and soft infrastructure and builds on Christaller's Central Place Theory (Christaller, 1933; Christaller and Baskin, 1966) and Hirschman's linkages. Following the Central Place Theory, the chapter argues that nodes or central places have crucial roles in the development of peripheral areas and in linking services between urban to rural areas using improved mobility.

3.3.2 Empirical framework

The first question studied in this chapter is about measuring the impact of rehabilitated infrastructure on access to utility services, namely - to water, gas, waste disposal and the Internet. Given distance to rehabilitated roads, what is the probability of households having access to each of these utility services? First, the paper uses the Probit estimation method to see the likelihood of access to each of the utility services. Then it analyzes how many utility services does a household has access to, depending on the distance to improved roads. Lastly, because of possible inter-linkages, these five types of utility services are aggregated into one variable and analyzed using Poisson regression.

$$Pr(Y_i = 1|x_{ist}) = \Phi(\alpha_1 + \beta_1 DistRR_{st} + \tau_1 S_{st} + \delta_1 H_{ist} + \mu_1 R_{is} + year_{ist} + \varepsilon_{ist}) \quad (3.3.1)$$

where, $Pr(Y_i = 1|x_{ist})$ is the probability function of observing $Y_i = 1$, probability of having access each of the utility services, given all sets of observable variables x_{ist}. $DistRR_{st}$ is log distance to rehabilitated roads, H_{ist} is a vector of household level characteristics, S_s is a vector of settlement level characteristics, R_{is} - region fixed effects and $year_{ist}$ - year fixed effects.

The utility services might have inter-dependences. Therefore, it is also necessary to observe the effects on an aggregated level. I sum up all four utility services, each of them with the weight equal to one. This method might have some caveats, since, for example, access to water might not be valued by the households in the same way as for example, access to the Internet. However, since data on household preferences is not available, I cannot assign other than equal weights.

At this stage, because the dependent variable is a count variable, a Poisson regression setup is used for the estimation. The reduced form regression is the following:

$$Utilserv_{ist} = \alpha_2 + \beta_2 DistRR_s + \tau_2 S_{st} + \delta_2 H_{ist} + \mu_2 R_{is} + year_{ist} + \epsilon_{ist} \tag{3.3.2}$$

Where $Utilserv_{ist}$ denotes number of accessed utility services by household i living in settlement s in time t.

The next research question is about accessibility to non-basic utility services. I differentiate access to water as basic service, and access to gas, waste disposal and the Internet as non-basic services. The question studied is on measuring the probability of households accessing at least one of the non-basic infrastructure given the distance to the nearest rehabilitated road. The dependent variable is binary: whether household has access to at least one of the non-basic utility services. Therefore, the reduced form equation uses Probit regression setup, similar to equation (3.1).

Constructing Instrumental Variables

Initial conditions are likely to determine the project placement, which might also influence the outcomes (Banerjee et al., 2012; Datta, 2012). In addition, road construction projects might be mis-targeted because of political and bureaucratic capture of goods.[5] An ideal setup of project implementation for impact evaluation would involve random allocation of road improvement projects. However, random placement of roads on a large scale is usually impossible due to its feasibility and investment intensive nature.[6] Non-random placement of roads makes it difficult to study causal effects of road rehabilitation projects. To address this problem, different quasi-experimental methods are employed. This paper addresses the endogeneity problem with an instrumental variable (IV) strategy, building on two instrumental variables, a straight line variable (Banerjee et al., 2012) and a least-cost path spanning tree network instrumental variable (Faber, 2014). Considering the setting - that one of the main purposes of the road rehabilitation projects

[5] For instance, Burgess et al. (2015) and Nguyen et al. (2011) show nepotism and ethnic favoritism in public construction projects, respectively in Kenya and Vietnam.

[6] There is the growing literature on evaluating the impacts of random placement of infrastructural works. However, these projects are usually on a relatively small scale and directed to urban poor areas. For instance, the Habitat program randomly allocated infrastructure improvement projects (including road rehabilitation) in low-income urban neighborhoods of Mexico, evaluated by McIntosh et al. (2018). Gonzalez-Navarro and Quintana-Domeque (2015) also document random allocation of first-time street asphalting of residential streets in Mexico.

was to connect district (municipal) centers to each other - we can construct hypothetical connectors between these centers. The idea is to get a hypothetical exogenous variable of the shortest distances between the central cities. I follow the identification strategies proposed by Faber (2014) and Banerjee et al. (2012) and build straight a line as well as "least cost" paths between the district centers.

Straight line - Euclidean line connector IV

Euclidean line connectors or straight lines are connecting different points to each other by straight lines. The idea is to get the shortest distance possible between two nodal towns. In other words, what would be the shortest road to connect two towns to each other, disregarding any geographical, political or economic characteristics. Banerjee et al. (2012) were the first ones to propose straight lines as proxies to predict the existence of transportation networks. They used this method to estimate the impact of transport infrastructure on economic performance in Chinese counties. The straight line instrument was quickly adopted by different studies for measuring various impacts of transport infrastructure (Atack et al., 2010; Faber, 2014; Khanna, 2014; Ghani et al., 2016).

There are 64 district centers in the country in total. The straight line paths are built according to the rehabilitated routes, forming a total of 92 sections. From Figure 3.2, it is evident that the lines quite often do not correspond to the actual roads. One of the main explanations for this would be the geographical heterogeneity of the country. In this case, the paths which account for the geographic conditions would be better proxies of the roads.

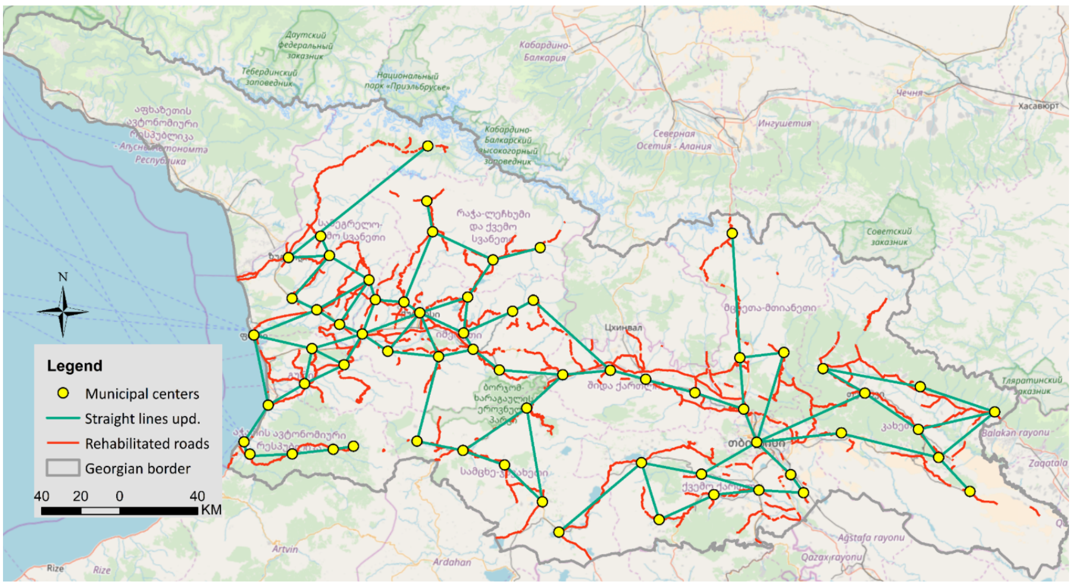

Figure 3.2: Straight line instrumental variable

Least-cost Path IV

Euclidean line connectors are exogenous, however, they do not take geographic characteristics into account and might not be good proxies for roads in geographically heterogeneous regions. Therefore, in addition to the straight-line instrument, Faber (2014) suggested a spatial instrument based on the least-cost path of connectivity. To construct the least-cost path instrument, it is necessary to use remote sensing data on land cover and elevation, the optimal route algorithm and the minimum spanning tree algorithm from infrastructure engineering. The main idea of the suggested instrument is to find the shortest path between two points by accounting for geographic characteristics.

I constructed hypothetical connectors between the district centers. If the sole reason of the setup of the road rehabilitation projects had been to connect the district centers to each other, the route rehabilitated between them would have been the shortest and the "least-cost" route.

Constructing a hypothetical least cost path spanning tree network consists of two steps:

- Step 1: Creating a cost surface raster.
  - Reclassifying remote sensing data on elevation, built-up areas and water cover.
  - Applying a cost function for pixel i (Jha et al., 2001)

$$c_i = 1 + Slope_i + 25 * Builtup_i + 25 * Water_i \tag{3.3.3}$$

where, c_i is the cost of crossing a land pixel i, $Slope_i$ is an average slope gradient of pixel i, $Builtup_i$ and $Water_i$ are dummies, indicating whether the pixel is covered by a built-up construction or water, respectively.[7] This cost function implies that flatter and shorter routes are less costly, while high cost is assigned to areas with water cover, built-up constructions, and higher slope (Figure 3.3).[8]

- Step 2: Applying Dijkstra's optimal route algorithm (Dijkstra, 1959), and Kruskal's minimum spanning tree algorithm (Kruskal, 1956).

Dijkstra's algorithm identifies the least cost path between these 64 district centers and every center of the grid covering the whole country. In total, 2,016 path are calculated (64*63/2). From these paths, Kruskal's algorithm is applied to calculate the least cost tree network.

[7]The cost function usually also contains wetlands. However, because wetlands are almost non-present in Georgia, I did not include it in the function.

[8]Factor of 25 is used in the cost function because it is generally considered that construction of bridges cost on average 25 times more than a regular road.

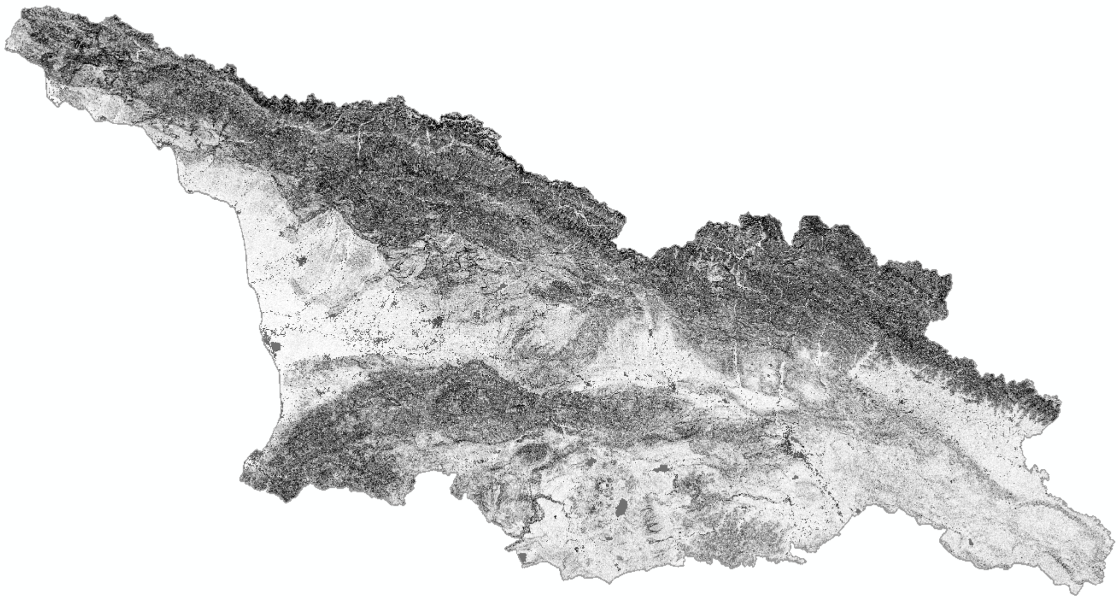

Figure 3.3: The figure depicts the construction of cost surface raster using the remote sensing data and pixel cost function. The cost assignment is based on the slope gradient, water cover and construction cover of each pixel. The color scale ranges from white to black, from very low to very high cost of crossing a pixel of land (for instance, the Caucasus mountains are in darker colors, as well as water bodies and urban centers).

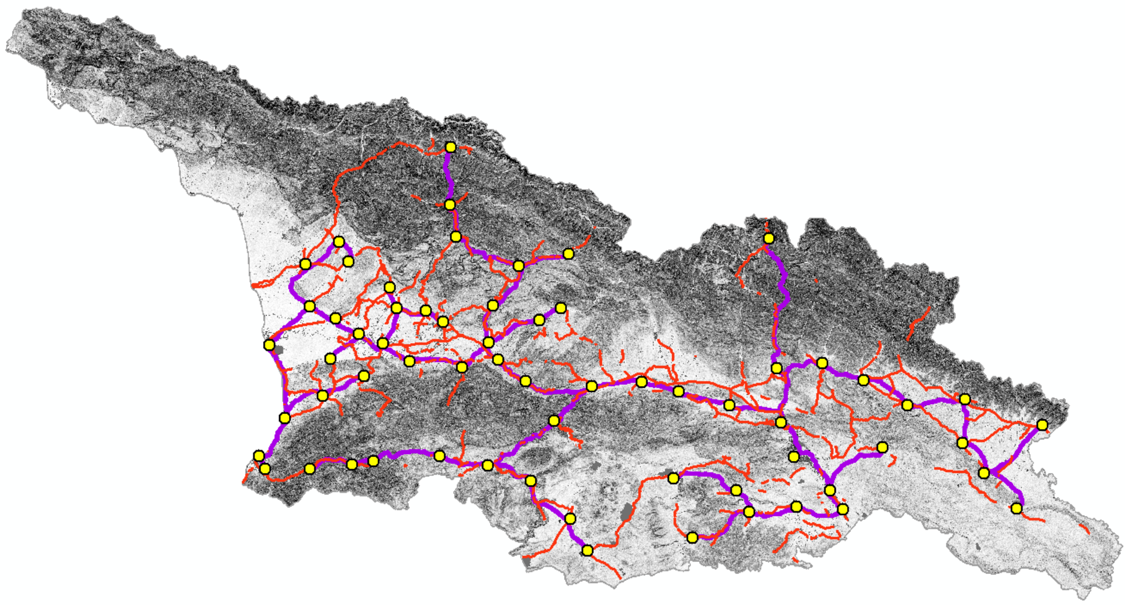

Figure 3.4: Cost raster with least cost path spanning tree network. The rehabilitated roads (red) and the cost tree network (purple).

