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School of Economics and Management

Master in Economic Development and Growth

Does Transportation Infrastructure Reduce Poverty?
Evidence from the Free Federal Trunk Highway System in Mexico

Nayeli Noyolitzin Salgado Granados
eut14nsa@student.lu.se

Abstract: This paper provides an exploratory analysis about the effect of transportation infrastructure on poverty reductions in Mexico between 1990 and 2010. Using the density of highways and unprecedented official estimations of poverty at municipality level, I show that this type of infrastructure lead to reductions in poverty. On average, for every additional kilometer (km) of highway (km/100km^2) poverty decreases in 0.4 percentage points. When comparing areas by the concentration of native population, there is no difference in the effect of highways for indigenous and non-indigenous municipalities. In addition, the study reveals that highways have more influence on poverty in periods of economic contractions. In order to address the problem of reverse causality in the placement of highways, this study applies a counterfactual proposed by Banerjee, Duflo and Qian (2012). Despite the efforts to determine causality of highways on poverty, the results have some limitations to be considered in future studies.

Keywords: poverty, highways, indigenous municipalities, Mexico, transportation infrastructure

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Acronyms and Abbreviations

CONEVAL	National Council for the Evaluation of Social Development Policy (Consejo Nacional de Evaluación de la Política de Desarrollo Social)
CDI	National Commission for the Development of Indigenous Peoples (Comisión Nacional para el Desarrollo de los Pueblos Indígenas)
CTMP	National Committee for Poverty Measurement (Comité Técnico para la Medición de la Pobreza)
INEGI	National Institute of Statitics and Geography (Instituto Nacional de Estadística y Geografía)
OECD	Organisation for Economic Co-operation and Development
Oportunidades (Progresa-Oportunidades)	Program for Education, Health and Nutrition (Programa de Educación, Salud y Alimentación)
NAFTA	North American Free Trade Agreement
SCT	Ministry of Communications and Transport (Secretaría de Comunicaciones y Transporte)
SEDESOL	Ministry of Social Development (Secretaría de Desarrollo Social)
UNPD	United Nations Program for Development

1 Introduction

Does transportation infrastructure lead to poverty reductions in developing countries? If so, to which extent? Is the impact of transportation infrastructure the same across space and time? Do all groups or regions benefit equally from this type of projects?

Some of the attempts to understand the impact of transportation infrastructure have emerged in recent decades due to increasing investments in roads and highways in low and middle income countries.[1] In these countries, transportation infrastructure is expected to foster economic growth and development by connecting the poor to jobs, education, and supply of basic goods and services.

Mexico is not an exception, in the last two decades public investment in transportation infrastructure, consisting mostly of highways, increased 26 times after the adoption of NAFTA in 1994.[2] According to the national development plans, the motivation for building and widening the existing highways is to promote competitiveness and regional integration (SHCP, 2000). However, 20 years later, Mexico still ranks poorly in terms of infrastructure, and is far from meeting the international road standards (OECD, 2013; Schwab, Sala I-Martin & World Economic Forum, 2014).[3]

In the same period, the country has undergone transformations with relevant implications for the population's wellbeing: the adoption of NAFTA; a financial crisis in the mid-1990s; the political transition in 2000 after 70 years of governance by the same political party with their corresponding structural and institutional reforms; and, the implementation of a strong social policy based on cash transfer programs such as *Oportunidades*.[4]

[1] In the last two decades public and international financing of roads and highways have increased in developed and developing countries, being higher in the latter. Only in this period, the World Bank has lent more than US$125 billion, nearly half of their total assistance to development. Within these years, the Chinese government has invested more than US$600 billion to upgrade its road system and to connect its larger cities (World Bank, 2011). China, is just one, but a very good example about how road infrastructure is becoming a priority in the developing countries agenda.

[2] Over the last 10 years, investment in infrastructure has increased 140% in terms of Gross Domestic Product (GDP). It represents an increase from 2% in 2000 to 5% in 2010.

[3] The recent version of the Global Competitiveness Index of 2014 ranks Mexico in the 69th place out of 144 countries in terms of transportation infrastructure: an improvement of 15 positions in less than 10 years (Schwab, Sala I-Martin & World Economic Forum, 2014). However, a report from OECD (2013) evidences that the country has still lower road density (0.19 km/km^2) when comparing with other countries in the region like Panama (0.20 km/km^2) or Uruguay (0.44 km/km^2), or countries with larger areas such as China (0.37 km/km^2) or Sweden (1.28 km/km^2).

[4] The political party transition was from *Partido Revolucionario Institucional* (PRI), which controlled government for more than 70 years, to *Partido Acción Nacional* (PAN). The latter modified the name of the cash transfer program called *Progresa* to *Oportunidades*. The new government drove reforms in social development such as the creation of *Seguro Popular* in 2001 that provides access to health services for all the population, and other programs to alleviate poverty. For more details see Székely & Rascón (2005).

Moreover, during these two decades, the level of poverty has been high and persistent. Recent official statistics show that almost 50% of 112.3 million people live in these conditions. In rural areas 60% are poor, but urban poverty is increasing in recent years due to the urbanization process that counts for almost 80% of the total population living in urban centers. In addition, poverty is strongly interconnected with ethnic and spatial inequalities that are very well defined regionally: the south is the poorest region, which is where most of the native population is concentrated (CONEVAL, 2010).[5]

Empirical evidence on the evaluation of roads has shown that this type of infrastructure promotes economic growth.[6] However, measuring its impact on the economy and welfare is difficult for two major reasons. Firstly, due to the lack of a theoretical framework that can explain the mechanism on which roads lead to economic growth or poverty reductions. Secondly, due to reverse causation in the road placement. In other words, establishing if roads lead to economic growth or if they were constructed in places with potential of growth (Ali & Pernia, 2003). The objective of this study is to provide some insights about the impact of transportation infrastructure on poverty levels in Mexico. Given the background of the country, this study aims to contrast whether or not transportation infrastructure promotes economic development. Therefore, it aims to answer the following questions:

- *Do highways contribute to poverty reductions? If so, to what extent?*
- *Is the effect of highways on poverty reduction different over time?*
- *If highways have an impact on poverty, is the effect different for indigenous and non-indigenous populations?*

In this study, the analysis is restricted to the Federal Free Trunk Highway System (FFTHS), a public road network financed and administrated by the Federal government. The FFTHS represents 80% of highways in the country.[7] The analysis focuses on highways rather than rural roads for three reasons: data availability, the relevance of larger investments in recent years, and because this type of infrastructure better represents the economic and demographic situation for the country.

This research uses the official definition of poverty (CTMP, 2002). According to SEDESOL, poverty is defined as the incapability to obtain a basket of food commodities, and the insufficiency to satisfy

[5] CONEVAL (2010; 2014a) estimates that 6.5% of the total population are indigenous in Mexico. Most of them live in rural areas located in the mountains in the north and south of the country. According to CONEVAL, in those municipalities where more than 70% of the population is indigenous, 4 out of every 5 people live in poverty.
[6] For more details see Ahmed & Donovan (1992), World Bank (1994), Pouliquen (2000), and Ravallion (2007).
[7] The remainder 20% are toll highways. Both federal and toll highways are administrated by the government but the latter are managed by privates through a license system. Toll highways were not included in the analysis because according to Ahmed & Donovan (1992, p.1), the definition of infrastructure should meet four conditions: to facilitate economic activity; preferably it should be public goods because of economic externalities; it should not be imported; and, investments in this type of infrastructure should be indivisible. In the case of Mexico the FFTHS meets all of them; toll highways do not since their purposes are only for profit-making.

other basic needs such as clothing, education, health, housing and transportation with the household's whole income.[8]

In this examination, the problem of reverse causality is addressed by applying the technique proposed by Banerjee, Duflo and Qian (2012). This strategy consists of drawing counterfactual lines that show what would have been the placement of the roads in previous periods that had different economic policies. By connecting historical cities, this counterfactual aims to respond to the question of which routes planners would have been likely to build if the sole objective was to connect city nodes.

Using pooled Ordinary Least Squares (OLS) and instrumental variables (IV), where the instrument is the counterfactual, the estimated results suggest that highways do reduce poverty. These results also indicate that when there are economic contractions, like the case of the economic recession in the year 2000, highways had a greater impact on poverty. Moreover, the results show that the effect of highways is the same for indigenous and non-indigenous municipalities.

Despite the implications that these results suggest in terms of policy making, this study has several limitations that should not be overlooked. First, it does not fully capture the difference in the types of roads and their different effects on poverty. Second, the proposed models do not capture all the possible determinants of rural and urban poverty at the municipality level. Third, this study omits the soft component of infrastructure (e.g. institutions and regulations, etcetera). And finally, despite the effort to prove causality, the study requires additional robustness checks with different methods and instruments, as will be discussed in the last section of the document.

The remainder of the thesis is structured as follows: *Section 2* offers a literature review based on empirical evidence of the effects of roads with different outcomes, and how previous research has addressed the causality problem; *Section 3* briefly explains how economic growth, the development of roads, and poverty have evolved in the last century in the country; *Section 4* describes the empirical strategy and data; *Section 5* shows the estimation results; finally, *Section 6* provides some elements for discussion and a conclusion.

[8] SEDESOL uses three definitions of poverty for targeting the population of their social programs: food or extreme poverty, poverty by capabilities, and patrimonial poverty. The first is defined as the incapability to obtain a basic food basket, even if the entire household's income is used for buying those commodities. The second is defined as the income insufficiency to acquire the previous commodities plus other commodities such as education and health. The last type of poverty is defined as the inability to acquire the previous commodities, and being incapable to expend the household's income in clothing, housing and transportation. By definition, patrimonial poverty includes poverty by capabilities, and the latter includes the line of extreme poverty. For more details see CTMP (2002).

2 Literature Review

Empirical literature considers that infrastructure reduces poverty both directly and indirectly (GRIPS, 2003; Jones, 2010; Loayza & Odawara, 2010). According to this perspective, roads improve wellbeing by facilitating the access to new opportunities.

Some of the channels are economic growth and public policies. However, most of the studies on evaluation of transportation infrastructure focus on how roads increase economic growth and how it reduces poverty. This is known as the market channel because it is assumed that any increase in GDP or income will reduce poverty due to a *trickle down* process (Dollar & Kraay, 2002; Ravallion, 2007).[9] From this perspective, infrastructure rises GDP or income from gains in competitiveness (e.g. productivity and cost reduction) or increases in economic activity. In this analytical framework, public policy complements the market channel by redistributing the benefits from economic growth. This mechanism includes those institutions, regulations, subsides and fiscal transfers that promote social and economic equity (social programs, public budget to the provinces or regions, public investment) (Jones, 2010; Loayza & Odawara, 2010).

Most of the studies on evaluation of transportation infrastructure have analyzed the effects of roads through the use of market channel (Ahmed & Donovan, 1992; OECD, 2006). This perspective suggests that the market channel can reduce poverty from the supply side or the demand side (Ali & Pernia, 2003; Loayza & Odawara, 2010).[10] On the *supply side*, infrastructure can create *pro-poor growth* by increasing the capital stock and productivity. More productivity attracts more investment (e.g. Foreign Direct Investment), and the latter increases the economic activity. As a consequence, there is more labor demand and more people benefit from the wages and salaries. Furthermore, transportation infrastructure promotes market integration by improving connectivity and reducing transportation time, which in turn reduces the costs of production, and leads to price convergence.[11] On the *demand side*, infrastructure increases the effective demand by stimulating employment during and after the construction of infrastructure. It also increases the aggregated demand from the consumption of those families employed in the projects and by the use of local or national inputs to build the infrastructure.