The least cost spanning tree network is an illustration of what would have been the least cost path to construct and rehabilitate the major roads, considering that all district centers needed to be connected. Compared to the straight line paths, Figure 3.4 shows that some of the networks paths follow similar routes to existing roads, accounting for geographic conditions.

Considering the instrumental variable strategy, two-stage regressions are proposed. The instrumental variable (z_i) is assumed to be correlated with the endogenous variable $DistRR_s$, but independent from the error ε_{ist}. In the first stage, the endogenous variable is a function of the IVs and other control variables.

$$DistRR_s = \alpha_3 + \gamma_3 DistStraightLine_s + \tau_3 S_{st} + \delta_3 H_{ist} + \mu_3 R_{is} + year_{ist} + \epsilon_{ist} \quad (3.3.4)$$

$$DistRR_s = \alpha_4 + \gamma_4 DistLeastCost_s + \tau_4 S_{st} + \delta_4 H_{ist} + \mu_4 R_{is} + year_{ist} + \varepsilon_{ist} \quad (3.3.5)$$

For the Probit regression an IV Probit estimation strategy is proposed, instrumenting the distance to the nearest rehabilitated road.

$$Pr(Y_i = 1|x_{ist}) = \Phi(\alpha_5 + \beta_5 \widehat{DistR}R_s + \tau_5 S_{st} + \delta_5 H_{ist} + \mu_5 R_{is} + year_{ist} + \upsilon_{ist}) \quad (3.3.6)$$

$$Utilserv_{ist} = \alpha_6 + \beta_6 \widehat{DistR}R_s + \tau_6 S_{st} + \delta_6 H_{ist} + \mu_6 R_{is} + year_{ist} + \xi ist \quad (3.3.7)$$

For the Poisson regression in Equation (3.7), a GMM estimator for additive model is used. The GMM estimator uses the additional variable (IV) to specify the moment condition that holds in population. The sample-moment conditions for GMM estimation are formed by replacing the expectation with the corresponding sample mean.

3.4 Data

3.4.1 Data on Roads and GIS data

Data on road rehabilitation works from 2006-2015 were provided as tables by the Roads Department and Municipal Development Fund of Georgia (MDF), both entities under the Ministry of Regional Development and Infrastructure (MRDI). I digitized the list and identified work done on each road section. Finally, mapped each section of each road rehabilitation work in ArcGIS using Route Event features. The final map is shown on Figure 3.1.

Geo-referenced data on the administrative border of Georgia, regional and district (municipal) borders, as well as locations of the district centers and all existing settlements in the country were provided by the National Statistics Office of Georgia (Geostat).

Part of geo-referenced major routes database was obtained from ArcGIS Online and complemented using the governmental document on the official list of major roads in Georgia (Decree 407, Government of Georgia (2014)).

Remote sensing data on slope and elevation was collected from the ASTER Global Digital Elevation Model V002 (provided jointly by the United States National Aeronautics and Space Administration (NASA) and the Ministry of Economy, Trade, and Industry (METI) of Japan). The data have 30m resolution.

The built-up grid used in this paper is derived from Landsat image collections using the Global Human Settlement Layer (GHSL) methodology. The layer is produced by the Joint Research Centre (JRC) from the European Commission. The data used to construct the least cost raster has 38m of resolution - Spherical Mercator (EPSG:3857) from Landsat GLS2000 from year 2000.[9]

Water cover data were collected from two sources: the U.S. Geological Survey (USGS) and OpenStreetMaps. The Global Surface Water layer provided by the USGS is a classification of persistent surface water bodies during the 2000 to 2012 interval at a 30m spatial resolution derived from Landsat scene. To ensure the continuity of rivers, vector data on major rivers was extracted from OpenStreetMaps.[10] This dataset was rasterized, reclassified, and combined with the Global Surface Water layer.

3.4.2 Surveys

Welfare Monitoring Survey

The Welfare Monitoring Survey is a longitudinal biennial survey conducted by the United Nations Children's Fund (UNICEF) Georgia. The paper covers the first four rounds of the survey (2009, 2011, 2013, 2015). The survey investigates the multi-dimensional wellbeing of the population and households in Georgia. The questions are related to household living conditions, assets, income and expenditure, and access to services. The survey has a particular focus on children (e.g., consumption poverty, school attendance, and material deprivations), as well as social transfers and their impacts on poverty.

The primary survey target sample consisted of households that participated in the Household Integrated Survey in 2008, conducted by the National Statistics office of Georgia (Geostat). The Household Integrated Survey used two-stage clustering with stratification by region, settlement size and mountain or lowland location (UNICEF Georgia, University of York, 2010).

The survey was conducted in 9 regions of Georgia and the capital city Tbilisi. In total, 76 municipalities (districts) were covered (64 self-governing communities and 12 self-governing cities). In total, 4,147 households were interviewed in 2011, constituted

[9] The built-up data from year 2000 was selected instead of the next available 2013/2014 collection to make sure that not much additional building construction would have taken place before the period of interest of this paper.

[10] The reason for complementing USGS data on Global Surface Water with OpenStreetMaps was that the highest available - 30m resolution only shows pixels with water body if the width/length of it is approximately 30 meters. However, since rivers often have a width of less than 30 meters, at least at some sections, it would show up in the map as fragmented rivers. Therefore, vector data on rivers was obtained from OpenStreetMaps and later rasterized and reclassified to combine with the Global Surface Water raster layer.

86.25% response rate of the 2009 sample. In the third round, in 2013, 3,726 households were interviewed, with a 10.15% attrition rate from the previous survey. Out of 4,147 panel households, 73% participated in the last, 2015 survey (Mshvidobadze, 2016). In the end, the total number of observations is 15,412 for the 4 interview waves, covering 318 settlements (panel of 307).

3.4.3 Descriptive statistics

The longitudinal data used in this study has 15,412 individual observations of an unbalanced panel of around 3,600 households (4,599 during the first wave in 2009, 4,108 in 2011, 3,690 in 2013 and 3,015 in 2015). From those, 10,590 observations are of rural households. Out of these rural households 10,255 had answered questions on access to utility services.

The main analysis of this paper is on rural households and whether they have access to different utilities. Figure 3.5 shows that most of the surveyed rural households already had access to electricity in 2009 and the coverage was almost full in 2015. Access to water supply had improved over the years but still remained a problem for 12% of the interviewed rural households in 2015. As for non-basic utilities - waste disposal, gas and the Internet - although improving, remained largely inaccessible to the rural households. Natural gas and the Internet had a relatively rapid increase in recent years. However, penetration still remained low.

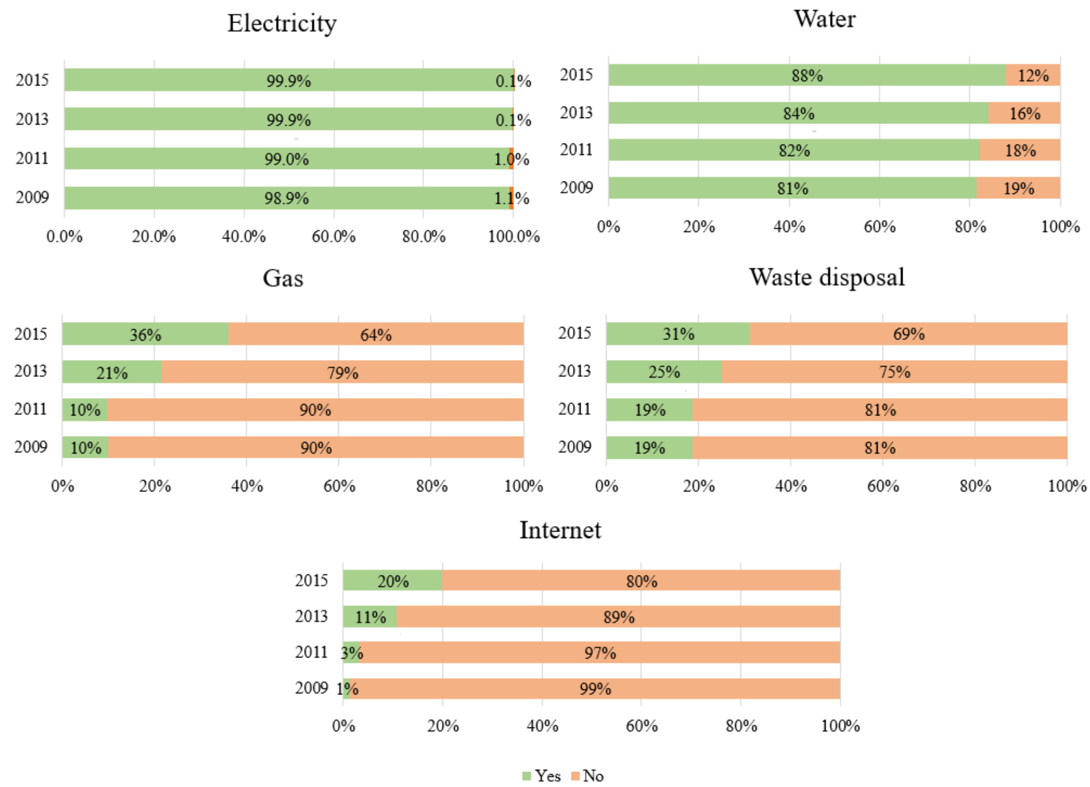

Figure 3.5: Access to utility services by rural households

The difference in accessibility is evident while comparing surveyed rural and urban households. While electricity is accessible for both groups, Figure 3.6 shows that households in municipal centers have better access to other utility services such as water supply, gas, waste disposal, and the Internet. For example, while almost all households in municipal centers had access to at least two of the utility services, 7% of rural households had access to only one of the services in 2015. However, the trend is improving. Rural households are getting more and more services in recent years, 51% of households have obtained access to at least three of the utility services. However, geographic disparities are evident. In 2015, 79% of urban households had access to four or five utilities, while only 24% of rural households had access to them.

The disparities could arise because of three main differences between rural and urban settlements: agglomeration, income, and accessibility. First, household agglomeration makes service provision easier and more cost-efficient. Urban areas are more densely populated than rural households, making it cheaper for companies to provide households with services.[11] Second, some of the non-basic services, for example, the Internet, could be accessible for households with higher income. Generally, urban households are wealthier, which could be another reason why they can access more non-basic services. Accessibility is the third main reason why urban settlements have lower access to services. Rural areas are often far from municipal centers, with poor quality roads. The machinery required to

[11] Although, municipal centers in Georgia are not necessarily of urban type, density is still higher than in rural areas.

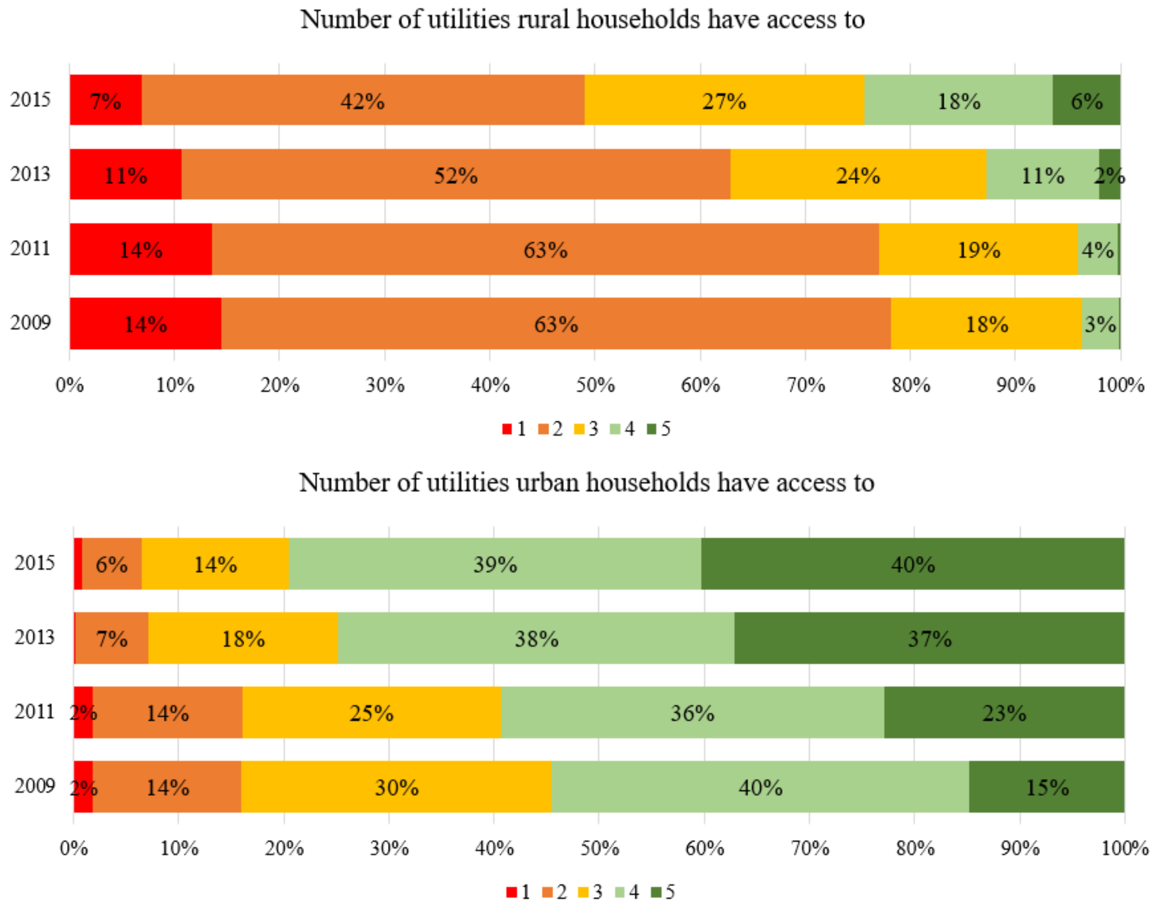

Figure 3.6: Access to utility services by rural and urban households by year.
Utilities include: electricity, water supply, gas, waste disposal, and Internet.

build infrastructure for the utility services needs accessible roads. Figure 3.7 shows that the distance from households to rehabilitated roads has been decreasing over time. In 2009, the average distance from a household to the nearest rehabilitated road was almost 7 kilometers, decreasing to around 4 kilometers in 2011, 3 kilometers in 2013, and to 2.2 kilometers by 2015.