[9] The type of growth that promotes poverty reductions is also known as pro-poor growth. There is a trend in recent studies to name pro-poor infrastructure to those provisions that aim to reduce poverty through the market channel or those projects that are targeted towards the poor (e.g. rural roads) (OECD, 2006).

[10] Trade models have been useful to explain how infrastructure has an impact on economic growth due to decreases of transportation costs and price convergence. These models include both production functions with mobility of one or both of the factors or production (labor and capital). For more revision of the approaches see Dissou & Sisic (2013).

[11] An example about how infrastructure reduce costs of production can be found in Ahmed & Donovan (1992, p.7).

In the market approach, transportation infrastructure creates positive and negative externalities. Among the positive externalities diversification in the diet, intercultural exchange, and innovation diffusion are included. On the other hand, negative externalities could include deterioration of the environment due to the construction of roads or inequality due to reallocation of certain industries (World Bank, 1994; World Bank, 2011).

Evidence on the impact of transportation infrastructure can be traced to the studies of railroads, precisely, on the seminal papers of Fogel (1962; 1964) and Fishlow (1965) about the impact of railroads on economic growth in the US in the 19th century. In his papers Fogel used quantitative analysis to measure what would have been the impact of railroads and compared this transportation with river boats. Subsequently, specialized literature has emerged to measure the impact not only of railways but also of roads and highways on different determinants of economic growth.

Some of those studies have found that roads and highways are beneficial to suburbanization (Lahr, Duran & Varghese, 2005), skill premium (Michaels, 2008), industrial earnings (Chandra & Thompson, 2000), GDP (Kwon, 2000; Fan & Chan-Kang, 2002) and household income (Corral and Reardon, 2001).

Mostly, the empirical evidence shows that roads are good for economic growth. However, those results also depend on the period of analysis, the country, the type of road (e.g. rural roads, paved roads, highways, motor highways), and measurement of the infrastructure (e.g. investment, physical infrastructure, intensity of use of road, density road, roads per capita). For instance, some studies have pointed out that roads promote income inequality between regions crossed by roads and those regions further away from them.

Studies on transportation infrastructure show that when a country has a greater rate of urbanization, highways are important for rural development. In United States (US), Chandra & Thompson (2000) found that industry earnings were 5-6% greater in rural counties crossed by a highway than those further away. For their analysis, these authors used panel data from 1969 to 1993. Using Pooled OLS and IV, Michaels (2008) proved that highways also increased earnings and the skill premium in rural counties closed to the interstate highways. He quantified the earnings for rural connected counties in 7-10 points more than non-connected rural counties.

Studies for roads and poverty are only available for developing countries. For example, in China where half the population lives in rural areas, Faber (2014) demonstrated that industrial output and GDP increased 18% more in counties connected to highways than in counties without the infrastructure. The same effect is shown by Michaels (2008) for US; this author applying OLS and IV for a 9 year period, got the same conclusion.

Studies about poverty can only be found for developing countries. For instance, Kwon (2000) examines the effect of roads on poverty in Indonesia between 1976 and 1996. Using OLS and IV, the author measures the elasticity of road density (1,000 km/km^2) to poverty for provinces with good-roads and bad-roads. According to his findings, good roads reduced poverty by 0.33%, and bad roads reduces poverty in only 0.09%.[12] In this study, he found that provincial roads lead to a direct improvement in the wages and employment of the poor, such that a 1% increase in road investment is associated with a 0.3% drop in poverty.

In the Philippines, Balisacan & Pernia (2002) using OLS and panel data (fixed-effects and the random-effects) with IV, found that a 1% increase in road density reduced the income of the poorest 20% of the population. According to these authors, this implies that most of the benefits from the roads went to the richest. In the same study, they proved that when provision of roads was accompanied with more schooling investment, the impact was positive for the poor since a 1% increase in road density was directly associated with a 0.11% increase of the poor's income.

Another study at province level on rural areas by Fan, Zang & Zang (2002) shows that different types of roads have different effects on poverty. These authors show that roads reduced rural poverty in China by increasing the productivity in agriculture and the employment in non-agriculture activities. According to them, the elasticity to road density of agricultural GDP was 0.08%, and the elasticity for nonagricultural employment was 0.10%. Moreover, they found that an additional kilometer of road per every 1000 km^2 of area increased the wages of nonagricultural workers by 0.15%. An achievement of this study is the quantification of the impact of investment in roads on poverty. They show that roads have one of the largest impact on poverty reduction in China: for every 10,000 yuan invested on rural roads, 3.2 poor persons are estimated to be drawn out of poverty.[13]

Rural roads have shown to be more efficient in less developed countries. Gibson & Rozelle (2003), Aggarwal (2014), Khandker, Bakht & Koolwal (2009) have evidenced that rural roads are more efficient to reduce poverty. Using a probabilistic model, Gibson & Rozelle (2003) estimated the likelihood of a household to get out of poverty in Papua New Guinea. According to their findings, households had 5.3% more chances of getting out of poverty when their community had a paved road. In rural counties some externalities have been investigated by Aggarwal (2014) & Khandker, Bakht & Koolwal (2009). Aggarwal (2014) has found that in India, rural roads changed the consumption of the poor by replacing their diet with more and better grains. Moreover, farmers increased their agricultural productivity because they were more likely to adopt hybrid seeds and fertilizers.[14]

There is less evidence of the impact of roads for Latin America and Mexico. Regardless of the region, their transportation infrastructure has been positive for economic development. In Nicaragua, Corral and Reardon (2001), using a probit model and the national household survey for 1998, found that

[12] For Kwon (2000) good roads are high quality roads such as highways, bad roads are those with lower quality like feeders and rural roads.

[13] A similar study was done in Tanzania by Fan, Nyange & Rao (2005). Using household survey data, they proved that public investment and roads increases the poor's income in a ratio of 1 to 9.

[14] In Bangladesh, Khandker, Bakht & Koolwal (2009) show how access to rural roads can influence positively poverty via improvements in the agricultural productivity. Aggarwal (2014) proved that roads were allowed farmers to use fertilizer and hybrid seeds.

rural counties with better quality roads had twice the opportunity to increase the wage and income of people in non-agriculture activities. A study on Peru found similar evidence, where Escobal (2001) found that access to new and improved roads in rural areas enhanced the opportunities of non-agricultural workers.

More research than in other countries in Latin America have been done in Mexico. Most of the studies have used aggregate production-functions and industry specific cost-functions using Gross Value Production or GDP, but none have focused on poverty.[15] Moreover, Duran-Fernandez & Santos (2014, p.18) confirm that "[…the linkage between economic activity and transportation infrastructure has not been fully studied for Mexico and the literature only presents a limited number of examples]". The conclusion about the contribution of roads to economic growth is ambiguous. For instance, German and Barajas (2014), Chiquiar (2004), Fuentes & Mendoza-Cota, (2003), and Mallick & Carayannis (1994) consider roads have benefited, but Feltenstein & Ha (1998) and Shah (1992) suggest that the national road network creates spatial inequalities. They also claimed that when infrastructure is not appropriated it represents a constraint for economic growth.[16]

2.1 Addressing Causality in Roads Placement

Empirical evidence shows that richer countries have more and better endowments of transportation infrastructure, or as the World Bank claims "infrastructure is strongly correlated with a country's average income" (World Bank, 2011, p.6). However, it remains unclear how to interpret this correlation. In other words, there is not a consensus on whether economic growth is a consequence of more transportation infrastructure, or if roads are constructed in richer areas or places with potential to generate economic growth (i.e. areas with more natural resources, human capital or industrial clusters).

One of the first authors to overlook this issue was Fogel (1964) in his study about the impact of railroads on economic growth. For solving the reverse causation problem, he designed alternative routes that connect cities in the West to cities in the East of US based on a cost-efficiency analysis. However, he could not solve the minimization problem, and he was unable to avoid the problem of reverse causality.

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15 There are studies that examines poverty but they analyzed the impact of rural roads or paved roads in small communities or municipalities. An example is the study of Acayucan by Gonzalez-Navarro & Quintana-Domeque (2012).

16 Feltenstein and Ha (1995) study the effect of transportation infrastructure in the national income for 16 major sectors of the economy between 1980 and 1990. The authors found that increased expenditure on infrastructure has rapidly decreasing benefits and it is unproductive.

Subsequent and recent studies on railroads and highways have used econometric techniques to measure the contribution of this type of infrastructure.[17] Econometrically, reverse causation occurs when the independent variable (e.g. rural roads or highways) is potentially caused by the dependent variable (e.g. GDP, income, wages, salaries, poverty). If this concern is overlooked, the effect could be overestimated or underestimated caused by omitted variable bias (Fan & Chan-Kang, 2002). Serven (2010) points out that recent literature finds smaller (and more plausible) effects than those reported in the earlier analysis partially as consequence of improvements in the methodological approaches. Recent studies about evaluation of infrastructure use cross section analysis, panel data and times series analysis to measure the impact of infrastructure. In those studies, reverse causality is addressed including relevant omitted covariates, differentiating, using lags or the IV approach.[18]

Analysis with IV approach frequently uses counterfactuals. These counterfactuals aim to estimate what would have been the placement of the roads if their only objective would have been to connect the cities. These counterfactuals aim to show that the placement of roads or highways is exogenous or not related to previous characteristics of the communities where they were constructed. Table 1 shows that some of those counterfactuals. They can be classified in the following categories: a) straight lines, b) alternative roads, and c) probabilities.

The first category consists of drawing *straight lines* that link historical cities or places in order to simulate what would have been a possible road in a period or era when the economic activity and the political interests were not related to the time when the construction of the infrastructure started. The second category simulates what would have been an alternative road network based on minimization costs analysis. This counterfactual uses some techniques from civil engineering that take into account cover land and elevation data, and commercial or military historical routes. The third category consists of estimating the probability of getting the infrastructure given a set of characteristics of the village, county, or province before the infrastructure was constructed. The variables included in these models are selected based on the description of the targets that the projects described *a priory*.[19]

Straight lines and alternative roads are created using geo-referencing techniques. An example for *straight lines* can be seen in Bernarjee, Duflo and Qian (2012). In their study about the impact on economic growth, these authors used historical data from the principal cities and ports in 1860 in China. Using straight lines to connect those places, they simulate what would have been the railroad's route if the only objective was connecting those cities. These instruments measure the distance from the line to the highway, or the distance from the centroid or capital of the counties to the closest line or alternative road.

[17] For more details see Fan & Chan-Kang (2002) & Ahmed & Donovan (1992).
[18] For further details see Chapter 15. Instrumental Variables Estimation and Two Stage Least Squares, Wooldridge (2012).
[19] This type of counterfactuals measure indirectly how policy makers deviate their decisions for favoring certain places or population groups. In the literature these type of techniques are useful to analyze corruption, electoral preferences, and other behaviors when constructing roads. For more details see Faber (2014).

In his study for China, Faber (2014) improves the technique propose originally by Bernarjee, Duflo and Qian (2012). He uses two counterfactuals: a Euclidian minimum spanning that consists in connecting points or nodes (e.g. cities, towns) by minimizing the distance of the total lines in such way that all points can be reached from another place; and, a least cost path spanning trees that connects points based on a minimization costs using geographic data.

A good example for counterfactuals with historical data can be seen in Donaldson (2010). In his study of railroads in India, he used and contrasted four historical routes: a planning railway proposed by the India's Railways Department between 1870-1947; a proposal by the Viceroy John Lawrence (head of the Government in India) in 1868; an alternative from the Bombay and Madras Chambers of Commerce, and maps and routes from the Indian's Chief Engineer.

Table 1. *Strategies for Addressing Reverse Causality in the Placement of Roads*

Type of Transportation Infraestructure	Country/ Period of Analysis	Unit of Analysis	Variable of Interest	Type of Analysis	Definition of the Infrastructure/ Indicators	Strategy for Correcting Endogeneity
Railroads						
Attack *et al.* (2009)	◦ United States (Indiana, Illionois, Ohio and Wisconsin) ◦ 1850s-60s	Counties	◦ Population density ◦ Fraction of population in urban areas	Difference in difference models with instrumental variables (IV)	Binary variable	Straight lines
Donaldson (2010)	◦ India ◦ 1853-1930	Districtes	◦ Trade costs (salt price) ◦ Trade flows ◦ Real Income	Structural models with IV	Units of railroads in kilometers	Straight lines (four different types)
Barnejee, Duflo & Qian (2012)	◦ China ◦ 1986-2006	Provinces	◦ GDP ◦ Household Income ◦ Inequality (Gini)	Difference in difference models	Distance from a centroid to the straight line	Straight lines
Highways						
Chandra and Thompson (2000)	◦ United States ◦ 1969 to 1993	Counties	See Appendix B, Table 6	Fixed effecs (ex-ante and expost)	Probability of new highway to be built, conditional to previous earnings/economic growth rates in the counties	◦ This study uses probabilities counterfactuals. It controls for the age of the the highway.
Michaels (2008)	◦ United States ◦ 1959-1975	Counties	See Appendix B, Table 6	OLS and IV (ex-ante and expost)	Indicator that measures the distance from the county	**Instruments:** ◦ Historical and original plans routes proposed in 1944 but never built. ◦ County's direction to the next city
Faber (2014)	◦ China ◦ 1992-2003	Counties	See Appendix B, Table 6	OLS and IV (ex-ante and expost)	◦Binary variable (has or not highway), and ◦ Straight lines	**Instruments:** ◦ Least Cost Path ◦ Euclidean network **Controls:** ◦ Dummy for prefactural city or township in 1990 ◦ Distance between counties and nearest targeted metropolitan city center
Rural roads						
Aggarwal (2014)	◦ India ◦ 2001-2010	Districts	◦ Poverty	Difference in difference with fixed effects	Percentage of population that received a road in each district (aggregated from villages)	◦ The author estimates the likelihood of constructing a road given the characteristics of the village. He compares these findings with the original plan routes prosed by the Social Program.
Khandker, Bakht & Koolwal (2009)	◦Bangladesh ◦ 2001-2010	Villages	◦ School enrollment ◦ Employment ◦ Occupational choice ◦ Innovation in agriculture ◦ Changes in consumption ◦ Quantities consumed	Fixed-effects quantile model	Binary variable	◦ The models include controls for households and time.

Source: Author's elaboration.

3 Context

3.1 Poverty, Economic Growth & Road Development in Mexico

A difference with other countries with strong social welfare states is that in Mexico poverty is highly sensitive to changes in the economic cycle and external shocks. Authors Lusting, Arias & Rigolini (2002) have pointed out that in Mexico the poor move one-to-one with overall average incomes, suggesting that poverty reduction requires nothing more than promoting rapid economic growth.

The actual condition of the economy and welfare state is a consequence of major policies and reforms that occurred in the early years of the last century, after the Revolution War in 1920. In 20th century three different economic models were implemented: the *Industrialization by Import Substitution (IIS)* from 1940s to 1960s, the *Stabilizing Development* from 1960s to 1980s, and the *Neoliberal Model* from the early 1980s to the present. Each model had different repercussions on the social and economic development of the country (Aspe, 1993).

During the first half of the past century, ambitious projects of infrastructure were carried out (e.g. roads, banks, and the irrigation systems) and financed due to the higher annual growth rates of GDP.[20] This period establishes the basics for the transition to industrialization, urbanization and the construction of the first stage of the modern road network. The new road network had as its objective to replace railroads, and to integrate the federation by connecting the capitals of each State to Mexico City.[21] Moreover, after the expropriation of the oil and mining industries and the railways from American and British companies, the demand for transportation infrastructure prioritized the investment on highways for development of the oil, automotive, and construction sectors (Chias, Reséndiz & García, 2010).

The second part of the century started with the launching of the *IIS* in 1947.[22] The industry promotion with strong state controls and protections increased the labor demand for the developing industry. Moreover, the need for mobilizing the factors of production (labor and capital) encouraged a second

[20] In the 1930s, the rates of growth of GDP were 5.8% on average. During the *Great Depression* in US it was no longer possible to finance those projects due to the decline of foreign demand of basic commodities (e.g. raw materials, oil and minerals). As consequence, unemployment rose and real wages went down (Villegas & Meyer, 1970).

[21] The backbones were constructed in parallel to the railways. Chias, Resendiz and García (2010) pointed out that this decision evidenced the planning incompetence of the government to integrate the territory. According to these authors, the new highways created more spatial concentration favoring Mexico City and other cities of second and third order such as Guadalajara, Monterrey, Aguascalientes and Merida.

[22] *ISI* promoted industrialization based on the protection, promotion and industry regulation that would decrease external dependency of imports. Some regulations were the exchange rate, fees and tariffs to encourage industrial investment.

highways construction stage. During this period the road network grew more than three times from 21.4 thousand km in 1950 to 73.8 thousand km in 1970, especially in the route from the capital to the northern border. However, this kept the south and southeast in backwardness (Chias, Reséndiz & García, 2010).

During the *Stabilization Development*, also known as *The Mexican Miracle*, the fast and high economic growth (i.e. rates of growth of GDP 7% annually) promoted high living standards in urban and rural areas (Aspe, 1993). The economic boom allowed the expansion of roads to small towns and isolated villages with roads and rural roads that permitted the entrance of teachers, doctors, and the provision of basic services. In spite of the fact that the total lengths of roads increased from 73.8 thousand km in 1970 to 212.6 thousand km in 1980, the infrastructure was insufficient to interconnect 33% of the 2,377 municipalities that did not have access to roads in those decades.

The Lost Decade started with a debt crisis in 1982 and the collapse of the international oil market. During this period, the construction of infrastructure was related to the development of transnational tourism and the oil industry. The coverage included the coasts and the connections between regions and urban areas (Aspe, 1993). However, areas of difficult access such as mountainous, jungles and desert areas and their populations were excluded from the development. In the 1990s, after the adoption of NAFTA, the state implemented ambitious transportation infrastructure projects to promote competitiveness. Only during the 1988-1994 administration, the length of roads increased six times the length when compared to the length of existing roads in the 1940s (Chias, Reséndiz & García, 2010).

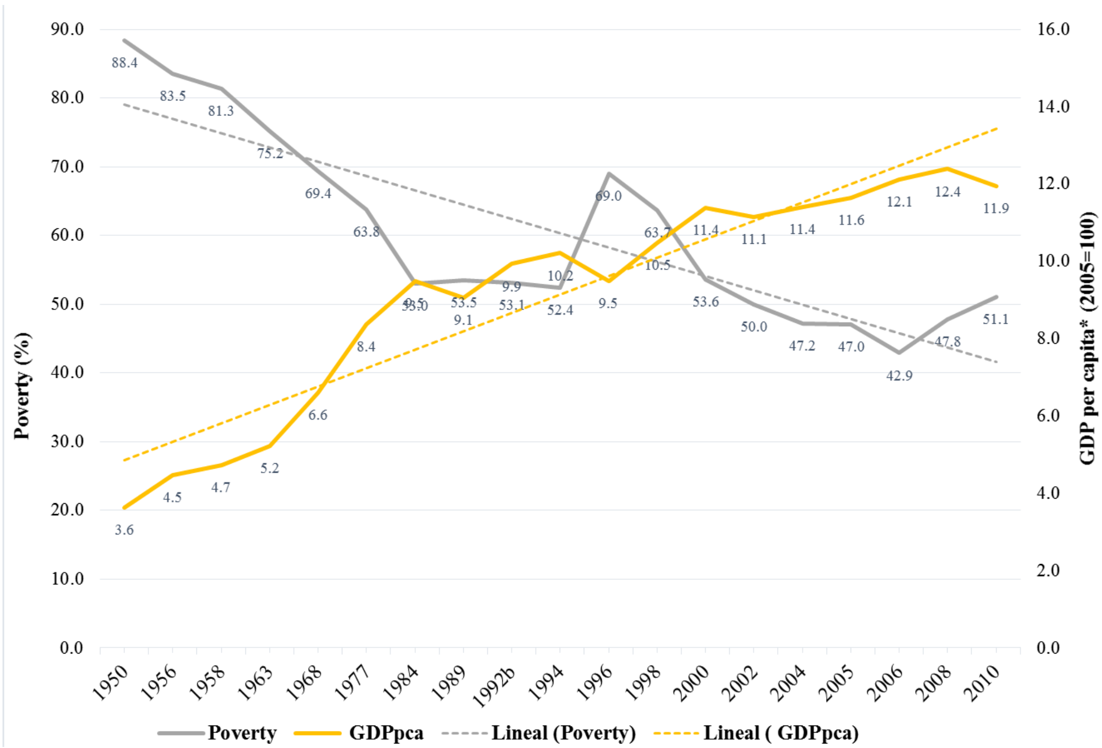
Although there is no historical indexes to trace back the evolution of poverty in the country during last century, some indicators from the census of population show that during the first decades, the improvements were done in terms of basic dotation of public services and education. For instance, the rate of adult literacy was 20% in 1985, but in 1950 it had increased to 80% (INEGI, 2014a). Figure 1 shows the poverty evolution in Mexico during the second part of the 20th century. As it can be seen, the percentage of population living in poverty reduced constantly from 1950 until 1980. This period includes the reforms applied during the *IIS* and the expansions of employment in the industrial sector that mobilized masses of population from rural areas to the growing cities.[23]

The characteristics of the adjustments of the crisis in the 1980s were unprecedented peaks in the exchange rates and volatility of prices that had implications in wages and non-wage income contractions. Only in this decade the GDP per capita (GDPpc) fell an average of 1.8% annually and wages 8.6% per year (Aspe, 1993). However, the levels of poverty from 1984 until 1994 were stable and they were decreasing despite the consequences of the crisis. This period ended with a deep fiscal

[23] Stabilizing Development covers 1960-1980. This period characterizes for rapid economic growth and economic stability because the rates of growth of GDP were 7% annually. In the manufacturing sector, the rates were on average 8.8% (Aspe, 1993).

economic crisis near the end of 1994, which lasted until the first half of 1995. In 1996, three out of every four Mexicans lived in poverty.

Figure 1. *Poverty and Economic Growth in Mexico, 1950-2010*



Source: CONEVAL (2014c), Heston, Summers & Aten (2012), & Székely (2005).
Notes: Poverty data from 1950 to 1989 was taken from Székely (2005); subsequent years were taken from CONEVAL (2014c). *GDP is at US dollars in constant prices of 2005. This data comes from Heston, Summers & Aten (2012).