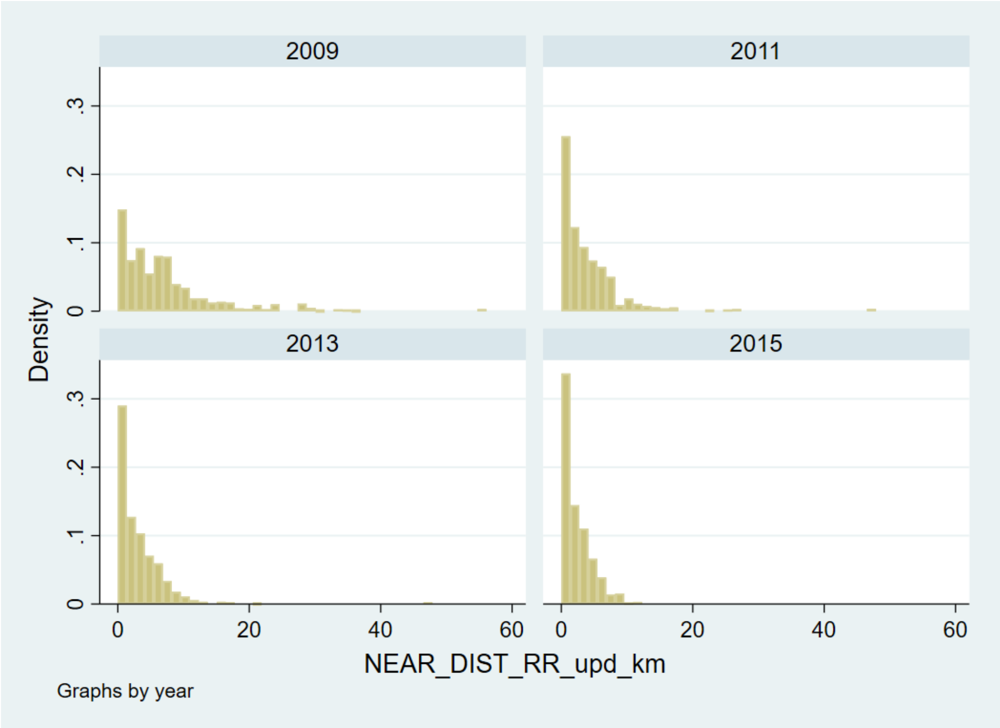

Figure 3.7: Distance to rehabilitated roads for rural HHs by survey year

3.5 Results

Table 3.1 shows the first stage regression results. I test two instrumental variables - the Euclidean distance straight line paths and the “least-cost paths”. Specifically, I instrument distance to the nearest rehabilitated road ($LogDistRR$) by either instrument one, distance to the nearest Euclidean straight line connecting municipal centers ($LogDistSL$), or the second instrumental variable - distance to the nearest branch of the least cost path spanning tree network, connecting municipal centers to each other ($logDistLC$).

Additionally, I include additional household and settlement level control variables, and control for regional and year fixed effects. In total, there are 9 regions and 4 surveyed years, covering a 6 year period from 2009 to 2015. Household level control variables include size of family ($familysize$), number of children of the age of 5 and below ($child5$), number of elderly people of the age of 65 and higher ($elder$), whether household members have a status of internally displaced persons (idp), age of household head ($hhead\_age$), gender of household head ($hhead\_sex$), highest education level achieved by the household head ($hhead\_edu$), whether household owns any livestock or poultry ($livestock$), and food expenditure ($logfoodexp$). Household income would have also been a good predictor of accessibility to the utility services. However, I avoid including it for two main reasons.

First, income is under-reported in the WMS survey, and second, income could be a “bad control” since it could also be affected by improved roads.

Settlement level controls include Log distance to the nearest district (municipal) center ($logDistMunic$),[12] population of a settlement a household is in ($logPop$),[13] and a dummy variable for whether a settlement is in a mountainous area ($mountain$). Table 3.1 reports the first-stage estimates of the regressions.

Table 3.1 shows that both instrumental variables have strong, significant correlation with the endogenous variable ($logDistRR$). However, the least-cost natural path IV has a somewhat stronger association, as well as a higher explanatory value (R^2), and higher first stage F-statistics than the Euclidean straight line instrumental variable. The difference is particularly evident when both instrumental variables are included in the same regression, as shown in columns (5) and (6). In this case, the least cost natural path IV shows much higher association.

The main explanation of the observed differences between the straight line and the least-cost instrumental variables might be that, while the least-cost paths are constructed using geographical data (elevation, water cover and built-up areas), accounting for topography, the straight lines are drawn without considering any geographic heterogeneity. Ali et al. (2015*a*) also argue that while straight lines might be good proxies of roads in relatively flat environments, they can be inaccurate in environments with high geographical heterogeneity. However, considering the high topographic heterogeneity of Georgia, the regression differences between the straight line and least-cost natural path are not very high. The main reason might be, that while the least cost path spanning three network algorithm calculates the shortest paths to connect all municipal centers to each other, it does not build hypothetical least-cost paths over all rehabilitated road links, generating 63 hypothetical paths in total (please see Figure 3.4). On the other side, the Euclidean straight line variable links municipal centers over all rehabilitated road links, generating 84 straight line links (please see Figure 3.2).[14] Overall, if there are more paths, like in the case of straight lines, overall average distances between straight lines or least-cost paths will not be very large. Since the least-cost natural path instrumental variable is more accurate and exogenous with higher explanatory power, for the sake of brevity, I will only report the estimation results using this instrumental variable.

The coefficients in Table 3.2 represent average marginal effects on the probability of having access to each of the utility services. With the exception of water, all utilities have negative association with distance to rehabilitated roads. The probability of having access to central gas supply decreases by 5.3 percentage points per one unit increase in the log of distance to the nearest rehabilitated road - or approximately 2.7-fold increase in distance ($e \approx 2.71828$). The impact is very high for waste collection - decreasing by 10.4 percentage points per one unit increase in log of distance to the nearest rehabilitated road. As for

[12]Calculated in ArcGIS using the NEAR function.

[13]Source: Population Census 2014. National Bureau of Statistics of Georgia (Geostat).

[14]For instance, if we compare Figure 3.2 and Figure 3.4, it is visible that there are more straight line links than hypothetical least cost paths.

Table 3.1: First stage IV regressions

	(1)	(2)	(3)	(4)	(5)	(6)
logDistLC	0.232***	0.237***			0.187***	0.216***
	(0.015)	(0.016)			(0.015)	(0.016)
logDistSL			0.207***	0.176***	0.120***	0.136***
			(0.016)	(0.019)	(0.016)	(0.018)
logDistMunic		-0.008		0.100***		-0.124***
		(0.036)		(0.036)		(0.039)
logPop		-0.375***		-0.370***		-0.382***
		(0.018)		(0.018)		(0.017)
mountain		0.101		0.049		0.042
		(0.078)		(0.080)		(0.078)
		(0.306)		(0.347)		(0.289)
Settlement controls	No	Yes	No	Yes	No	Yes
Household controls	No	Yes	No	Yes	No	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	10,255	10,255	10,255	10,255	10,255	10,255
R-squared	0.143	0.189	0.134	0.180	0.147	0.193
First stage F-stat	250.92	219.88	161.15	89.65	143.88	132.53

Dependent variable is *logDistRR*. Household controls include: *familysize, child5, elder, idp, hhead_age, hhead_sex, hhead_edu, livestock, logfoodexp.*
Robust standard errors in parentheses ***p<0.01, **p<0.05, *p<0.1

the Internet access, the impact is relatively low, with a 2 percentage points decrease per 1 unit increase in log distance. The average marginal effect for water (Column (2)), is positive but statistically insignificant. One explanation for the opposite sign could be the availability of spring water and water from wells in rural areas. The positive significant effect of the *mountain* variable is also expected, since water supply in these forms is more abundant in mountainous areas. Another unexpected sign is the negative association between the *logPop* variable and waste disposal. One of the explanations could be that most households that reported having access to waste disposal from small villages were from villages with historical sites. These villages are often visited by people during the summer on day trips. It is possible that the service is therefore available during summers. However, the data do not allow me to explore this explanation further.

Separately estimating probabilities of having access to each of the utilities might be problematic, since households that have access to one of the utilities might also have access to the other ones, especially when it is related to non-basic utilities. A better way for estimation would be using scores (weights) of household preferences for having access

Table 3.2: Marginal effects of rehabilitated roads on access to utilities

	(1) Gas	(2) Water	(3) Waste	(4) Internet
logDistRR	-0.053***	0.011	-0.104***	-0.020**
	(0.010)	(0.014)	(0.005)	(0.010)
logDistMunic	-0.058***	-0.019**	-0.019***	-0.004
	(0.007)	(0.008)	(0.007)	(0.005)
logPop	0.045***	0.010*	-0.011**	0.010**
	(0.007)	(0.006)	(0.004)	(0.004)
mountain	-0.039***	0.031**	-0.031**	-0.015
	(0.012)	(0.014)	(0.014)	(0.011)
familysize	0.001	0.001	-0.002	0.015***
	(0.002)	(0.002)	(0.002)	(0.002)
child_un5	0.004	-0.002	0.011	-0.029***
	(0.007)	(0.009)	(0.007)	(0.005)
elder	0.012**	-0.011*	0.005	-0.014***
	(0.006)	(0.007)	(0.006)	(0.005)
idp	0.098***	-0.002	0.025	-0.025
	(0.036)	(0.050)	(0.041)	(0.031)
hhead_age	-0.000	0.001**	-0.001	-0.000*
	(0.000)	(0.000)	(0.000)	(0.000)
hhead_sex	0.003	-0.002	0.009	0.009
	(0.007)	(0.008)	(0.007)	(0.006)
hhead_edu	0.009***	0.014***	0.005**	0.016***
	(0.002)	(0.002)	(0.002)	(0.002)
livestock	-0.017**	0.002	-0.003	0.004
	(0.008)	(0.010)	(0.008)	(0.008)
logfoodexp	0.011**	0.028***	-0.001	0.060***
	(0.005)	(0.004)	(0.004)	(0.008)
Region FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	10,255	10,255	10,255	10,255
Wald test	38.10	5.38	176.74	4.38

Robust standard errors in parentheses ***p<0.01, **p<0.05, *p<0.1.

to each of the utility services. However, since such weights are not available, I assigned them the similar weight of one and summed them up to identify how many of these services a household has access to, given distance to the nearest rehabilitated road. Columns (1) and (2) of Table 3.3 report these results, following equation (3.3.7).

The IV Poisson (GMM) regression estimation results show that living further from the nearest rehabilitated road decreases the expected number of accessible utility services. Living further from district centers as well as living in a mountainous area has a negative effect, while in bigger settlement households are more likely to have access to more utility services.

The second part of the Table 3.3 (columns (3) and (4)) shows results regarding accessibility to non-basic utility services like gas, waste disposal and the Internet. The dependent variable is binary, i.e. whether a household has access to at least one of these four utility services. The margins estimated for the IV Probit regression show that the likelihood of having access to the non-basic utility services decreases by 10.3 percentage points with one unit increase in the log of distance to the nearest rehabilitated road.

Table 3.3: Access to utility services

	(1) IV Poisson	(2) IV Poisson	(3) Margins (IV Prob.)	(4) Margins (IV Prob.)
logDistRR	-0.204***	-0.134***	-0.123***	-0.103***
	(0.024)	(0.018)	(0.004)	(0.007)
logDistMunic		-0.042***		-0.036***
		(0.008)		(0.008)
logPop		0.002		0.019***
		(0.009)		(0.007)
mountain		-0.040**		-0.067***
		(0.017)		(0.016)
Household controls	No	Yes	No	Yes
Region FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	10,255	10,255	10,255	10,255
Wald test			201.89	90.73

Dependant variable for Columns (1) and (2) is *Utilserv* - combining electricity, water, gas, waste collection, sewage and the Internet. Dependant variable for columns (2) and (3) is *extradum* - binary variable whether household has access to one of the extra utilities such as gas, waste collection, sewage or the Internet. Robust standard errors in parentheses ***p<0.01, **p<0.05, *p<0.1.

Lastly, after looking at the channels, I studied their possible effects on the availability of facilities in rural households. Table 3.4 shows the average marginal effects on the probability of having different facilities, such as availability of a shower or bath (column (1)), whether the shower or bath is inside the house (column (2)), whether the water supply is inside the house (column (3)), if hot water is available in a household (column (4)), and whether the household's gas or electric heater is the main heating source (column (5)). Overall, as expected, longer distance to rehabilitated roads is negatively associated with having different facilities in the household. For instance, 1 unit increase in the log distance to the nearest rehabilitated road (appr. 2.7-fold increase) decreases the probability of having a shower or bath by 9.2 percentage points. Also, households that have a shower or bath are 5.1 percentage points less likely to have them inside their houses if they live further from a rehabilitated road. Households in mountains are less likely to have showers/baths. However, the ones that have them are more likely to have them inside the house. Similar results are found in relation to the population number and the probability of having water access inside the house. Table 3.2 shows that villages with a smaller population are less likely to have access to water, but the ones that have access to water, seem to have it inside their houses as Table 3.4 shows. These results are in line with the outcomes indicated in column (2) of Table 3.4 that households living in mountainous settlements are more likely to have showers or baths inside the house. A one unit increase in the log distance to the nearest rehabilitated road (appr.-2.7 fold increase) decreases the probability of having a water inside house by 8.7 percentage points and probability of having hot water by 3.5 percentage points.

Firewood usage is still high in the country. The trend is decreasing quite slowly. According to the Welfare Monitoring Survey, in 2009 95% of surveyed rural households used firewood as the main mean of heating. The number decreased only to 92% by 2015. The usage of electric and gas heaters increased from 2% in 2009 to 7% in 2015 but it still remains low. Firewood consumption is producing significant health issues due to indoor air pollution and ambient particulate matter pollution (Fullerton et al., 2008). The analysis shows that households closer to rehabilitated roads have a lower probability of using firewood as main source of heating and higher likelihood of using electric or gas heaters. A one unit increase in the log of distance to the nearest rehabilitated road decreases the likelihood that a household uses electric or gas heater as the main source of heating by 3.8 percentage points.

Table 3.4: Marginal effects on availability of the facilities in rural households

	(1)	(2)	(3)	(4)	(5)
	Shower/bath	Shower/bath in	Water in	Hot water	Electric/gas heater
logDistRR	-0.092***	-0.051*	-0.087***	-0.035***	-0.038***
	(0.008)	(0.028)	(0.009)	(0.011)	(0.011)
logDistMunic	-0.019**	0.026	0.002	-0.019***	-0.003
	(0.008)	(0.022)	(0.008)	(0.005)	(0.006)
logPop	-0.000	-0.000	-0.013**	0.006	-0.002
	(0.006)	(0.009)	(0.006)	(0.005)	(0.004)
mountain	-0.050***	0.082**	-0.013	-0.025**	-0.029***
	(0.016)	(0.034)	(0.017)	(0.012)	(0.010)
HH controls	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
N	10,252	3,088	8,569	10,255	10,166

Household controls include: *familysize, child5, elder, idp, hhead_age, hhead_sex, hhead_edu, livestock, logfoodexp.*

Robust standard errors in parentheses ***p<0.01, **p<0.05, *p<0.1.

3.5.1 Robustness checks

The attrition rate between the first (2009) and the last (2015) surveys was 23%. The main reasons of non-response were that the house was closed (no one lived there) - 8%, no one was at home - 6%, another household was at this address - 4%, among others (Mshvidobadze, 2016). To check the robustness of the results, I used a balanced panel of only the households that interviewed all four times. In total, the number of observations was 7,879 compared to 10,255 in the unbalanced one. However, looking at the marginal effects on the probability of having access to each of the utilities, estimated on the balanced panel, (Table 3.7), results seem similar to the ones of the unbalanced panel (Table 3.2). Only the coefficient of probability of having access to the Internet decreases slightly and has lower statistical significance.

The instrumental variables used for the estimation are time invariant, measuring distance to the nearest hypothetical paths. Therefore, I also tested whether the coefficients hold when they are estimated only on the final survey year of 2015, when most of the projects were finalized. However the coefficients of marginal effects for probability of having access to gas and the Internet decrease and have lower statistical power, the marginal effects for $Wastedisposal$ obtained from using the complete 2009-2015 dataset and only 2015 are very similar.

Lastly, I estimated the marginal effects of rehabilitated roads on the households in municipal centers. In total, there are 5,152 observations for the four-year survey period. Results are shown in Table 3.9. The coefficients of marginal effects are higher and statistically more significant for Gas and $Water$, lower but statistically significant for $Waste$ and higher but statistically not significant for $Internet$. These results show that proximity to improved roads also matters for households living in more populated areas, like municipal centers.

3.6 Conclusion and discussion

The main objective of this chapter was to examine the effects of large-scale road rehabilitation projects on household accessibility to other utility services. Building on Christaller's Central Place Theory and Hirschman's infrastructure linkages, the theory suggests that having improved transportation network leads to accessibility to services. Road improvements tend to decrease travel costs and travel time, and make settlements more accessible. Passable roads are necessary to use machinery to provide necessary works for water or gas pipes, as well as to provide services such as waste disposal. The results of this study show that being closer to improved roads increases the number of utility services households have access to. It also increases the probability of having access to non-basic utility services, such as gas, waste disposal and the Internet. A one unit increase in log distance to the nearest rehabilitated road - or approximately a 2.7-fold increase in distance - decreases the likelihood of having access to gas by 5.3 percentage points, waste disposal by 10.4 percentage points, and to the Internet by 2 percentage points.

After looking at the channels, the paper also studies the availability of different facilities in households and finds that households closer to improved roads have a higher probability of having water inside the house, available hot water, a shower or bath, and are more likely to use a gas or an electric heater as the main source of heating rather than firewood. The results show that a one unit increase in distance to the nearest rehabilitated road - or an approximate 2.7-fold increase - decreases the likelihood of a household having a bath or shower by 9.2 percentage points, having bath or shower inside the house by 5.1 percentage points, water inside the house by 8.7 percentage points, access to hot water by 3.5 percentage points, and using an electric or gas heater as the main source of heating by 3.8 percentage points.

The study has several limitations. First, the paper cannot observe the period before the start of the projects. However, the analysis uses an exogenous geographic instrumental variable, such as least-cost spanning tree network, in combination with regional and year fixed effects to show unbiased causal effects of the road improvement. Another limitation of the study is that the usage of each utility services cannot be observed, neither it is known the household preferences and valuation for each of them. Therefore, this chapter looks at the probability of having access separately for each item as well as in combination. Lastly, the chapter looks at household proximity to improved roads, although the data limitations do not allow us to see how often these improved roads are actually used by the households. However, since most of the improved roads were major roads leading to municipal centers, it is more likely that these roads would be used to build necessary infrastructure for utility services and to provide services, such as waste collection.

These findings are very policy relevant, considering the increasing trend of road infrastructure investments particularly in low- and middle-income countries. It is important to identify the linkages of road infrastructure and accessibility to other utility services. The results show the synergies of different Sustainable Development Goals, such as improving infrastructure, water and sanitation, and good health and well-being. The combination of improved road network and utility services serve to improve the well-being of households.

The results are particularly relevant for rural development. Urban centers tend to have better services because of agglomeration of households, and feasibility and cost-efficiency of service provision. While in rural areas, where population density is quite low and accessibility is a problem, households are often deprived from these services. Even though the major motivation of the road rehabilitation projects, studied in this chapter, were not necessarily to increase the connectivity of rural settlements, they still had positive externalities on the rural population. Households living in settlements laying nearby the rehabilitated roads gain more benefits.

3.7 Appendix

Table 3.5: Summary statistics of variables used

Variable	Variable description	Obs.	Mean	Sd.	Min.	Max.
Outcome						
Water	Dummy: household has access to water supply	10,255	0.84	0.37	0	1
Gas	Dummy: household has access to natural gas	10,255	0.18	0.38	0	1
Waste	Dummy: household has access to waste collection	10,255	0.23	0.42	0	1
Internet	Dummy: household has access to the Internet	10,255	0.08	0.27	0	1
Utilserv	Utilities combined (electricity, water, gas, waste, Internet)	10,255	2.45	1.02	0	6
Extrautil	Dummy: HH has access to at least one of gas, waste, internet	10,255	0.42	0.49	0	1
bath	Dummy: shower/bath available in the house	10,252	0.30	0.46	0	1
bathin	Dummy: shower/bath available inside the house	3,088	0.64	0.48	0	1
waterin	Dummy: household has water supply inside the house	8,569	0.32	0.47	0	1
hotwat	Dummy: household has access to hot water	10,255	0.10	0.30	0	1
elgasheat	Dummy: electric/gas heater main heating mean	10,166	0.03	0.18	0	1
Treatment						
DistRRupd	Distance to rehabilitated road	10,255	4.22	5.45	0.002	54.72
IVs						
DistSL	Distance to the nearest straight line connecting towns	10,255	4.28	4.47	0.007	34.82
DistLC	Distance to the nearest Least Cost Path connecting towns	10,255	5.56	5.12	0.003	33.35

Continued next page.

Table : *Continued:* Summary statistics of variables used

Variable	Variable description	Obs.	Mean	Sd.	Min.	Max.
Controls						
DistMunic	Distance to the nearest district center	10,255	9.34	5.19	0.49	34.82
Population	Village population	10,255	1549	1611	5	8191
mountain	Whether village is located in mountains	10,255	0.14	0.34	0	1
familysize	Number of members in family	10,255	3.60	2.00	1	18
child5	Number of children of age 5 and under	10,255	0.19	0.51	0	5
elder	Number of elderly people of age 65 and over	10,255	0.70	0.73	0	3
idp	Dummy: family has IDPs	10,255	0.01	0.08	0	1
hhead_age	Age of household head	10,255	63.70	13.71	18	106
hhead_sex	Dummy: gender of household head	10,255	0.33	0.47	0	1
hhead_edu	Highest education achieved by household head	10,255	4.27	1.65	1	8
livestock	Dummy: household owns livestock and/or poultry	10,255	0.80	0.40	0	1
foodexp	Monthly food expenditure (GEL)	10,255	265	211	0	5877

Source: Welfare Monitoring Survey, village population was collected by Census 2014. $DistRRupd$, $DistSL$, $DistLC$, $DistMunic$ - generated in ArcGIS using NEAR function.

Note: variables $DistRRupd$, $DistSL$, $DistLC$, $DistMunic$, *Population*, and $foodexp$ are converted into logarithms.

Table 3.7: Marginal effects of rehabilitated roads on access to utilities - balanced panel

	(1) Gas	(2) Water	(3) Waste	(4) Internet
logDistRR	-0.059***	-0.013	-0.102***	-0.014
	(0.011)	(0.017)	(0.007)	(0.012)
logDistMunic	-0.055***	-0.008	-0.024***	-0.004
	(0.009)	(0.008)	(0.008)	(0.006)
logPop	0.044***	0.004	-0.011*	0.013**
	(0.008)	(0.007)	(0.005)	(0.005)
mountain	-0.041***	0.046***	-0.039**	-0.025**
	(0.013)	(0.015)	(0.016)	(0.012)
HH controls	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	7,879	7,879	7,879	7,879
Wald test	29.75	0.16	102.71	1.04

Household controls include: *familysize, child5, elder, idp, hhead_age, hhead_sex, hhead_edu, livestock, logfoodexp.*
Robust standard errors in parentheses ***p<0.01, **p<0.05, *p<0.1.

Table 3.8: Marginal effects of rehabilitated roads on access to utilities - year 2015

	(1) Gas	(2) Water	(3) Waste	(4) Internet
logDistRR	-0.013	-0.007	-0.114***	-0.013
	(0.031)	(0.023)	(0.009)	(0.027)
logDistMunic	-0.110***	-0.015	-0.040***	-0.030**
	(0.017)	(0.013)	(0.015)	(0.015)
logPop	0.125***	0.018	-0.013	0.023*
	(0.017)	(0.011)	(0.008)	(0.013)
mountain	-0.012	0.110***	-0.105***	-0.102***
	(0.029)	(0.029)	(0.029)	(0.033)
HH controls	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	2,121	2,028	2,121	2,121
Wald test	0.46	0.09	49.77	0.19

Household controls include: *familysize, child5, elder, idp, hhead_age, hhead_sex, hhead_edu, livestock, logfoodexp.*
Robust standard errors in parentheses ***p<0.01, **p<0.05, *p<0.1.

Table 3.9: Marginal effects of rehabilitated roads on access to utilities - only nodal (municipal center) households

	(1) Gas	(2) Water	(3) Waste	(4) Internet
logDistRR	-0.160***	-0.055***	-0.036***	0.034
	(0.013)	(0.021)	(0.012)	(0.024)
logPop	0.078***	0.018***	0.058***	0.044***
	(0.005)	(0.004)	(0.003)	(0.007)
mountain	-0.163***	-0.007	0.032*	0.064**
	(0.030)	(0.016)	(0.017)	(0.032)
familysize	0.005	0.005*	0.004	0.053***
	(0.003)	(0.003)	(0.003)	(0.004)
child5	0.003	0.018*	-0.005	-0.075***
	(0.011)	(0.010)	(0.010)	(0.012)
elder	0.035***	0.020***	-0.005	-0.038***
	(0.010)	(0.008)	(0.008)	(0.011)
idp	-0.164***	0.053**	0.040*	-0.116***
	(0.025)	(0.025)	(0.024)	(0.026)
hhead_age	-0.001**	-0.000	0.000	-0.003***
	(0.000)	(0.000)	(0.000)	(0.001)
hhead_sex	-0.026**	-0.010	-0.019**	0.019
	(0.010)	(0.008)	(0.009)	(0.013)
hhead_edu	0.016***	0.009***	0.013***	0.046***
	(0.003)	(0.002)	(0.002)	(0.003)
livestock	-0.056***	-0.030***	-0.143***	-0.091***
	(0.013)	(0.008)	(0.009)	(0.016)
logfoodexp	0.019***	0.007***	0.007	0.057***
	(0.004)	(0.003)	(0.005)	(0.011)
Region FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
N	5,152	5,152	5,152	5,152
Wald test	86.84	12.15	1.87	4.56

Robust standard errors in parentheses ***p<0.01, **p<0.05, *p<0.1.