Table 2 shows that during the period of analysis, GDPpc has duplicated twice its value from 1990 to 2010. In recent years, the growth rate of the GDPpc has not increased more than 2.6% annually. However, that wealth has not reflected on the household income, which has practically not changed: within this period, it has only increase 160 pesos, approximately $16USD. Moreover, external shocks like the international crisis of 2009, tend to rise unemployment and decreases real wages. During the crisis of 2009, the levels of poverty were similar to those at the beginning of the 1990s, when half of the population lived in poverty.

***Table 2**. Macroeconomic Indicators. Mexico, 1990 and 2010*

Indicator(s)	**1990[a]**	**2010**
GDP per capita (thousands of pesos) [b]	6,427	11,010
Average annual growth rate of GDP	2.6	
GDP by sector share [c]	100.0	100.0
Primary	6.7	3.5
Secondary	28.1	36.4
Terciarty	65.2	60.1
Mean household per capita income [d]	3,310	3,479
Annual inflation rate [e]	1.5	9.8
Unemployment rate [f]	3.1	4.1

Source: Author's calculations based on ENIGH 1992 and 2010.
a. ENIGH is only available for 1989 and 1992, the values for 1990 are those calculated based on ENIGH 1992.
b. National Accounts from INEGI. GDP in constant prices (2012=100).
c. World Development Indicators, World Bank (2014).
d. ENIGH 1992 and 2010. Total current income at constant prices (2012=100).
e. INEGI (2012=100).
f. Encuesta Nacional de Empleo 1992 and Encuesta Nacional de Ocupación y Empleo 2010, INEGI.

Even though the monetary dimensions for reducing poverty are a challenge in the country, there are some advances in other non-monetary aspects. Table 3 displays certain indicators that have improved over the last two decades. Advances in health services and social security in the last decade should be highlighted, in which the access to health services increased by 66%. In a longer period (1990-2010), other indicators show progress: the Infant Mortality Rate (IMR) has decreased by 50% and social security has risen by 43%. Moreover, there has been improvements in the coverage of basic services in the dwelling (e.g. electricity, piped water, and sanitation).

Table 3*. Socioeconomic Indicators. Mexico, 1990, 2000 and 2010*

Indicator(s)	1990	2000	2010
Education			
School attendance, children 3-5 years old [a]	62.9	85.2	71.9
School attendance, children 6-15 years old	86.0	90.3	94.1
Health			
Access to health services [a]	NA	41.4	66.8
Life expectancy	71.7	73.9	75.6
Infant Mortality Rate (1000 live births)	31.5	19.4	16.2
Social Security			
Percentage of households with social security (it includes those houseolds that received benefits from the social programs)	30.7	49.9	60.5
Housing			
Dwelling with proper roofing, flooring, walls and overcrowding	58.5	70.6	83.0
Dwelling with proper flooring	79.2	85.1	94.2
Dwelling with proper roofing	87.6	93.3	97.3
Dwelling with electricity	86.9	95.2	98.1
Dwelling with drainage system	59.7	73.1	88.0
Dwelling with piped water	75.8	84.2	88.4
Inequality [a]			
Gini	0.543	0.552	0.499
Ratio of the average inocme of the richest10% and the poorest 10%	31.3	36	25.2

Source: Author's elaboration based on CONEVAL.
a. Reporte de Evaluación en México 2014, CONEVAL (2014d).
NA (Not Available).

Improvements in social dimensions are consequence of the social programs created after the financial crisis in the mid-1990s like the cash transfer program *Oportunidades,* which also supplies health services and promotes education. Amongst these programs there is *Seguro Popular*, which aims to provide universal access to health services and *Piso Firme* that constructs concrete floors.[24] At the beginning most of those programs targeted households in rural areas due to their higher levels of poverty. However, in recent years, the coverage has included urban areas, where 80% of the total population

[24] CONEVAL (2015) counted 234 social programs and actions that focused on different aspects of social development. This list is done annually and shows how over the last 10 years they are increasing.

lives. Table 4 shows the evolution of rural and urban poverty from 1992 until 2012. As it can be seen, in rural areas poverty is almost twice than urban areas. In these places, two out of every three live in poverty. However, in the urban areas there are millions of people in the same condition.

Table 4. *Rural and Urban Poverty in Mexico, 1992-2012*

Year	**Urban**		**Rural**	
	Percentage	Million	Percentage	Million
1992	44.3	23.1	66.5	23.0
1994	41.2	22.2	69.3	24.8
1996	61.5	34.7	80.7	29.3
1998	55.9	32.4	75.9	28.3
2000	43.7	26.2	69.2	26.5
2002	41.1	25.7	64.3	24.7
2004	41.1	26.5	57.4	22.1
2005	38.3	25.1	61.8	23.8
2006	35.8	24.3	54.6	22.2
2008	40.0	27.9	60.9	25.5
2010	45.3	32.4	60.7	26.1
2012	45.5	33.3	63.6	28.0

Source: CONEVAL (2014c).

Some hypotheses that explain the gaps between rural and urban areas are studies by Nicita (2004), and Legovini, Bouillon & Lustig (2004). They suggest that the deterioration of urban areas could be consequences of the trade liberalization in the 1980s. According to them, the neoliberal model affected the economic activity in the counties and deteriorated trade in agricultural products (e.g. coffee, cacao, guaranteed prices) promoting migration of the best qualified workers to urban areas. Those gaps are visible in regions of the country, where the southern region is the poorest and least developed. This is a historical fact. However, some authors have suggested that the regional differences in the last 15 years are consequence of the foreign investment that have benefited more the development of the manufacturing sector in the north and north-center, larger cities, touristic regions and areas where expertise and infrastructure are more competitive (Mendoza, 2006).

Over the last 20 years there has been regional convergence (Appendix B, Table 8). For instance, GDPpc has increased by 42% in the south, in the north-center by 33%, in the center by 26%. However, the north, the richest region, only increased its GDPpc by 11%. This process of convergence has been accompanied by an urbanization process, especially in the north and north center. This is a possibly consequence of the labor migration from the north-center and the south and a consequence of the improvement in the economic conditions in northern cities like Monterrey, Tijuana, Ciudad Juárez (Esquivel, 2009; Mendoza, 2006). It has been claimed that one of the possible factors to explain the backwards in the south could be due to differences in human capital (Legovini, Bouillon & Lustig, 2004), infrastructure (Aguayo, 2006), and investment (Mendoza, 2006). In any case, the south has a unique characteristic: it is the base for 90% of the native population.[25] The indigenous population make up 25% of the municipalities in Mexico, most of them rural. Moreover, they have a higher rate of poverty, as in indigenous municipalities three out of four live in this situation (CONEVAL, 2012; CONEVAL, 2010).

Poverty and Highways in the Space

The actual *National Networks of Roads* (Red Nacional de Caminos, RNC) measures 377.6 thousand kilometers. From this the federal highways are 49.6 thousand kilometers, 40.7 thousand kilometers are free, and 8.9 thousand kilometers are tolled. Tolled roads are mainly operated by private concessionaires. The whole federal system has fourteen main highways that provide a connection between the Atlantic and Pacific coasts, and the northern and southern borders of the country (SCT, 2014).[26]

According to SCT (2014), current roads connect 550 towns in the national urban system, covering more than 64.8 million people in 11 large cities with 23% of the urban population, 112 medium cities with 55% of the urban population lives, and 427 small towns with 22% of the urban population.

Figure 2 shows the distribution of the federal free highways and poverty for the 2,456 municipalities in 2010. The map shows that the actual road network responds to the interactions and areas of influence of Mexico City and the Metropolitan areas such as the Valley of Mexico, the Midwest (Guadalajara), and the north-east (Monterrey). Moreover, it shows that the concentration of highways is denser in the south than the north. In municipalities that are closer to the megapolis the poverty is lower than 25%. Figure 2 also shows that the municipalities in the north have, in general, less poverty than those municipalities in the south, where 3 out of 4 people live in poor conditions. This figure shows that the distribution of highways interconnecting the surrounding municipalities go to towards the direction of the capitals of the States.

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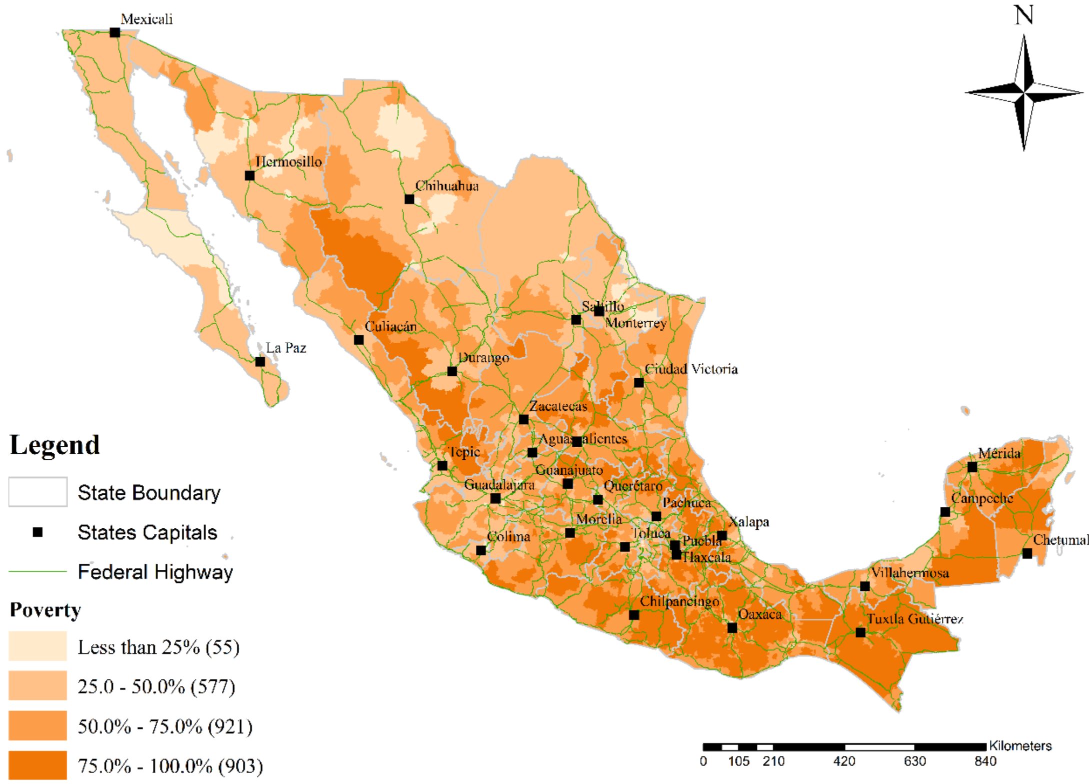
25 For instance, in Mexico the proportion of indigenous has decreased over the last century, from 15.3% in 1900 to 7.1% in 2010 (CONEVAL, 2014a).

26 The RNC includes three additional types of roads: State roads that measures 83.9 kilometers; the rural road network of 169.4 thousand kilometers, and improved connectors that counts 74.5 thousands kilometers (SCT, 2014).