Chapter 4

Impact of road infrastructure network improvements on household income and spending: evidence from Georgia

4.1 Introduction

Improved connectivity decreases mobility costs of people, goods, and services. Investing in improving and maintaining infrastructure is widely believed to be a crucial factor in economic development. Therefore, investments in road infrastructure have been rapidly increasing in recent years, particularly in low- and middle-income countries (Raitzer et al., 2019). Investments have been directed to new road construction projects, as well as rehabilitation and maintenance of existing roads. Different types of roads have different purposes: on the one hand, large highways and major roads connect cities and towns to each other, carrying consolidated traffic between them; on the other hand, local and access roads provide last-mile connectivity to rural areas (Iimi et al., 2018). All types of road works contribute to reducing travel time and costs. However, different types of roads might also have different effects on GDP, poverty, prices, input and output markets (Fan and Chan-Kang, 2005; Iimi et al., 2018; Bell and van Dillen, 2014). Considering the importance of heterogeneous impacts between different types of road infrastructure projects, there is a gap on studying the effects on household expenditure.

This chapter aims to contribute to this gap in the literature by studying the short-term impacts of road rehabilitation works done in Georgia in 2009-2010. As it is the case in most low- and middle-income countries, the government of Georgia has also been heavily investing in road rehabilitation and construction projects since the mid-2000s: expanding existing major roads into highways, building new road sections, and paving and rehabilitating existing roads.

Endogeneity of road rehabilitation project placement is a major concern in studying causal impacts of road infrastructure. To overcome this issue, the paper uses a difference-in-difference estimation strategy. In this study, in total, 135 settlements were identified in the baseline year of 2009. These settlements had not received any prior road rehabilitation work and were reported to have "very poor" or "poor" roads leading to the settlements. By 2011, 94 from these settlements had received some kind of road improvement, while the other 41 had not yet received any. The initial conditions of these settlements were compared to rule out that the pre-project characteristics were driving the road placement decisions. The paper combines road infrastructure data from two sources: administrative data from the central government and survey data from the local government, calculating settlement proximity to rehabilitated roads and comparing them to the ones reported by the village representatives.

The results show that households in settlements receiving improved roads increase overall household income and spending. The effects are even higher on rural households. Receiving improved roads increases regular monthly income, long and short-term expenditure, and spending on education. When looking at heterogeneous impacts of different types of road rehabilitation projects, households who have received only small roads (local or access roads) have higher spending and higher monthly income than households receiving only large roads (highways and major roads). The combination of the rehabilitation of large and small road networks shows higher impacts.

The research contributes to the growing literature on road infrastructure work on households in low- and middle-income countries. As road networks improve, mobility of people increases. Increased mobility of people and goods has been shown to decrease prices and affect household consumption patterns (Aggarwal, 2018; Donaldson, 2018; Andrabi and Kuehlwein, 2010; Casaburi et al., 2013), increases non-agricultural employment by growing opportunities to new labor markets, or by increasing agricultural productivity (Khandker and Koolwal, 2011; Asher and Novosad, 2016); hence leading to increased household income and welfare (Gibson and Rioja, 2019; Ali et al., 2015*b*; Wiegand et al., 2017). The studies done on the impact of highways or expressways focus mostly on more aggregate level, like provinces or regions (for example, Faber (2014), Khanna (2014), Banerjee et al. (2012), Ghani et al. (2016)) and do not look at different types of roads in combination with major highways.

There are a few exceptions in studying heterogeneous impacts of different road infrastructure projects. For instance, Fan and Chan-Kang (2005), doing cost-benefit analysis, found that considering investment costs, in China of low-quality (mostly rural) roads had raised far more rural and urban poor above the poverty line than high-quality (mostly urban) roads had. Iimi et al. (2018) show that in Ethiopia while farmers' access to input markets had been improved mainly through major corridor improvements, an output market had been enhanced through feeder road improvement. Comparing crop prices by feeder roads and highways, Bell and van Dillen (2014) show that in India prices decreased across the stretch of major road links, but increased along a stretch of district roads.

The paper also contributes to the limited literature on studying road infrastructure projects in Georgia. Usually, most of the road infrastructure impact evaluation studies are carried out by MDBs, evaluating each specific road rehabilitation project they are financing.[1] The evaluation reports on ongoing East-West Highway of Georgia have undertaken an ex-ante analysis (ISET Policy Institute, 2015; Demir and Monsalve, 2016), reporting a positive impact on the road infrastructure on Georgian economy and exports. The ex-post analysis of the rural road rehabilitation projects evaluate effects of recently improved secondary roads in Georgia only on one project in one region of the country (NORC, University of Chicago, 2013). The authors report that due to the short post-project period, the report could not find any significant results on the improvements of the households' social-economic situation. Lokshin and Yemtsov (2005) conducted a similar study to this paper, evaluating several infrastructure rehabilitation projects in Georgia between 1998 and 2001. However, other than roads, they also included rehabilitation projects of schools and hospitals. They found that the road and bridge rehabilitation projects contributed to the increase in the number of small and medium sized enterprises and in the reduction of barter trade.

4.2 Conceptual framework

Different types of roads fulfill different purposes. While highways and major roads connect urban centers and take the heavy weight of mobility of goods, feeder and access roads connect rural areas, and farmers to local markets. However, major and feeder roads are often built and rehabilitated simultaneously.

The pathway from policy intervention to outcomes goes through output and responses. In the case of road infrastructure improvement, the immediate short-term outcome is a decrease in travel time, which is usually translated to reduced transportation and time costs. Reduced costs stimulate mobility. Therefore, the responses to decreased transportation and time costs are increased trade and easier access to markets and services (Fujita et al., 2001; Aggarwal et al., 2018; Allen and Arkolakis, 2014). Intensified trade decreases prices, providing different variates of consumption goods (Aggarwal, 2018).

The hypothesis of this research is that improved roads increase household consumption and income as a response to the change in time and costs to access to markets and services, and possible lower prices of increased trade (Aggarwal, 2018; Donaldson, 2018; Andrabi and Kuehlwein, 2010; Casaburi et al., 2013). Since households in rural and mountainous areas are usually likely to have inadequate infrastructure, the impact on these groups is expected to be higher.

[1]For example, see BenYishay and Tunstall (2011) for a review on project evaluation works on projects implemented by the Millennium Challenge Corporation

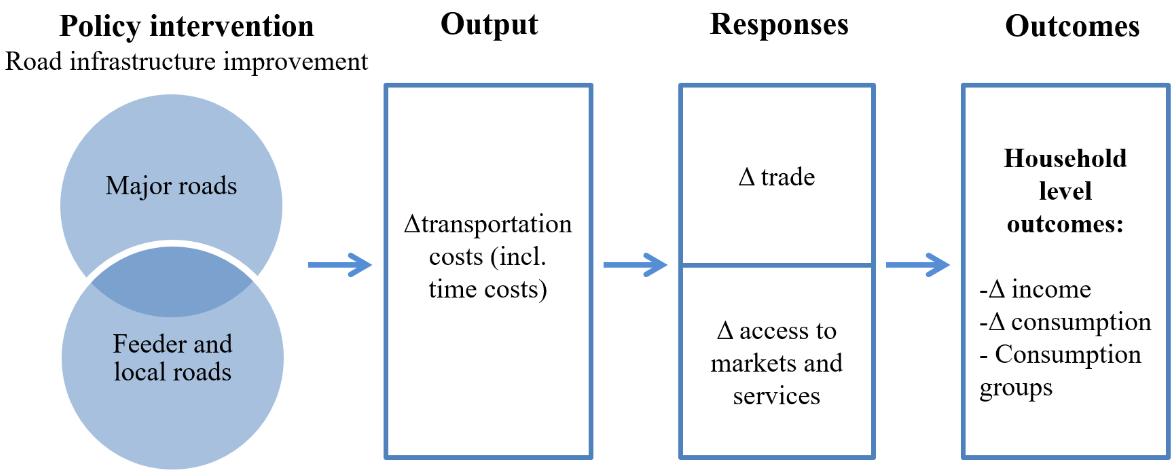

Figure 4.1: Conceptual framework: impacts of road infrastructure improvements on household income and expenditure. (Adapted from Laird and Venables (2017) and Berg et al. (2016)).

4.3 Context

Georgia is a low middle-income country in the South Caucasus region with a population of 3.7 million[2] and a per capita GDP of USD 4,084 in 2016 (constant 2010 US$). During the Soviet Union Georgia enjoyed a fairly high standard of living compared to the neighboring republics. The country was an exporter of agricultural and energy-intensive industrial products, and infrastructure was well developed. After independence in 1991, the Georgian economy collapsed because of conflicts and political instability, and the loss of markets. The crisis in the 1990s resulted in poor financing of public infrastructure, quickly deteriorating the quality of roads (World Bank, 2013).

Georgia is perceived as a transit corridor country from Asia to Europe (part of Transport Corridor Europe-Caucasus-Asia (TRACECA)), and therefore has attracted huge amounts of investments and loans to build high speed highways and rehabilitate feeder roads. Since the early 2000s, several MDBs and the Georgian central government have heavily co-financed road infrastructure improvement projects - building and rehabilitating different types of roads.

There are three types of roads in Georgia: roads of international importance, national importance and local importance. Roads of international importance are the major roads of the country, connecting with roads from the neighboring countries. Roads of national importance are also major roads, connecting municipal centers to each other, as well as regional and cultural centers. Roads of local importance are roads connecting regional centers with settlements, cultural or touristic centers, and linking settlements to each other Mchedlishvili et al. (2009).

[2]Census of Georgia, 2014. Excluding population in the conflicted territories of Abkhazia and South Ossetia.

The Road Department of the Ministry of Infrastructure and Regional Development (MRDI) is responsible for maintaining 1528 kilometers of international roads and 5298.1 km of national roads. Some national and all local roads fall under the responsibility of municipalities.[3] The municipalities have a budget which can be used for road infrastructural works. However, they can also ask for grants from international donor organizations. The mediator between the municipalities and MDBs is the Municipal Development Fund of Georgia (MDF) under the MRDI.

Overall, there are 13 international road links in Georgia, total of 1603 kilometers. The Roads Department of the Ministry of Infrastructure and Regional Development is responsible for maintenance of 1528 kilometers of international roads, the remaining 75 km are under the responsibility of several self-governing cities: Tbilisi (36km), Batumi (8.5km), Sokhumi (11km), and Tskhinvali (3.5km). As for the roads of national importance, there are 202 road links in total with the length of 5298.1 kilometers. The roads fall under the responsibility of the Roads Department, with the exception of 1.5 km of road for which Gori municipality is responsible (Decree 407)(Government of Georgia, 2014).

This paper studies the effects of road rehabilitation projects implemented in 2009-2010. The studied projects are the World Bank's Secondary and Local Roads Project (plus the additional financing), part of East-West Highway Project and part of Kakheti Regional Roads Improvement Project, and Millennium Challenge Corporation's Samtskhe-Javakheti Roads Rehabilitation Project. The road links from these projects were completed during either 2009 or 2010. All road rehabilitation works completed during this time period were done on already existing roads.

4.4 Data

The data combines household and settlement longitudinal surveys, administrative data on road improvement works, and spatial data on roads. Administrative data on road rehabilitation projects is complemented by the settlement infrastructure survey.

4.4.1 Roads and spatial data

This study uses administrative data from both institutions of the Ministry of Regional Development and Infrastructure - the Roads Department and the Municipal Development Fund of Georgia. In total, 1,218 road links have been rehabilitated between 2006-2015, 941 by the administered by Road Department, and 277 by the Municipal Development Fund. 800 of these projects were on road rehabilitation, 218 on bridges and river pipes, 68 road safety works, and 114 projects urgent rehabilitations were due to extreme weather events.

[3]In total, there are 76 municipalities in the country, from which 12 are self-governing cities.

During the period of our interest, in 2009-2010, works on 281 road links were completed from which 235 were road rehabilitation works. 108 projects were done on internal or local roads - including access roads, 99 road works were on national roads, and 42 on international roads. The intensity and the funding per project, as expected, was higher on international roads.

The administrative dataset was received in tables. I digitized the list, identified each road and each rehabilitated road section, then mapped them on road vector data. In addition, road dataset was complemented by online sources. International and national roads of Georgia - the layer indicating type of road, start, end and the length of the road was obtained from ArcGIS online. I edited the data to categorize the types of roads and the names of roads according to the Georgian Government's decree 407 on roads in Georgia.[4] Local roads were obtained from the open source Openstreetmaps (OSM) roads database. Local roads data were necessary to construct the shortest driving/walking distance to the rehabilitated roads.

Origin-destination Cost Matrix

The distance from settlements to rehabilitated roads was calculated using Network Analysis. Specifically, OD Distance Matrix - origin-destination (OD) cost matrix analysis was performed to identify the shortest walking/driving distance from settlements to rehabilitated roads in radius of 5 and 10 kilometers.

First, I identified all possible drivable routes in the country using the open source database from OSM. This list not only includes all-weather roads, but also inner village roads, as shown in Figure 4.3. Then, I complemented the road vector layer with vector data I generated on road sections of each road rehabilitation project and each rehabilitated road section. Lastly, after the complete road of map was built, I added settlement locations.

The main idea of the OD Cost Matrix is that it finds the shortest paths along the existing road network from multiple origins to multiple destinations. In this case, origin was the center of a settlement and destination was every possible rehabilitated road in radius of 5 and 10 kilometers.

4.4.2 Welfare Monitoring Survey

The Welfare Monitoring Survey is a longitudinal biennial survey conducted by UNICEF Georgia. So far, four rounds of data have been released (2009, 2011, 2013, and 2015). The survey examines the multi-dimensional wellbeing of households in Georgia. The survey has a particular focus on children, and also focuses on public social transfers and their impacts on poverty. The survey questions are related to household living conditions, household facilities, assets, income, consumption, prices of consumed items, and access to services.

[4] List of International and National Roads of Georgia. Government of Georgia, Decree 407 `http://www.georoad.ge/uploads/files/407.pdf` (Reviwed Dec. 2017).

The primary survey target sample consisted of households which participated in the 2008 annual repeated cross-sectional Household Integrated Survey, conducted by the National Statistics office of Georgia. The Household Integrated Survey used two-stage clustering: first stratifying by region, and then by settlement size and mountain or lowland location (Mchedlishvili et al., 2009).[5]

The survey covered 9 regions of Georgia and the capital city Tbilisi. In total, 76 municipalities (districts) were covered. For the scope of this paper, only the first two rounds of survey data will be used in analysis. In total, 4147 households have been interviewed in 2011, which constituted an 86.25% response rate in the 2009 sample.

4.4.3 Settlement Infrastructure Survey

The Settlement Infrastructure Survey is a three round panel data on infrastructural conditions at the settlement level, collected by NORC at the University of Chicago for the Samtskhe-Javakheti Rural Roads Rehabilitation project in 2007, 2010, and 2012. The dataset combines the settlement statistics together with the information about all kinds of infrastructural projects that have been done in the settlements.

The Settlement Infrastructure survey is a part of the Millennium Challenge Corporation's (MCC) Samtskhe-Javakheti Roads project. It was done to evaluate the impacts of the MCC funded road infrastructure project in Samtskhe-Javakheti region of Georgia implemented in 2008-2010. The baseline survey was conducted in 2007, another round in 2010, and the last one in 2012 - after the completion of the project. During the survey period, face-to-face interviews were conducted with local government representatives from the selected settlements. The questions that were asked included about 15 different categories. The questionnaires also included questions on quality of road leading to settlements and inner roads of the settlements. The baseline survey in 2007 included a wider range of questions on each category. However, the number of questions from selected categories were reduced later.

The evaluation research described in NORC, University of Chicago (2013), employed the difference-in-difference method to study the impacts. For this methodology, treated and controlled observations are compared over time. Therefore, in addition to the settlements in Samtskhe-Javakheti region which were to receive the improved roads, other settlements from all over the country were also interviewed to act as a control group. This gave me the possibility to merge the settlement infrastructure survey from the MCC with the UNICEF's WMS household level survey to identify the effects of road infrastructure on household level. From the total of 346 locations from the WMS data 96% or 333 locations were identified in the MCC's settlement survey.

[5] Source: How do Georgian children and their families cope with the impact of the financial crisis? Report on the Georgia WMS 2009, UNICEF Georgia. p.8.

4.5 Empirical strategy

The problem of endogenous placement of infrastructure projects arises since roads are not randomly built or rehabilitated in certain areas (Banerjee et al., 2012; Datta, 2012; Chandra and Thompson, 2000). This challenges the way to look at causal effects: areas with better infrastructure have better economic outcomes due to the improved infrastructure, or since some areas have better potential to attract more economic activities, they also attract more road rehabilitation projects (Datta, 2012). Roads might be built in more economically disadvantaged areas to promote economic activities, and also might be more likely to be built in regions with easier land acquisition policies or more suitable terrain (Khanna, 2014). There are different quasi-experimental methods used in the literature to tackle this issue.

One way to capture the causal effects of improved road infrastructure is by using a difference-in-difference strategy to compare the areas receiving the treatment to the areas without it. In this case variables of interest are observed in the households in treated areas and compared with the households in the controlled areas (for example, see Aggarwal (2018); Iimi et al. (2018)).

In case, when road infrastructure program rules provide discontinuities in the probability of receiving treatment (in this case, a rehabilitated road), regression discontinuity design can be used. This quasi-experimental method gives the possibility to test the variable of interest on villages slightly above and below the threshold line.[6] In absence of random selection or discontinuities in receiving improved roads, a panel data fixed effects method is used to study the impact of road infrastructure. Panel data analysis allows for household level fixed effects to solve the bias of household unobserved heterogeneity (Khandker et al., 2009). In addition, this method allows to capture the spatial characteristics at the village level. For example, neighboring villages, one receiving an improved roads and other not, might not be considered as a control and treatment if the villagers with non-improved roads also use the improved road to access services. Therefore, spatial analysis was employed by analyzing the road network across the settlements.

This paper combines a difference-in-difference estimation strategy with panel data fixed-effects regression. The main advantage of the difference-in-difference estimator is that it allows the control of unobserved heterogeneity between the treatment and control groups and mitigates the self-selection bias, as far as time-invariant unobservable characteristics are concerned. However, as often discussed, this may be a strong assumption. To reduce this risk, time-variant household and settlement characteristics are included as

[6]For example, Asher and Novosad (2016) study the effects of the Prime Minister's Village Road Program in India, providing roads to villages with more than 1000 inhabitants by 2003 and with 500 inhabitants by 2007; Casaburi et al. (2013) use the cutoff point of the assigned scores to villages, comparing the areas which received the road because of the score assignment to the one which was rehabilitated even though it was not supposed to. The main reason why using regression discontinuity design might not be possible is that many times the infrastructure rehabilitation programs do not provide discontinuities in receiving the treatment. The second reason is that, quite often the comparison is not possible because of the low number of comparable settlements.

explanatory variables. Then, the fixed-effects panel data regression is performed.

4.5.1 Identification strategy

The difference-in-difference panel data analysis was conducted on household level, using household level fixed effects clustered on settlement level to control for unobserved heterogeneity.

$$y_{ist} = \alpha + \delta_s + \gamma_t + \beta * D_{ist} + \varepsilon_{ist} \tag{4.5.1}$$

Where, y_{it} is an outcome variable (income and different types of monthly expenditures and incomes) of household i living in settlement s in time t. δ_s is a set of settlement fixed effects, γ_t is set of year fixed effects (first difference). D_{ist} is an indicator variable of being exposed to road rehabilitation project (equals 1 if household is in a treatment group - living in a settlement which received improved road, 0 if in a control group), β shows average treatment effect of having access to improved road.

By taking the difference between two periods of study, the sources of endogeneity will be dropped. But this only happens when household and settlement characteristics are assumed not to change over time. Ravallion (2007) argues that receiving treatment or the changing impacts of public infrastructure might depend on the initial area conditions. In this case, unobserved heterogeneity will not remain constant over time. This might lead to significant omitted variable bias. Therefore, settlement and household specific characteristics should be taken into account:

$$y_{ist} = \alpha + \delta_s + \gamma_t + \beta * D_{ist} + \tau R_{st} + \mu H_{ist} + \varepsilon_{ist} \tag{4.5.2}$$

R_{st} is a vector of time-variant settlement level characteristics, H_{ist} is a vector of household level characteristics. R_{st} is a binary variable indicating the type of road improvement project: presence of a major road improvement, presence of an improved local or feeder road, or their combination.

According to the Settlement Infrastructure Survey, in the baseline year none of the 135 settlements had received any kind of road improvement projects in last two years and most of them were reported to have “very poor” or “poor” quality roads leading to the settlement. Combining the survey data with the administrative data on road rehabilitation projects and the spatial analysis on road placements showed that in 2011, 94 settlements had received some kind of road rehabilitation: nearby major road, road leading to settlement, access road, or internal road rehabilitation, while the remaining 41 had received no road improvement project. This resulted in putting households living in these 94 settlements in treatment group and the households living in the other 41

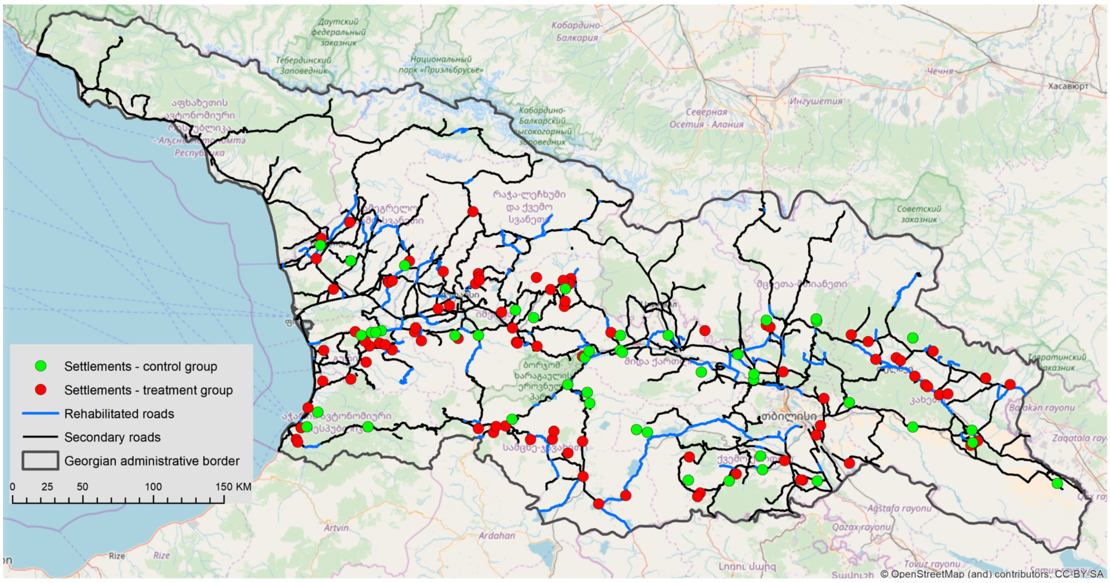

Figure 4.2: Rehabilitated roads and control and treatment settlements.

settlements in control group. The settlements were present in all regions of Georgia (except the conflicted territories).

Table 4.1: Pre-project settlement comparisons between groups.

	Control	**Treatment**	**Pr**$(\lvert T\rvert > \lvert t\rvert)$
Population (hh)	404.98 (73.08)	603.62 (202.8)	0.525
Altitude (meters)	665 (68.80)	532 (49.21)	0.13
Rural settlement	0.98 (0.24)	0.87 (0.34)	0.062*
Distance to municipal center (km)	16.65 (1.42)	13.96 (1.57)	0.295
Distance to nearest health center (km)	5.56 (1.66)	4.45 (0.10)	0.551
Distance to nearest market (km)	0.10 (0.047)	0.03 (0.18)	0.115
Distance to nearest major road (km)	35.95 (7.12)	42.37 (5.54)	0.506
Distance to nearest secondary road(km)	13.88 (4.32)	10.52 (1.70)	0.384
Distance to nearest int. railway (km)	77.66 (11.62)	84.19 (10.50)	0.712
Number of schools in the settl.	1.34 (0.09)	1.39 (0.14)	0.812
Number of settlements	41	94	

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Pre-project comparison was conducted between treatment and control settlements to rule out initial conditions as driving factors for road improvement. Table 4.1 shows that between the treatment and control groups, there was no significant difference found in number of population in the settlements, altitude, distance to municipal center, to the nearest health center, to the nearest market,[7] major road, secondary road, railway or health center. However, treatment settlements were slightly more likely to be municipal centers rather than rural settlements. Considering this, I also ran analysis separately on rural settlements.

In addition to pre-project settlement comparisons, I also looked at the probability of receiving a road rehabilitation project by 2009 based on the settlement level characteristics. The analysis shown in Table 4.2 demonstrates that none of the factors were statistically significant to influence the likelihood of receiving a road rehabilitation project by the year 2009, including the placement of road project at the municipal center. Of course, this still does not rule out the endogeneity of road project placement. However, based on observable characteristics, there were no differences between the groups.

One of the main reasons why there were no significant differences found between the regions, could be that the control areas were also to receive road rehabilitation projects, which indeed happened few years later. This could mean that while some households received roads slightly earlier than others, there were not significant differences between them.

Table 4.2: Likelihood of receiving road rehabilitation by 2009

	(1)	(2)
	coeff.	se
Population (hh)	0.0000777	(0.000086)
Altitude (meters)	-0.000374	(0.000453)
Rural settlement	-0.756	(0.555)
Distance to municipal center (km)	0.000599	(0.00924)
Distance to nearest major road (km)	0.00291	(0.00353)
Distance to nearest secondary road (km)	-0.00424	(0.00562)
Distance to nearest int. railway (km)	-0.000486	(0.00163)
Number of schools in the settl.	0.00915	(0.110)
_cons	0.996	(0.653)
Region FE	Yes	
N	135	
$R-squared$	0.129	

Robust standard errors in parentheses.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[7] Data on distance to markets and distance to health centers were not available for 2 settlements.

This chapter looks at impacts of road infrastructure improvement on affected settlements, namely, on household income and expenditure. The WMS survey has collected data on two main income groups - regular monthly income and annual income. Regular monthly income includes monthly wages, regular monthly income from self-employment, and social transfers. Annual income includes income from selling agricultural products, property income, and cash assistance from family members.

Expenditure data were collected on food items, long term consumption goods, short term consumption goods and services, healthcare and education. Expenditure on food items includes purchasing food or eating out during the last week, aggregated on a monthly level. Long-term non-food items include purchasing machinery for agriculture, cars, clothing, home-renovations, renovating house, or buying long-lasting household items. Short-term non-food expenditure combines hygiene items, costs on utilities, transportation, and financial services.

Comparing the pre-project outcome variable shows that the households in treatment and control areas were very similar in terms of spending, spending groups, and income. The only statistically significant difference between the households in treatment and control areas seems to be that the households in control areas on average spent slightly more on healthcare in 2009 compared to the households in treatment areas.

Table 4.3: Pre-project outcome variable means

	Control	**Treatment**	$\mathbf{Pr}(\|T\| > \|t\|)$
Family size	3.34 (0.276)	3.74 (0.198)	0.2524
Total expenditure	381.475 (16.84)	355.594 (8.292)	0.1250
Food expenditure	190.122 (9.871)	178.146 (3.717)	0.1629
Total non-food expenditure	92.70 (6.457)	84.007 (3.849)	0.2340
Long-term non-food expenditure	24.90 (4.267)	22.739 (2.152)	0.6181
Short-term non-food expenditure	69.44 (3.729)	62.525 (2.46)	0.1271
Exp. on education	7.454 (1.289)	9.159 (1.20)	0.4064
Exp. on healthcare	43.82 (3.80)	35.469 (1.773)	0.0238**
Income (month)	106.03 (6.76)	114.89 (4.48)	0.283
Income (other - annual)	400.88 (41.88)	323.72 (25.03)	0.104

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: Income and expenditure is given in Georgian Lari (GEL). 1 USD = 1.67 GEL (National Bank of Georgia, 2009)

4.6 Results

The difference-in-difference estimation method was used to measure the effects of rehabilitated roads on household consumption. The dependent variables are logarithm of different groups of monthly spending: total monthly expenditure ($totexp$), food expenditure ($foodexp$), total non-food expenditure ($totnfexp$) - which is the combination of long-term ($ltexp$) and short-term non-food expenditure ($shtexp$), spending on education ($eduexp$) and on healthcare ($hcexp$). The analysis also looks at regular monthly income ($regincome$) - which includes: monthly wages, regular monthly income from self-employment, and social transfers, and it also estimates an annual income ($otherincome$) - which includes regular or one-time income from selling goods, services or receiving transfers from family. Time variant household controls are included and standard errors are clustered on district (municipal) level. The difference-in-difference estimator DiD measures the percentage change of spending groups between pre-project 2009 to post-project 2011 between the households in treated settlements and households in control settlements.