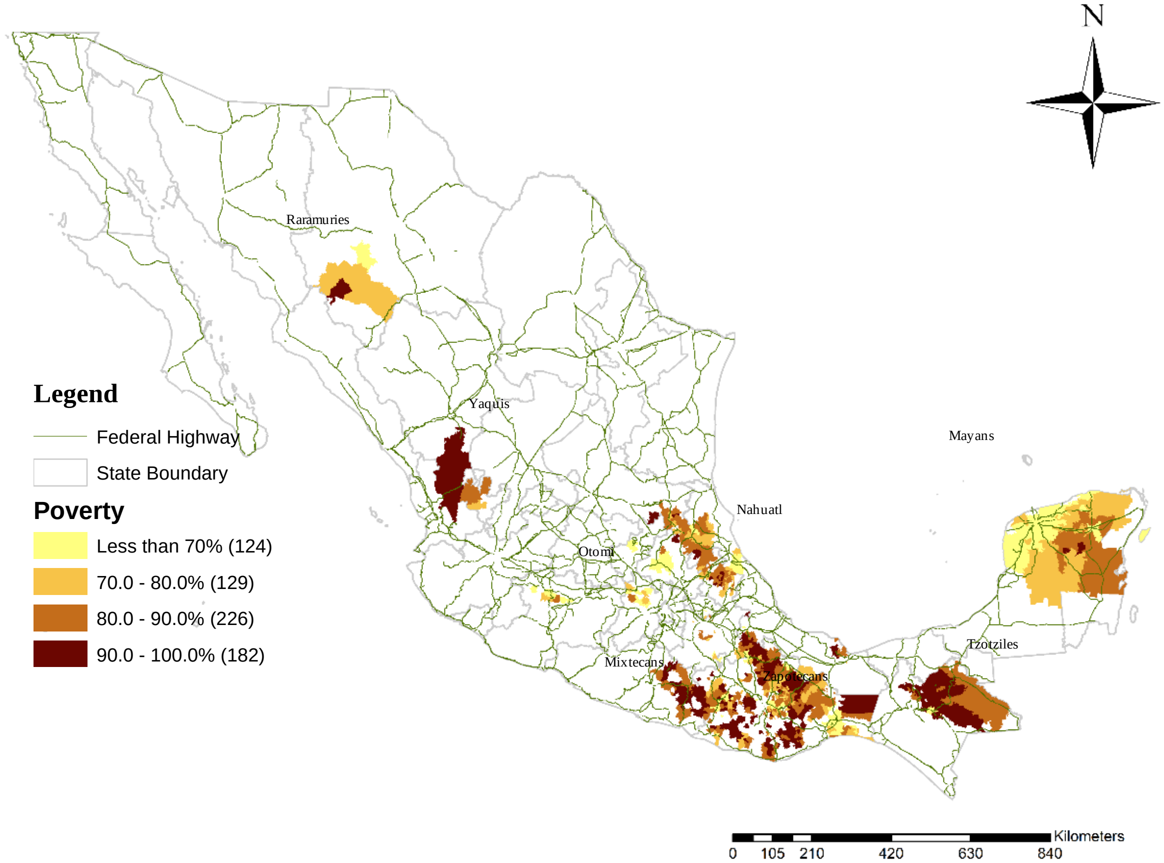
***Figure 2**. Distribution of Poverty and Free Federal Highways in Mexico, 2010*



Source: Author's elaboration based on CONEVAL (2014c) & INEGI (2014b).

Figure 3 shows poverty and the distribution of highways for the indigenous municipalities. These municipalities represents 25% of the total; in 537 of the municipalities (80% from the 25%) poverty was greater than 70%. This map also shows that *Raramuries* municipalities in the north do not have access to highways. The same for *Yaquis* municipalities in the north-western, and *Zapotecans* in the south. On the other side, *Mayans* have lower levels of poverty than other indigenous populations, but none of the indigenous municipalities have a lower poverty rate than 20%. In 2010, 1,127 municipalities were not crossed by any highway. From them, 402 were indigenous. In other words, 60% of indigenous municipalities did not have this type of infrastructure endowment.

***Figure 3**. Distribution of Poverty and Free Federal Highways in Indigenous Municipalities. Mexico, 2010*



Source: Author's elaboration based on CDI (2014), CONEVAL (2014c) & INEGI (2014b).

4 Empirical Strategy

4.1 Econometric Model

In order to measure a possible causal effect of highways on poverty this study uses a model based on OLS. The first strategy estimation is the following:

$$Y_{it} = \alpha_0 + \beta_1 H_{it} + \delta_1 D2_{it} + \delta_2 D3_{it} + \gamma X_{it} + \varepsilon_{it} \,, \qquad (1)$$

where Y_{it} is the percentage of population in the municipality i living in poverty in the year $t = 1990, 2000, 2010$, α_0 is the constant term for regression, and H_{it} is the density of highways per municipality i in each year t. H_{it} is a variable defined as the length of highways in linear kilometers divided by the total area in each municipality i; this variable is expressed in km/100km^2. $D2_{it}$ and $D3_{it}$ are year dummies, where $D2_{it}$=2000 and $D3_{it}$=2010. The year of reference is $D1_{it}$= 1990. X_{it} is a vector of municipality-specific control variables that includes demographic, socioeconomic and regional characteristics for each municipality. Finally, ε_{it} is a residual.

The first category of covariates of the vector X_{it} includes different levels of urbanization. This is defined using the classification from INEGI (2014a), which distinguishes four types of localities depending on the concentration of the population: a) d_loc1 or those municipalities with less 2,500 inhabitants, b) d_loc2 or municipalities with more than 2,500, but less than 14,999 inhabitants c) d_loc3 with more than 15,000 but less than 99,999 inhabitants, and d) d_loc4 or municipalities more than 100,000 inhabitants. Any comparisons in the model in terms of urbanization will be compared with d_loc1 or rural municipalities of less than 2,500 inhabitants.

The second category of covariates includes three variables: (i) a dummy variable that is equal to 1 when the municipality is indigenous, 0 otherwise, (ii) the percentage of adult illiteracy for those individuals who are 15 or older, and (iii) the percentage of labor force employed in the primary sector.[27] The last set of control variables are three dummy variables for the regions north, north-center, center, and south. Any comparisons in the model will be compared with the south region.

The first strategy consists of an estimating equation 1 using Pooled OLS. This model includes the time dummies ($D1_{it}$, $D2_{it}$, and $D3_{it}$) in order to capture the fact that poverty changes over time. The

[27] The primary sector includes agriculture, forestry, finishing and mining.

coefficient of interest is $\beta_1 = \frac{\Delta Y_{it}}{\Delta H_{it}}$, since it captures the change of poverty due to a change in highways.[28]

The second strategy, equation 2, includes interactions between the year dummies and highways in order to capture if the effect of highways is different for every year. In this equation 2, the total effect of highways on poverty will be captured by $\frac{\Delta Y_{it}}{\Delta H_{it}} = \beta_1 + \beta_2 D2_{it} + \beta_3 D3_{it}$. Then the effect of highways in the year $D1_{it}$ =1990 will be captured by $\left.\frac{\Delta Y_{it}}{\Delta H_{it}}\right|_{D1=0} = \beta_1$. The effect of highways in the year $D2_{it}$ =2000 will be captured by $\left.\frac{\Delta Y_{it}}{\Delta H_{it}}\right|_{D2=1} = \beta_1 + \beta_2$, and for the $D3_{it}$ =2010, $\left.\frac{\Delta Y_{it}}{\Delta H_{it}}\right|_{D3=1} = \beta_1 + \beta_3$. The relevance of highways effect of highways in this model will be confirmed by testing $H_0: \beta_2, \beta_3 = 0;\ H_1: \beta_2, \beta_3 \neq 0$.

$$Y_{it} = \alpha_0 + \beta_1 H_{it} + \delta_1 D2_{it} + \delta_2 D3_{it} + \beta_2 (H_{it} * D2_{it}) + \beta_3 (H_{it} * D3_{it}) + \gamma X_{it} + \varepsilon_{it} \quad (2)$$

The third equation (3) captures the effect of highways on poverty in indigenous municipalities by adding some interactions between highways, indigenous municipalities, and the years. If highways have an effect on poverty in indigenous municipalities, it will be shown by the next marginal effect $\left.\frac{\Delta Y_{it}}{\Delta H_{it}}\right|_{I_{it}=1} = B_2 (H_{it}) + \beta_3 (H_{it} * D2_{it}) + \beta_3 (H_{it} * D3_{it})$.

$$Y_{it} = \alpha_0 + \beta_1 H_{it} + \delta_1 d1_{it} + \delta_2 d2_{it} + \beta_2 (H_{it} * I_{it}) + \beta_3 (H_{it} * I_{it} * D2_{it}) + \beta_4 (H_{it} * I_{it} * D3_{it}) + \gamma X_{it} + \varepsilon_{it} \quad (3)$$

If there are omitted variables correlated with both Y_{it} (poverty) and H_{it} (highways), the results from equations 1, 2, and 3 will not be consistently estimated and there will be bias in the magnitude of the impact. In order to avoid this problem of reverse causality, in equations 1, 2, and 3, I use instrumental variables where the instrument is the straight lines described in the following section.

[28] If the effect is significant it will be capture by $H_0: \beta_1 = 0, \beta_1 \neq 0$, where β_1 is the coefficient for highways.

Straight lines

Routes used for economic benefits have origins since the Pre-Hispanic times when the Aztecs developed different routes from Mexico to the South for trading and tax purposes. During the colonial era Spanish authorities made new routes to meet the requirements of the mining industry and the transportation of commodities from the cities to the main ports in the Atlantic and the Pacific. The instrument that I proposed uses this period as a reference, specifically, data of important cities and ports at the end of the 19^{th} century.

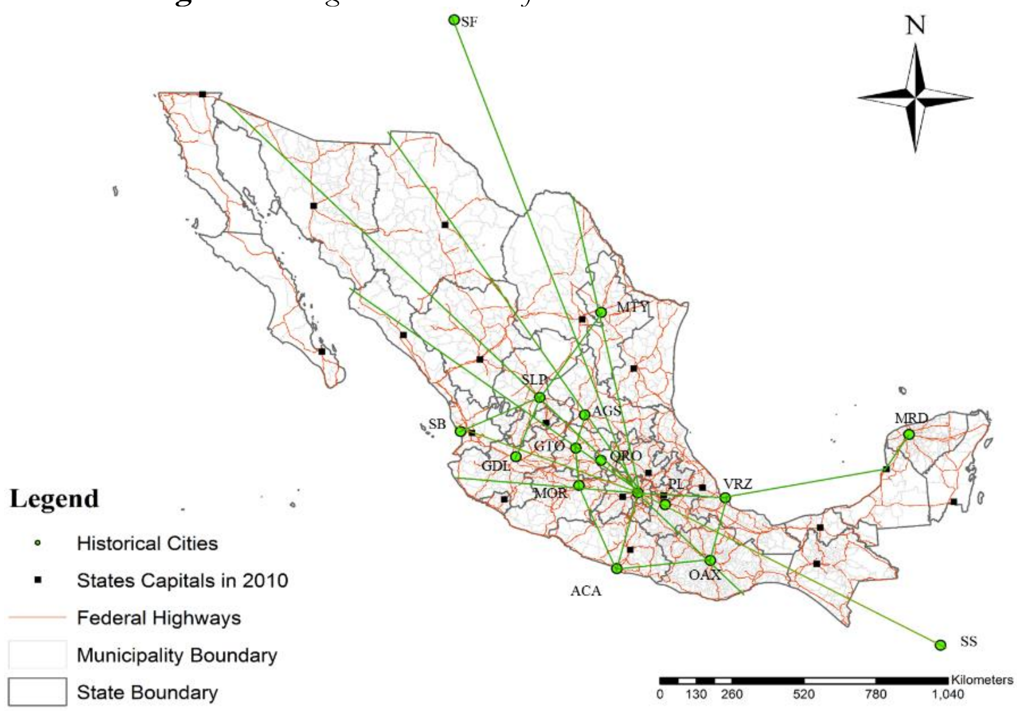
In the 19^{th} century, Mexico City was the most important political and economic center due to the concentration of native population and the administration of the Viceroy of New Spain. According to Ortiz (1974), the principal road in that century was *The Royal Road,* which was designed to connect the administrative capital (Mexico City) with cities in direction to the US and other places in the Viceroy of New Granada (current Central America). The author estimates that in the early 19^{th} century the length of the roads in the country was closer to 12.5 thousand kilometers.

Following Bernarjee, Duflo and Qian (2012), a counterfactual for roads was constructed using the map from Ortiz (1974) as a reference. The strategy is shown in Figure 4 and the procedure is described as follows: I drew different lines from Mexico City to three important Ports in the 19^{th} century: San Blas, Acapulco, and Veracruz. More lines were drawn to connect the capital to cities like Monterrey and Guadalajara; mining cities like Zacatecas, Puebla, San Luis Potosí, and Guanajuato; and, commercial or administrative relevant places such as Queretaro, Morelia, and Merida. The lines continue where there was a city outside the border of the viceroy of New Spain.[29] If there were two cities (or ports) where the difference in distance was less than 100km a line was drawn to connect both of them. Using the *proximity tool* from ArcGIS, I calculated the distance in kilometers from each centroid in a municipality to the closest line in order to avoid possible reverse causation in the construction of roads.[30] Using the historical information in periods where the construction of roads were promoted due to different economic proposals than the ones in recent times, I isolate the effects of the economic decisions in the development of modern infrastructure.

[29] For instance, Santa Fe is a city in New Mexico in US which was part of the New Spain in the 18^{th} century, therefore, a line from Mexico City connected both places. In the south a line was drawn from Mexico City to current days San Salvador in the viceroy of New Granada.

[30] Rather than using the centroid I could have used the municipality capital, however, I was unable to find this data geo-referenced. The centroids of the municipalities were calculated with the *geometry tool* and the North America Lambert Conical Projection.

***Figure 4**.Straight Lines Counterfactuals based on Historical Data*



Source: Author's elaboration based on Appendix A, Figure 5.

4.2 Data

This paper uses data from multiple sources. Measures of poverty comes from CONEVAL (2014c) for 2,443 municipalities in 1990; 2,452 municipalities in 2000, and 2,457 municipalities in 2010. The specific type of measure used is the Headcount Index or the proportion of the population that is counted as poor.[31]

Demographic and socioeconomic indicators for each municipality, such as illiteracy, urbanization, and shares of employment, come from the Census of 1990, 2000, and 2010 reported by INEGI. Regions (north, north-center, center and south) were classified using as a reference The Report of Regional Economies (Reporte de las Economías Regionales), which is published every three months by the Central Bank (El Banco de México).[32]

Data about indigenous municipalities comes from the *Basic Information for the Indigenous Populations in Mexico (*Cédulas de información básica de los pueblos indígenas de México*)* for 1990, 2000, and 2010. This data is reported by CDI (2014). This organization defines four types of municipalities in accordance to their level of concentration of indigenous population:[33]

- *Indigenous municipalities*: municipalities where more than 70% of their total population who are 5 years or older and speak a native language.
- *With indigenous populations*: municipalities where more than 40% but less than 70% of their population who are 5 years or older and speak a native language.
- *With disperse indigenous population*: municipalities with less than 40% of the population who are 5 years or older and speak a native language.
- *Non indigenous*: No population of indigenous people.

Geo-reference data of roads and boundaries come from INEGI (2014b). Roads data was obtained from the *National Networks of Roads*, however, it is only available for 2014. Geo-reference data for boundaries comes from the *National Geostatistical Framework* (Marco Geoestadístico Nacional, MGN) for 1990, 2000, and 2010.

Optimal data to carry out this analysis would have been georeferenced data of highways for the years of study. However, it was not available. Instead, this study uses Annuals Statistical Yearbooks from SCT but reported by INEGI (2014c). This is annual data about the kilometers of highways per municipality from 1990 until 2010 or 2009 (for some observations). This source has several

[31] The indexes of poverty were constructed using the net total per capita income.
[32] See Figure 8 for details.
[33] In this study, I classify the first two categories following CDI (2014).

limitations.[34] First, there is incomplete data about the number of kilometers of roads for all the municipalities for different years. Second, when contrasting this data with other official reports the numbers do not coincide. Third, Oaxaca and Puebla, two of the States with more municipalities have missing values for one or two of the years of the analysis.

In order to solve some of the deficiencies in the data, I imputed some values following the next procedures:

1. When the length per highways was not reported in the yearbooks, I used the next or previous observation (i.e. 1991 for 1990; 1999 or 2001 for 2000, and 2009 for 2010). I assumed and later verified possible discrepancies or radical changes. However, it was not the case that radical changes existed. This procedure was mostly applied to 300 out of 7,352 observations for three years. Those observations were for Oaxaca and Puebla.
2. When the previous procedure was not possible and when there was no consistent data overtime, I used linear interpolations for the calculation of almost 70 observations.
3. Alternative yearbooks and official statistics from other dependencies were used to get an approximation of the kilometers of highway per municipality when data was non-existent. Based on this statistics I calculated the shares of highways per municipality using the georeferenced data for 2014 as follows: I estimated the shares of highways per municipality by using ArcGis and then I multiplied those values by the State endowment reported in the official statistics. The final product was the number of kilometers per municipality. Fifty observations were obtained using this method.
4. Finally, when none of the previous methods were suitable, the observation was deleted from the database.

These resources provided a database of 7,368 observations at the municipality level within 32 States across 3 years of the period: 1990, 2000 and 2010.

[34] One of the reasons for using highways rather than other types of roads was due to data restrictions. This was a recommendation by the staff from the General Direction Highways Maintenance at SCT.

5 Estimation Results

Do highways contribute to poverty reductions? The results presented in Table 5, columns (1)-(7) suggest that they do. The first model shows the effect of highways on poverty without using IV. These results show that holding constant other variables ΔH_{it}, the density of highways lead to a poverty reduction by 0.21 percentage points. The analysis shows that the effect of highways is different in time. In 2000 highways had more impact on poverty reductions. The corresponding poverty reduction was 0.17 percentage points more than 1990.

A possible problem from the previous results is that they may have omitted the reverse causality concern and may have sub estimated or overestimated the effect of highways. If there were omitted variables correlated with both Y_{it} (poverty) and H_{it} (highways), the results of Model 1 would not be consistently estimated. In the case of highways in Mexico, historical evidence suggests that this Model might have problems with reverse causality based on the explanation provided in section 3.1. However, in order to confirm the existence of reverse causality, I performed the Haussmann test. Following Carrasco (2014) and Wooldridge (2012), I performed the analysis by regressing the H_{it} on all the vector X_{it} in order to compute the residual $\hat{v}$. Under endogeneity, the slope $\hat{v}$ is significant, which was the case for the models presented.

Models (2)-(4) show the results using instrumental variables – *straight lines* (z_1) –. In the terminology of the IV approach, we can say that those models are exactly identified since each endogenous variable (*highways*) has just one instrument (*straight lines*) (Wooldridge, 2012). In order to be valid the values obtained from the *straight lines* should have an effect on poverty only through highways. These models suggest that highways and poverty holds an inverse relationship. In other words, that more highways reduce poverty. Furthermore, the IV coefficients and standard errors are larger than the OLS estimates. Model 2 and Model 3 show that highways managed to reduce poverty by 0.401 percentage points for every 100 km^2 of area when holding everything else constant. Here, the coefficient of interest (*highways*) is three times larger than the one presented in Model 1 suggesting that the OLS regression was sub estimating the effect. However, the coefficient is not significant.

Is the effect of highways on poverty reduction different over time? Model 4 includes the interactions with the year dummies in order to capture the impact on highways in each year. In this version, an increase of 1 km of highway per every 100 square kilometers of area leads to a poverty reduction of 2.75 percentage points in the whole period. In year 2000 poverty reduced in 1.6 percentage points more than 1990. In 2010 the reduction was smaller with only 0.27 percentage points.

Do highways have an effect on poverty reductions in indigenous municipalities? Results in columns 5 and 6 suggest that highways reduces poverty for indigenous municipalities. However, the effect is similar to non-indigenous municipalities. In Model 5, the coefficient of highway and its interaction with 2010 are insignificant. Model 6 shows that when including the time, highways reduces poverty in non-indigenous municipalities but it does not in indigenous municipalities. Moreover, this model shows that in 2000 and 2010 highways increased poverty in indigenous municipalities.

Three important aspects rise up from all models: the relevance of the time captured by the dummy years, the relevance of the size of population in each municipality, and the regional effects.

First, those models that included time dummies showed that highways had a stronger effect in the year 2000. This is an interesting finding because in that year a recession was documented, yet poverty did not increase like in other times when there is crisis or economic slowdowns. Székely & Rascón (2005) suggested that poverty in this year did not increase due to the support of the social programs. However, during the 2008-2009 crises, even with the support of the social programs, poverty increased.

Second, all the models show that population agglomeration leads to more poverty reduction. [35] In other words, in urban municipalities with more concentration of population are more likely to reduce poverty; the bigger the population the larger the effect. In these models, semi-rural municipalities (with less than 15,000 inhabitants) tend to reduce poverty by 1 percentage point on average more than those with less than 2,500 when holding other aspects constant. A similar effect is for those urban municipalities with more than 15,000 but less than 99,999 inhabitants. When the municipality has more than 100,000 inhabitants, poverty can be reduced by 7 points.

Third, these models confirm what many authors have discussed in terms of regional integration: the gaps between the regions present a challenge when trying to reduce poverty in the country. These models show that municipalities closer to the US border have greater possibilities to reduce poverty than municipalities in the south.

Moreover, the other covariates related to other determinants of poverty behaved as expected. Municipalities with less endowments of human capital tend to have an increase in levels of poverty than those where the labor force is more educated. Thus, in municipalities where most of the population works in agriculture, mining, and forestry are more likely to have a higher levels of poverty. In addition, the level of poverty increases in municipalities with a higher concentration of native population.

As an exercise of robustness check and for comparison purposes, Table 10 in Appendix B shows the results for the models described above but using as a dependent variable extreme poverty. As it can be seen, the effect is similar to the patrimonial poverty, except for the results for the indigenous municipalities where highways reduced more poverty.

[35] Other regressions that used a different threshold for rural areas (with less than 15,000 inhabitants) lead to similar results to those presented in this document. Results are available upon request.