Table 4.4 shows that the improved roads had a significant positive impact on the monthly spending of households in treatment settlements compared to the households in control settlements. The impact was statistically significant on spending on total non-food items - particularly on short-term non-food expenditure - and on spending on education. Overall, households in treated settlements spent approximately 30% more per month on non-food goods and services than households in control settlements. The increase is mainly driven by short-term non-food expenditure which grew by 31.4%. The difference is also significant in the education spending category, 46.3% compared to the control group.

Next, the research looks at the heterogeneous impacts of roads on only rural settlements. The regression results shown in Table 4.5 demonstrate higher statistically significant impacts of road rehabilitation works on rural households. In addition to the increase to the short-term non-food items by 34% and education spending by 46.9%, rural households seem to have benefited by increased regular monthly income by 36.6% and long-term non-food expenditure by 40.8%. Long-term non-food expenditure includes expenditure on furniture, durable household items and house renovation costs. Considering that rural households without good access roads to town markets would have higher transportation costs, the results are rather logical. These results are particularly policy relevant, showing the higher impact of improved connectivity on rural households. The results show statistically not significant results on food expenditure, healthcare expenditure and non-regular annual income.

Lastly, the research looks at heterogeneous impacts of different types of rehabilitated roads. Spatial analysis was done using an OD cost Matrix in ArcGIS to calculate the distances between different settlements and rehabilitated roads. Roads within 5 and 10 kilometers of driving distance were selected. Later, these roads were divided in three categories: international roads (including highways) and national roads were considered as “large roads”, while local roads and access roads were categorized as “small roads”.

The third group was categorized as "combined roads". The road networks were set using the Spatial Join method of ArcGIS, combining intersected or closely placed rehabilitated roads. These road networks were categorized as combined roads, meaning that near a settlement, the roads which were rehabilitated were both, a major road as well as local or access road.

The results of the analysis studying the impacts of different types of roads is shown in Table 4.6. The analysis includes all three road categories discussed above. The "large roads" category - the group where only rehabilitated large roads are included - is a reference category. Interestingly, *smallroad* shows that households in settlements which received only small roads were significantly better off than the control group. The households in treatment areas receiving only small roads showed higher regular monthly income, and higher spending in long and short-term non-food and education spending. Rehabilitation of large and small road network or *combroad* also shows statistically significant higher household expenditure compared to baseline *largeroad*. These results are in line with the research of Fan and Chan-Kang (2005), showing that small road rehabilitation projects are particularly crucial for rural households.

Table 4.4: Impact on expenditure and income of urban and rural households

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	totexp	foodexp	totnfexp	ltexp	shtexp	eduexp	hcexp	regincome	otherincome
DiD	0.043	-0.092	0.300**	0.232	0.314***	0.463**	0.400	0.317	0.378
	(0.072)	(0.083)	(0.113)	(0.185)	(0.115)	(0.216)	(0.308)	(0.192)	(0.435)
time	0.243***	0.483***	0.093	0.488***	0.020	0.080	-0.176	0.024	0.311
	(0.067)	(0.077)	(0.106)	(0.139)	(0.116)	(0.194)	(0.243)	(0.164)	(0.399)
HH controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2,887	2,887	2,887	2,887	2,887	903	2,887	2,887	2,887
HH	1,444	1,444	1,444	1,444	1,444	584	1,444	1,444	1,444
R-squared	0.172	0.169	0.119	0.116	0.097	0.116	0.040	0.116	0.020

Dependent variables: *totexp* - Total monthly expenditure, *foodexp* - Monthly food expenditure, *totnfexp* - Total monthly non-food expenditure, *ltexp* - Monthly long-term non-food expenditure, *shtexp* - Monthly short-term non-food expenditure, *eduexp* - Monthly expenditure on education, *hcexp* - Monthly expenditure on healthcare, *regincome* - Regular monthly income, *otherincome* - Other regular/one time annual income.

Household controls include: *familysize, child5, elder, idp, hhead_age, hhead_sex, hhead_edu, livestock.*

Robust standard errors clustered in parentheses on district level ***p<0.01, **p<0.05, *p<0.1.

Table 4.5: Impact on expenditure and income of rural households

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	totexp	foodexp	totnfexp	ltexp	shtexp	eduexp	hcexp	regincome	otherincome
DiD	0.060	-0.090	0.351***	0.408*	0.340**	0.469**	0.307	0.366*	0.345
	(0.076)	(0.090)	(0.125)	(0.203)	(0.127)	(0.215)	(0.248)	(0.208)	(0.485)
time	0.222***	0.488***	0.065	0.463***	-0.001	0.098	-0.011	0.034	0.314
	(0.070)	(0.082)	(0.108)	(0.137)	(0.120)	(0.199)	(0.177)	(0.170)	(0.428)
HH controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,522	2,522	2,522	2,522	2,522	780	2,522	2,522	2,522
HH number	1,261	1,261	1,261	1,261	1,261	505	1,261	1,261	1,261
R-squared	0.179	0.187	0.122	0.115	0.101	0.127	0.046	0.124	0.020

Dependent variables: *totexp* - Total monthly expenditure, *foodexp* - Monthly food expenditure, *totnfexp* - Total monthly non-food expenditure, *ltexp* - Monthly long-term non-food expenditure, *shtexp* - Monthly short-term non-food expenditure, *eduexp* - Monthly expenditure on education, *hcexp* - Monthly expenditure on healthcare, *regincome* - Regular monthly income, *otherincome* - Other regular/one time annual income.

Household controls include: *familysize, child5, elder, idp, hhead_age, hhead_sex, hhead_edu, livestock.*

Robust standard errors in parentheses ***p<0.01, **p<0.05, *p<0.1.

Table 4.6: Impact on expenditure and income by road rehabilitation type

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	totexp	foodexp	totnfexp	ltexp	shtexp	eduexp	hcexp	regincome	otherincome
smallroad	0.039	-0.104	0.312**	0.354*	0.311**	0.555**	0.404	0.352*	0.275
	(0.072)	(0.089)	(0.125)	(0.211)	(0.131)	(0.217)	(0.320)	(0.207)	(0.473)
combroad	0.057	-0.053	0.261*	-0.154	0.325**	0.250	0.387	0.206	0.708
	(0.101)	(0.124)	(0.152)	(0.352)	(0.160)	(0.251)	(0.328)	(0.252)	(0.641)
time	0.243***	0.483***	0.093	0.486***	0.020	0.082	-0.176	0.023	0.312
	(0.062)	(0.077)	(0.108)	(0.128)	(0.118)	(0.183)	(0.242)	(0.164)	(0.372)
HH controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2,887	2,887	2,887	2,887	2,887	903	2,887	2,887	2,887
HH	1,444	1,444	1,444	1,444	1,444	584	1,444	1,444	1,444
R-squared	0.172	0.170	0.119	0.119	0.097	0.122	0.040	0.116	0.021

Dependent variables: *totexp* - Total monthly expenditure, *foodexp* - Monthly food expenditure, *totnfexp* - Total monthly non-food expenditure, *ltexp* - Monthly long-term non-food expenditure, *shtexp* - Monthly short-term non-food expenditure, *eduexp* - Monthly expenditure on education, *hcexp* - Monthly expenditure on healthcare, *regincome* - Regular monthly income, *otherincome* - Other regular/one time annual income.

Household controls include: *familysize, child5, elder, idp, hhead_age, hhead_sex, hhead_edu, livestock.*

Robust standard errors in parentheses ***p<0.01, **p<0.05, *p<0.1.

4.7 Robustness checks

Parallel trend assumption

The difference-in difference estimation method assumes that in the case of no intervention there would be a parallel trend of outcomes between households in treatment and control settlements. Due to the lack of pre-baseline data, it is not possible to check for pre-project trends between the groups of settlements. Placebo regression is performed to rule out pre-project trends. Using OLS regression on pre-project dependent variables for year 2009 - right before the settlements received the projects - shows that it is likely that there were no pre-trends in outcomes. The placebo specifications are statistically insignificant in most cases and statistically significant at 10% for the short term expenditure measure. However, the coefficient of the short-term non-food expenditure is negative, showing reverse association - that households in settlements which were to receive road projects in the coming years were spending less on short-term non-food items compared to the households in the control group. This could mean that pre-project trends were unlikely to affect consumption and income growth in treatment areas after the road rehabilitation period.

Table 4.7: Placebo test - program roads on 2009 outcomes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	totexp	foodexp	ltexp	shtexp	eduexp	hcexp	reginc	otherinc
treat	-0.05	0.03	-0.37	-0.22**	0.04	-0.24	-0.07	-0.30
	(0.07)	(0.08)	(0.24)	(0.08)	(0.19)	(0.17)	(0.19)	(0.50)
_cons	4.89***	3.99***	0.058	3.13***	1.44***	0.78	-1.14*	1.3
	(0.17)	(0.20)	(0.44)	(0.21)	(0.38)	(0.55)	(0.59)	(1.11)
Geogr.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HH con.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1,444	1,444	1,444	1,444	441	1,444	1,444	1,444
R-squared	0.269	0.190	0.255	0.129	0.102	0.062	0.377	0.099

Geographic controls include: *pop, altitude, rural, mountain, Dist_municipal, Dist_health, Dist_market, Dist_majorroad, Dist_secondroad, Dist_railway, schools.*

Household controls include: *familysize, child5, elder, idp, hhead_age, hhead_sex, hhead_edu, livestock.*

Robust standard errors in parentheses clustered on district level ***p<0.01, **p<0.05, *p<0.1.

Time invariant characteristics

The fixed effects estimation method takes away time invariant characteristics of treatment and control settlements. However, controlling for the pre-project characteristics between the groups helps to rule out any doubts of settlement initial conditions driving road placement decisions (Khandker et al., 2009). Incorporating changing household and settlement heterogeneity in terms of initial area conditions, Table 4.10 shows the estimation results using GLS Panel Data Random Effects method that controls for initial community endowments. Using Generalized Least Squares - Panel Data Random Effects method, pre-project time-invariant settlement characteristics were also included in the model. The additional controls include population, altitude, rural and mountain dummies, distances to the nearest municipal center, to the nearest major road, to the nearest secondary road, to railway, and number of schools in the settlement. Table 4.10 shows that the statistically significant impact of improved roads on total and short-term non-food expenditure and spending on education still hold after controlling for time-variant settlement characteristics.

Inflation

The large spending differences between treatment and control areas could be explained if there is high inflation in place. If, for example, urban areas had been experiencing higher prices, they would have spent more. This is a genuine concern, since the treatment group has more urban settlements. The National Statistics Office of Georgia does not collect data for calculating different inflation rates between towns and villages. However, data are collected in different cities every year. Looking at the inflation rates in different cities overtime, the differences between them are not more than 2%.[8] Since the results show a significant increase of spending on non-food items, the concern of different inflation rates should be less of a concern. If there are differences on food prices between rural and urban areas, this would result in the downward bias of spending on food. However, when analysis is performed on only rural households, the results on food-items are still similar to the analysis performed on all settlements.

4.8 Conclusion and discussion

Inadequate road infrastructure causes limitations in access to public services and markets. This might cause spatial fragmentation in low- and middle-income countries. In recent years policy-makers have been attempting to address this problem by heavily investing in road infrastructure improvement projects.

Investments in large transport projects can create winners and losers (Roberts et al., 2018). However, since most of the road infrastructure evaluation works are done on specific roads or types of roads, the impact of different types and the combination of different types of roads had not been well-studied. This chapter looked at different road types and road networks to identify impacts on household income and spending.

[8]Source: Consumer Price Indices (Same month of the previous year=100) by Region (towns), Groups, Year and Month. Statistics Database, National Statistics Office of Georgia.

The chapter studied the short-term impacts of road rehabilitation works implemented in Georgia between 2009-2011.The results of the difference-in-difference estimation show that improved roads have a statistically significant effect on household spending on long and short-term non-food items, and on education. Looking at only rural settlements, the results show even higher impacts - overall monthly spending on non-food items has increased by 35% in treated rural households, and income has increased by 36.6%.

The heterogeneous impacts of different types of infrastructure show additional benefits on rehabilitating small roads, and large and small road combinations. Overall, small roads tend to be very beneficial for households, increasing regular monthly income by 35%. These results are in line with existing research on heterogeneous impacts of different types of infrastructure (Stifel et al., 2016; Iimi et al., 2018; Fan and Chan-Kang, 2005; Bell and van Dillen, 2014), and show the importance of rehabilitation and maintenance of local and access roads.

The results capture the change in around a two-year period between the baseline and post-project survey. Considering the short time, the estimated results are quite high. The results are particularly high for expenditure in short-term and long-term consumption items. Improved roads have higher impact on households living in rural communities. Since people from mountainous and rural areas are more likely to have higher transportation and time costs due to inadequate infrastructure, reduced transportation cost and travel barriers seem to have a high impact on their spending and income.