Table 5*. The Effect of Free Federal Highways on Poverty in Mexico, 1990, 2000 and 2010*

VARIABLES	(1) OLS	(2) IV	(3) IV	(4) IV	(5) IV	(6) IV
Highway density	-0.156***	-0.401*	-0.374	0.873*	-0.258	0.781
Highway density*2000[1]	-0.0167			-2.479***		-2.085***
Highway density*2010	-0.0458			-1.146**		-0.980
Highway*Indigenous municipality					-0.284	-2.020***
Highway*Indigenous municipality*2000						2.526***
Highway*Indigenous municipality*2010						2.588***
Adult Illiteracy Rate	0.866***	0.803***	0.831***	0.854***	0.841***	0.878***
Share Primary Sector	0.133***	0.126***	0.126***	0.132***	0.128***	0.122***
Indigenous Municipality	1.334***	1.642***	1.347***	1.166***	2.570	2.262
Urbanization in the municipalities[2]						
2,500-15,000 inhabitants	-1.126***	-0.904*	-0.977**	-0.992	-1.048**	-1.160**
15,000-99,999 inhabitants	-0.916**	-0.617	-0.719	-0.688	-0.835	-0.876
More than 100,000 inhabitants	-7.669***	-7.377***	-7.370***	-7.004***	-7.586***	-7.238***
Regions[3]						
North	-17.07***	-18.68***	-18.26***	-17.94***	-17.76***	-17.31***
North-center	-6.675***	-7.631***	-7.367***	-7.187***	-7.094***	-6.791***
Center	-2.979***	-3.308***	-3.193***	-3.516***	-3.267***	-3.348***
Year dummies						
2000	4.376***		4.167***	16.26***	4.209***	11.87***
2010	1.744***		1.519***	7.054*	1.496***	4.040
Constant	51.78***	56.39***	53.85***	47.22***	53.01***	48.99***
Observations	7,261	7,261	7,261	7,261	7,261	7,261
R-squared	0.639	0.621	0.631	0.434	0.628	0.497

*** p<0.01, ** p<0.05, * p<0.1

1. In all models the category of reference year dummies is 1990.
2. The category of reference for urbanization is municipalities with less than 2,500 inhabitants.
3. The category of reference is South

Source: Author's elaboration.

Note: The IV models were using 2SLS. The postestimation tests showed that the instrument was significant (p=0.00), and strong enough with an F=56.587 (for being strong it should be greater than 10). Regressions were done using robust standard errors.

6 Final Concerns

The primary objective of this document was to analyze the contribution of road endowments to Mexico poverty's reduction using a specific type of roads: highways. As it was shown, in general transportation infrastructure reduces poverty. Using data for 1990, 2000, and 2010 at the municipality level, the results showed that the road development – highways – lead to poverty reduction.

How big is the contribution of infrastructure? The results showed that for every additional kilometer of highway in every 100 square kilometers of area, poverty reduces by 0.4 percentage points. In other words, 10 km of construction would lead to a reduction of poverty by 4 percentage points if Mexico were a 100 square kilometer country. This is actually the case for 697 municipalities around the 100km^2 threshold, where these seemingly small investment would have great poverty reduction payoffs. The size of the effect is not surprising. Moreover, it is consistent with similar studies.[36]

Is investment on highways a good strategy to reduce poverty? The answer is ambiguous for Mexico given the fact that the country has failed in achieving rapid economic growth and poverty reduction. A proper quantification of the impact of highways should include the hard and soft (e.g. institutions, regulations, procedures) components of the infrastructure. This study only covers the first component; in terms of the hard part of infrastructure and its benefits. One of the most significant findings of this study is that highways have more impact during periods of economic contraction. Some models show that when there is economic stagnation, as it occurred in 2000, when holding other factors constant, highways become more important in reducing poverty. These results suggest that highways might be a possible mechanism for escaping poverty by migrating to places where people are more likely to find a job. Further research is necessary in order to understand if this effect can be generalized or if it was only relevant to that time period.

As mentioned in the previous section, the year 2000 is different from other periods of economic contraction because in this period poverty did not increase. Studies like the one from Székely and Rascón (2005) suggest that it was a consequence of the social programs that help to mitigate the negative impacts. But this finding could help explain a possible alternative way on how

[36] See Banerjee, Duflo and Qian (2012) and later improved by Faber (2014).

people use the infrastructure as a means to improve their economic circumstances in periods of difficulties.

Recent statistics from the census in 2000 and 2010 show that this mobility and temporal migration is a common phenomenon in metropolitan areas (INEGI, 2014a). These censuses show that 13.7% of the total labor force work in a different place other than their municipality of residence. For instance, almost 40% of the labor force in the Distrito Federal (Mexico City) and Monterrey (the second biggest city) commute daily from their municipality to cities for labor purposes. Moreover, the censuses suggest that regional migration is a common and increasing phenomenon, especially for municipalities or States that neighbor a megalopolis.

Another interesting finding is that highway's effect on poverty is almost the same for indigenous and non-indigenous municipalities, however, for the indigenous it is slightly different. Why? Possible explanations includes are that the location of indigenous municipalities in rural areas mostly isolated by mountains and their traditional practices of production (i.e. personal consumption based on maize and bean farming) and exchange (i.e. barter) not linked to markets. Therefore, it is possible that the channel through which this type of infrastructure reduces poverty do not occur as predicted from the theory. In other words, it is possible that economic growth does not favor the poorest among the poor.

When considering the time, highways tend to increase poverty in indigenous municipalities. Why has infrastructure increased the gap for the indigenous in the last years? There are many reasons. First, their restrictions to social mobility due to discrimination and their low educational achievement, which prevent them from migrating to the city in order to find a job. Second, their limitations to speak Spanish. Third, their location as many of them live in scattered and isolated places where it is necessary to construct rural roads before they can benefit from highways.

This study also reveals persistency regional inequalities and poverty. As it has been explained, the historical evolution of roads and its planning have been related to the economic potential of the regions during the different economic models. For instance, Garduño (2014) pointed out that NAFTA has increased inequalities, especially among municipalities that are linked to the exportations sector or where endowments of human capital are more competitive.[37] Other authors, like Aguayo (2006), have suggested that NAFTA is prioritizing those entities closer to US under a logic of transports cost. This is resizing the economy and giving more importance to the north. Both hypothesis can also be useful to explain what has happened in the indigenous municipalities, which are mostly located in rural areas in the south and have agriculture as the primary activity.

[37] An interesting fact during this period is that the population in the north has increased more than the south. It is possible that creations of highways in the south have incentive migration to the north. However, this hypothesis requires further research.

It is important to highlight some of the caveats of this study. First, the limitations related to the variables in the models. For instance it is possible that the covariates included in the study do not capture all the possible determinants of poverty at a municipality level. In all the models education is measured as the percentage of adult illiteracy, which seems to be an important determinant to reduce poverty. However, more accurate models should have included indicators of educational attainment, however, at the moment of collecting data it was not available. Similar concerns arise with the variables of employment in primary sector which may not reflect the reality of a country where the services sector is more relevant. Complementary covariates of income should be included in futures analysis.

Second, although literature on transportation infrastructure suggest the use of instrumental variable for avoiding reverse causality, the results need to be contrasted with other econometric techniques as a robustness check. As part of those checks, next exercises should improve the counterfactual proposed in this study such as the version provided Faber (2014). Moreover, following Fan & Chan-Kang (2002), a more complete analysis should include different types of roads due to the different returns on poverty reductions.

Quality of the roads is not included in this analysis, therefore, it is possible that the impact of the infrastructure will be lower when the quality is bad. In their study, German and Barajas (2014) found that rural areas in Mexico with more infrastructure had higher rates of growth. In the long run, when the infrastructure was insufficient or inadequate, the returns of transportation infrastructure were lower and represented a restriction to economic growth. In a report from SCT (2014) there is evidence that Mexico's infrastructure is insufficient but also in bad conditions. According to this report, only 10% of the federal highways were in good condition, 30% in a regular condition, and the remaining 60% was in bad condition.

A complementary study of the soft components of infrastructure can play an important role for promoting economic growth and reducing poverty. Serven (2010) points out that the efficiency of the infrastructure could be constrained when there is an inadequate institutional framework; this may be the case in Mexico. In his speech, during the inauguration of a highway, the Minister of SCT mentioned that 4 billion pesos or US$307million were invested to construct 149 kilometers. In other words, the cost per kilometer was 26.8 million of pesos or 2 million US dollars. The media and news reported that this was seven times more expensive than in Europe.

Moreover, these projects are associated with corruption, as just the last month the media published an infiltrated conversation between a public servant and a representative of a Spanish company in charge of the construction of the highway in the State of Mexico. The conversion indicates that the budget was overestimated and the quality of the highways do not correspond to the requirements established in the contracts.

What is true, however, is that transportation infrastructure creates negative externalities but also positive ones that are not always easy and immediate to measure. For instance, Gonzalez-

Navarro & Quintana-Domeque (2012) performed a study in the municipality of Acayucan in the State of Mexico, which found that two years after the construction of paved roads in urban areas, poor people increased their consumption of durable goods and acquired more motor vehicles. It is important to highlight the study by Noriega and Fontela (2005), which found that the effect of highways is visible until after eight years of the construction of the highways.

Despite the limitations, this study has some important contributions to highlight. First, the efforts to address reverse causality. Then, the contribution to the literature on infrastructure evaluation that is limited for Mexico. In addition, this is the first study that uses poverty data to better measure the contribution of infrastructure to economic development. Finally, the results presented are relevant to public policy for future projects that aim to reduce spatial and ethnical gaps from an inclusive and an equality perspective.

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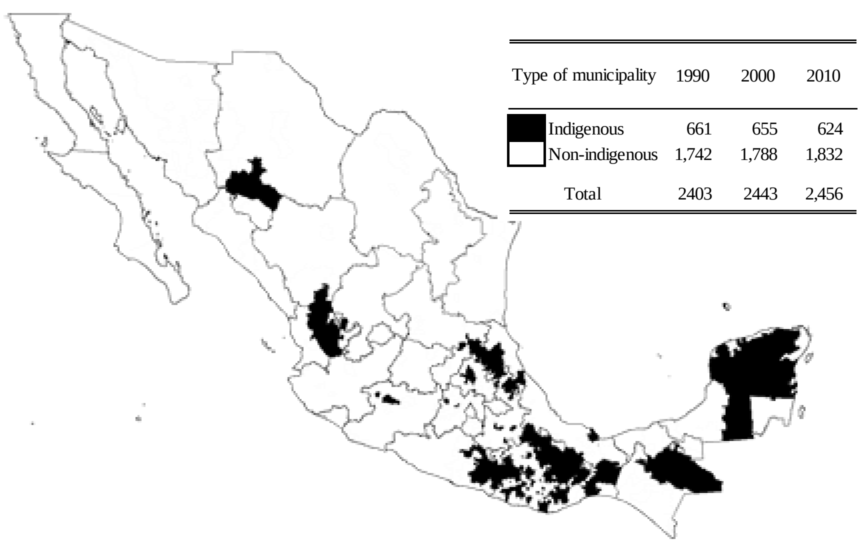
Appendix A: Figures

Figure 5.*Principal Cities and Historical Roads in Mexico*

Source: Ortiz (1974)