Road infrastructure investment constitutes a major portfolio of public investment in many low- and middle-income countries. Therefore, it is important to understand the impact of road infrastructure in terms of road types. The small roads and combined roads of large roads (international, national) and small roads (local and access) yield higher impact on household income expenditure than rehabilitating only large roads. It is very important for policy planning to take the spatial setting of road networks into account, and rehabilitate the combination of small and large roads.

4.9 Appendix

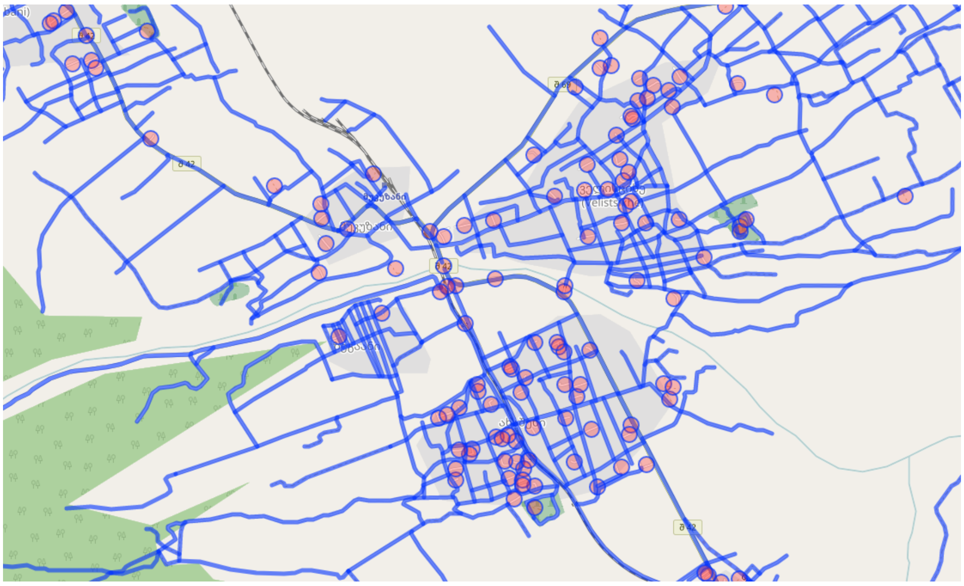

Figure 4.3: Fragment of all types of roads connecting four villages in Kakheti region. Source: *compiled by author using open-source Openstreetmaps database.*

Table 4.8: Summary statistics of variables used

Variable	Variable description	Source
time	Dummy: 0 if year is 2009, 1 if 2011.	Generated
treat	Dummy: whether household lives in treated settlement	Generated
did	Difference-in-difference estimator	Generated
Outcome		
totexp	Log of total household monthly expenditure	Welfare Monitoring Survey
foodexp	Log of household monthly expenditure on food	Welfare Monitoring Survey
totnfexp	Log of household monthly expenditure on non-food items	Welfare Monitoring Survey
ltexp	Log of household monthly expenditure on long-term non-food items	Welfare Monitoring Survey
shtexp	Log of household monthly expenditure on short-term non-food items	Welfare Monitoring Survey
eduexp	Log of household monthly expenditure education	Welfare Monitoring Survey
hcexp	Log of household monthly expenditure on healthcare	Welfare Monitoring Survey
regincome	Log of regular monthly income of household	Welfare Monitoring Survey
otherincome	Log of other regular/one time annual income of household	Welfare Monitoring Survey
Controls		
familysize	Number of members in family	Welfare Monitoring Survey
idp	Dummy: family has IDPs	Welfare Monitoring Survey
child_un5	Number of children of age 5 and under	Welfare Monitoring Survey
elder	Number of elderly people of age 65 and over	Welfare Monitoring Survey
hhead_age	Age of household head	Welfare Monitoring Survey
hhead_sex	Dummy: gender of household head	Welfare Monitoring Survey
hhead_edu	Highest education achieved by household head	Welfare Monitoring Survey
livestock	Dummy: household owns livestock and/or poultry	Welfare Monitoring Survey

Continued next page.

Table : *Continued:* Summary statistics of variables used

Geographic controls		
pop	Number of households living in the settlement	Settlement Infrastructure Survey
altitude	Altitude of settlement	Google Maps API
rural	Dummy: settlement is rural or municipal center	Settlement Infrastructure Survey
mountain	Dummy: settlement is in a mountainous area	Settlement Infrastructure Survey
Dist_municipal	Distance to the closest municipal center (km)	Google Maps API
Dist_health	Distance to the nearest polyclinic (km)	Settlement Infrastructure Survey
Dist_market	Distance to the nearest market (km)	Settlement Infrastructure Survey
Dist_majorroad	Distance to the nearest major road (km)	Settlement Infrastructure Survey
Dist_secondroad	Distance to the nearest secondary road (km)	Settlement Infrastructure Survey
Dist_railway	Distance to the nearest int. railway (km)	Settlement Infrastructure Survey
schools	Number of schools in the settlement	Settlement Infrastructure Survey

Table 4.10: Impact on household expenditure and income: Diff-in-diff Random effects

	(1) totexp	(2) foodexp	(3) totnfexp	(4) ltexp	(5) shtexp	(6) eduexp	(7) hcexp	(8) regincome	(9) otherincome
DiD	0.042	-0.102	0.313***	0.226	0.330***	0.385**	0.388	0.306	0.338
	(0.072)	(0.084)	(0.116)	(0.183)	(0.121)	(0.191)	(0.317)	(0.197)	(0.440)
treat	-0.049	0.018	-0.202**	-0.238	-0.198**	-0.008	-0.288	-0.096	-0.231
	(0.062)	(0.077)	(0.081)	(0.212)	(0.084)	(0.183)	(0.189)	(0.172)	(0.443)
time	0.252***	0.502***	0.089	0.520***	0.011	0.079	-0.166	0.021	0.421
	(0.067)	(0.077)	(0.109)	(0.144)	(0.122)	(0.179)	(0.253)	(0.171)	(0.399)
Geogr. contr.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
HH controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2,887	2,887	2,887	2,887	2,887	903	2,887	2,887	2,887
HH	1,444	1,444	1,444	1,444	1,444	584	1,444	1,444	1,444

Geographic controls include: *rural, mountain, population, altitude, Dist_municipal, Dist_majorroad, Dist_secondroad, Dist_railway, schools.*

Household controls include: *familysize, child5, elder, idp, hhead_age, hhead_sex, hhead_edu, livestock.*

Robust standard errors in parentheses ***p<0.01, **p<0.05, *p<0.1.

Chapter 5

Conclusion

5.1 Summary of the findings

The main objective of this thesis has been to study the different economic impacts of improved connectivity through road construction and rehabilitation projects. Particularly, the thesis looks at the road infrastructure projects implemented in Georgia and Armenia and their impacts on various individual and household level outcomes. The quantitative economic analysis is accompanied by a qualitative study which I have conducted in both countries. The results from the quantitative analysis are in line with the qualitative research, finding that improved connectivity through road rehabilitation and construction projects increases the likelihood of non-agricultural employment for rural individuals and increases the probability of working outside of village. It also finds improved living conditions and increased accessibility to utility services, improved household living conditions, and increased regular income and expenditure.

The first chapter sets the stage for the research questions discussed throughout the thesis, highlights the importance of combining qualitative and quantitative data, and describes the recent trends in utilizing spatial data for development. The chapter also overviews Armenia and Georgia in terms of general economic indicators and road infrastructure stock and development in recent years. The qualitative study performed for this research is also discussed in this chapter. The results show that improved connectivity reduced travel time and travel costs, improved accessibility to markets, jobs and services, and attracted more intermediate traders. However, it also highlights the need of complementary infrastructure and underlines the safety concerns.

The second chapter concentrates on the impacts of road quality on agricultural and non-agricultural employment and draws on the evidence from Armenia. The study uses a triangulation method utilizing different sets of data and different methodological approaches. In order to address endogeneity problems and reverse causation, the study exploits the historical setting of roads, using a historical instrumental variable obtained by georeferencing and digitizing a military-topographic map of the Caucasus region from 1903. The individual level results show that a shorter distance to a good quality road (one unit increase in log distance or approximately 2.7-fold increase in distance) has a statistically significant positive impact on overall non-agricultural employment (5.7 percentage points (p.p.)), on skilled manual employment (6.1 p.p.) and non-seasonal employment (10.7 p.p.) for rural men. Individuals are also more likely to work outside of their villages if they have access to good quality roads (2.8 p.p.). With shorter distance to roads in good condition, women are more likely to work in non-agricultural employment and earn cash for their work (9.3 p.p).

Improved road quality plays an important role in extending the urban perimeter - providing not only jobs, but also access to different services to rural people. The third chapter studies this relationship using the data on large scale road rehabilitation projects in Georgia in the period of 2006-2015. The rehabilitation projects were designed to improve the connectivity of municipal district centers to each other. As a side effect, a large number of peripheral settlements also appeared better connected, creating an interesting setting to study the impacts of rehabilitated roads. In order to address the non-random selection of improved roads between the targeted district center nodes, I use an instrumental variable strategy based on the Euclidean straight-line connector and the least cost path spanning tree network. The estimation results suggest that being better connected improves household accessibility to different utility services such as gas, waste disposal, and the Internet. One unit increase in log distance to rehabilitated road increases the likelihood of having access to gas by 5.3 percentage points, to waste by 10.4 percentage points and to the Internet by 2 percentage points. In addition, households closer to rehabilitated roads are more likely to have piped water in house, shower or bath, and use electricity or gas as main mean of heating instead of firewood.

Looking deeper into various types of road rehabilitation works and household impacts, the fourth chapter focuses on different types of roads rehabilitated in Georgia and evaluates their short-term impacts on household income and expenditure. The study uses the combination of household and settlement surveys, and administrative and spatial data with a difference-in-difference methodology to study the causal effects of improved roads on households in 135 settlements. The results show that households in settlements which received improved roads report increased spending on long and short-term non-food items, and on education. Rural households benefited more - reporting higher monthly income and increased non-food spending. Total monthly non-food expenditure increased by 35% in households living in rural areas which received improved road network, and regular monthly income increased by 36.6%. Comparing the heterogeneous impacts of different types of rehabilitated roads reveals that local and access roads seem to bring the highest benefits to the households, increasing monthly income and non-food spending. The combination of large and small road rehabilitation projects also seems to benefit households more than only large road rehabilitation projects.

5.2 Policy implications, limitations and further research

Road infrastructure construction and rehabilitation spending has drastically increased in the recent decades. The trend is particularly growing in low- and middle-income countries. It is important for policymakers to empirically quantify the effects of transport infrastructure projects. Growing road infrastructure spending requires analyzing the impacts on various economic, social and environmental factors. This dissertation has addressed this need, it has shown the benefits and co-benefits of improving and building road infrastructure and maintaining good quality roads. Drawing from the results of the analysis studied during the course of the thesis, there are several considerations policy makers should take while planning for infrastructural works.

First, improved road connectivity might have large positive impacts on employment outcomes of rural individuals. Improved roads decrease travel time and travel costs, and promote rural-urban, urban-urban, and rural-rural connectivity. Maintained good quality roads, which lead rural settlements to urban areas increase the urban perimeter, connect people to jobs, markets and services. This is a very important factor in terms of structural transformation. The thesis has shown that good quality roads are one of the major factors obtaining non-agricultural employment which is a key driver of structural transformation. Proximity to good quality roads has a large effect on women, increasing their likelihood of being employed in non-agricultural sectors and obtaining cash earnings. This is also a very policy relevant factor especially in low- and middle-income countries since women's empowerment is heavily dependent on financial independence.

Second, while planning the road projects, different positive and negative externalities should be taken into account in addition to the goals of road infrastructure projects. The thesis identifies some of the positive externalities of road infrastructure projects. Even when the main goal of a road rehabilitation project is to improve connectivity between different urban areas, rural areas in-between them also benefit from improved connectivity through diffusion of benefits. As Chapter 3 shows, improved roads might bring complementary services, such as improved water supply, gas, waste disposal, the Internet and, in general, improve living conditions of rural households. These results might be very important for improving healthcare outcomes and increasing human capital accumulation in rural populations. Access to clean drinking water, hot water and non-firewood heating have shown from the literature to have positive effect on health outcomes. In addition, access to the Internet has shown lead to better educational and business outcomes.

Lastly, policy-makers should keep in mind that even if roads have positive externalities through diffusion, different roads serve different purposes. Even if large road rehabilitation projects are increasing the rural perimeter and provide additional services, as shown above, small roads might be more beneficial to the rural populations for accessing local markets, therefore, increasing their income and expenditure.

The thesis has several limitations. First, data availability has been a major concern for evaluating the impacts of different interventions. Namely, long-term panel data with in-depth questions on employment and mobility are rarely available for middle and low income countries, which has also been the case for Georgia and Armenia. The thesis attempted to fill this gap by combining different surveys, and administrative and geographic data. However, these data have often been cross-sectional. Given the data limitations, channels through which employment, income, expenditure and living condition outcomes have been affected could not be directly measured during the course of the thesis. Further research would be needed to measure possible agricultural productivity growth through improved market connectivity, direct change in mobility patterns and trip frequencies, visits to markets, educational institutions and health facilities. Second, increased investments in improving connectivity do not speak of road quality. Additionally, road quality data are very scarce and rarely available for multiple time periods. Governments and international organizations should collect data on road quality more intensively and should make the already collected data publicly available for further research.

Overall, the dissertation is in line with Rozenberg and Fay (2019), and considers that the discourse on infrastructure spending should rather be on investment goals and efficient spending than on attracting as many investments as possible to satisfy the growing need for infrastructure. Considering the existing research, policymakers should identify what the objectives of each project are, what they want to achieve, what would be expected economic, social, and environmental impacts, and possible winners and losers, if any. It is important to measure the impacts of road infrastructure investments from the improved connectivity viewpoint, identify benefits, co-benefits and challenges, and recognize possible positive and negative externalities of the transport projects.

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