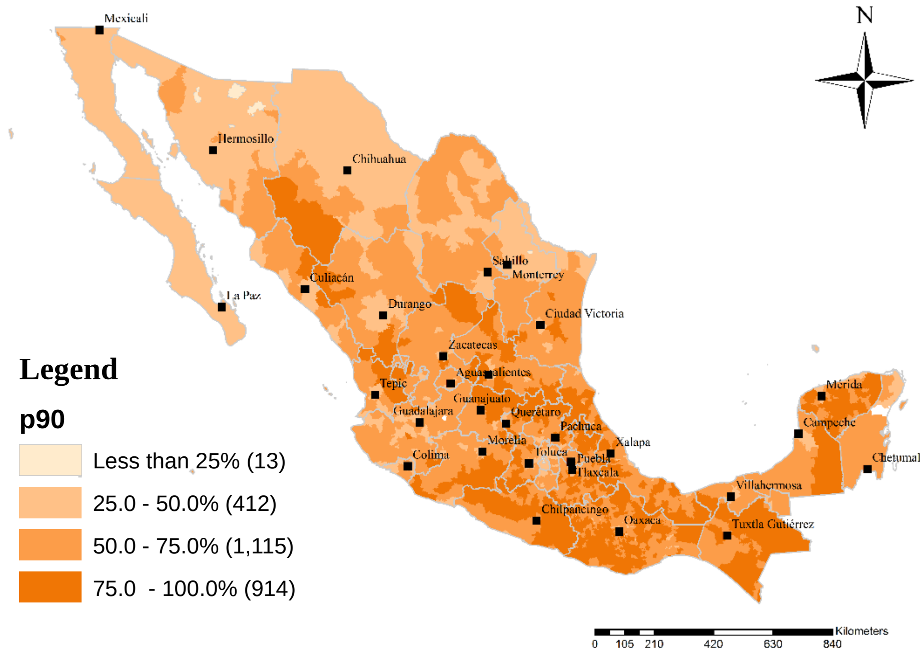
***Figure 6**. Distribution of the Indigenous Municipalities in Mexico*

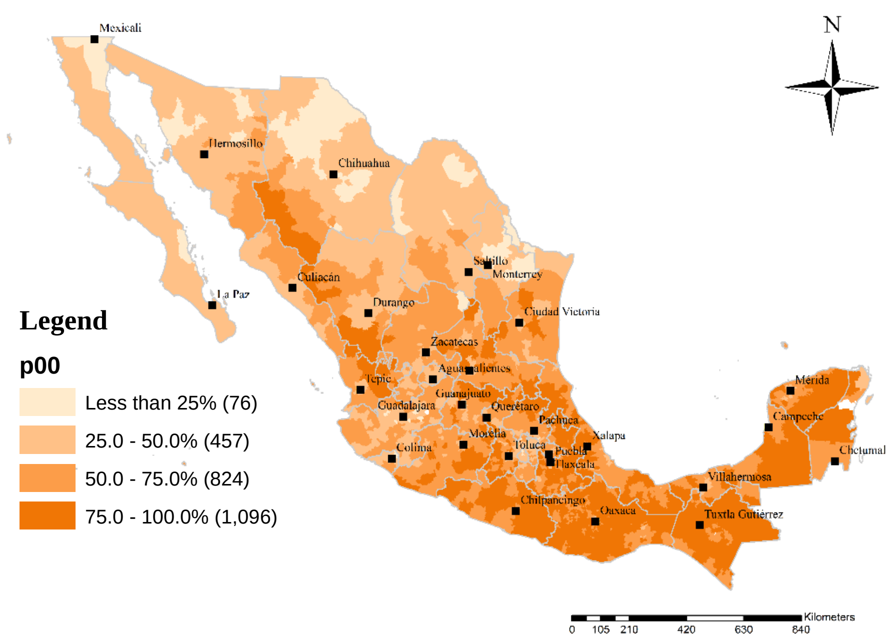


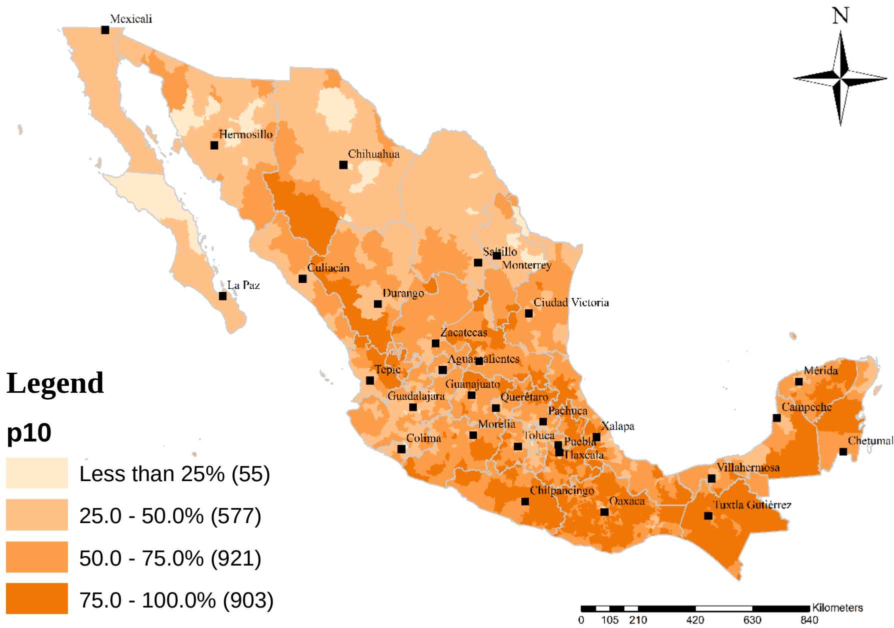
Type of municipality	1990	2000	2010
Indigenous	661	655	624
Non-indigenous	1,742	1,788	1,832
Total	2403	2443	2,456

Source: Author's elaboration based on CDI (2014).

Figure 7. *Distribution of the Poverty in the Municipalities, 1990, 2000 and 2010*

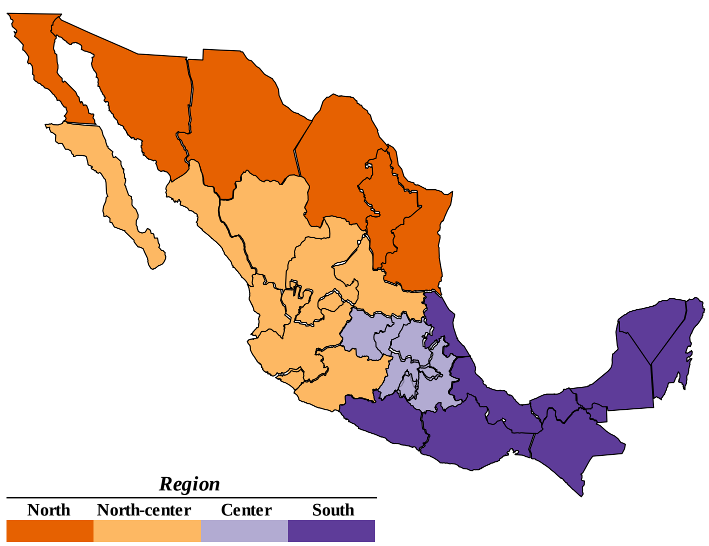






Source: Author's elaboration based on CONEVAL (2014c).

Figure 8. *Distribution of the Regions in Mexico*



Source: Author's elaboration based on El Banco de Mexico (2014).

Appendix B: Tables

Table 6. *Relevant Studies of the Effect on Highways on Different Economic Outcomes*

Country	Author(s)	Variables of Interest	Findings
United States	Chandra & Thompson (2000)	◦ Earnings from manufacturing, services and retails industries	− Different impact across industries − Growth of some industries as consequence decreasing transportation costs − Economic activity reallocation
	Lahr, Duran & Varughese (2005)	◦ Population change ◦ Urbanization	− Different impacts depending on the type of road − Possitive and larger effects on urbanzation in metropolitan areas for highways and arterials than other types of roads
	Michaels (2008)	◦ Skill premia (high skilled-low skilled) ◦ Trade ◦ Industry composition	− Positive effects in rural counties where the infraestructure was provided − Widen inequality gaps between counties closer counties to highways and those further away
China	Faber (2014)	◦ GDP (agriculture, industry and services) ◦ Population change ◦ Industrial Gross Value Added	− Trade costs reductions − Decreases of GDP in distant counties − Industrial output reductions

Source: Author's elaboration.

Table 7. *Poverty Trends. Mexico, 1950-2010*

Year	Poverty	GDPpc[a]
1950	88.4	3.6
1956	83.5	4.5
1958	81.3	4.7
1963	75.2	5.2
1968	69.4	6.6
1977	63.8	8.4
1984	53.0	9.5
1989	53.5	9.1
1992[b]	53.1	9.9
1994	52.4	10.2
1996	69.0	9.5
1998	63.7	10.5
2000	53.6	11.4
2002	50.0	11.1
2004	47.2	11.4
2005	47.0	11.6
2006	42.9	12.1
2008	47.8	12.4
2010	51.1	11.9

Source: CONEVAL (2014).

a. Poverty indexes from 1950-1989 are from Székely(2005), values from 1992-2010 from CONEVAL(2014).

b. GDPpc (2012=100), Heston, Summers & Aten (2012).

Table 8. *Indicators for Four Regions in Mexico, 1990 and 2010*

Category of indicators	North		North-center		Center		South	
	1990[a]	2010	1990	2010	1990	2010	1990	2010
GDP per capita (thousands of pesos) [b]	12,352	13,810	6,923	9,201	8,903	11,234	5,852	8,282
Total population (million people)	14.2	21.0	19.1	24.8	33.2	44.5	20.4	27.0
Urbanization								
100,00 or more	63.1	71.2	39.8	41.5	59.4	54.6	20.5	24.1
15,000-99,999	13.2	13.2	11.7	16.7	13.4	12.3	16.1	17.8
2,500-15,000	3.9	3.9	17.6	17.7	9.5	15.8	19.3	17.1
Less than 2,500	11.8	11.8	30.9	24.1	17.8	17.3	44.1	41.0
Household size	4.2	3.5	4.7	3.9	4.8	3.7	4.9	3.8
Average years of schooling	7.8	10.0	6.7	9.1	7.4	9.5	6.0	7.8

Source: Author's calculations based on ENIGH 1992 and 2010.
a. ENIGH is only available for 1989 and 1992, the values for 1990 are those calculated based on ENIGH 1992.
b. National Accounts from INEGI. GDP in constant prices (2012=100).

***Table 9**. Selected Socioeconomic Indicators. Mexico, 1990 and 2010*

Indicator(s)	1990[a]	2010
Total population	86.9	117.3
Household size	4.7	3.7
Average years of schooling	7.0	9.1
Level of education		
Elementary School	52.7	32.4
Junior High School	20.7	29.6
High School	15.0	19.9
Graduate Studies	11.0	10.1
Postgraduate Studies	0.5	8.1
Urbanization rate	73.8	76.8
Population by size of the locality[b]		
100,000 or more	49.9	6.1
15,000-99,999	13.3	44.3
2,500-15,000	13.2	39.3
Less than 2,500 inhabitants	23.7	10.2
Participation in the labor force: employee (percentage)		
14-17 age group	8.4	5.1
18-35 age group	53.6	44.7
36-55 age group	31.8	40.5
56-65 age group	6.2	9.7

Source: Author's calculations based on ENIGH 1992 and 2010.
a. ENIGH is only available for 1989 and 1992, the values for 1990 are those calculated based on ENIGH 1992.
b. It shows the number of inhabitants according to INEGI's definition.

Table 10. *The Effect of Free Federal Highways on Extreme Poverty in Mexico, 1990-2010*

VARIABLES	(1) OLS	(2) IV	(3) IV	(4) IV	(5) IV	(6) IV
Highway density	-0.133***	-0.405	-0.359	1.071**	0.135	1.310*
Highway density*2000[1]	-0.0941**			-2.662***		-2.036***
Highway density*2010	-0.0241			-1.417**		-1.305*
Highway*Indigenous municipality					-1.212**	-3.641***
Highway*Indigenous municipality*2000						4.019***
Highway*Indigenous municipality*2010						3.308***
Adult Illiteracy Rate	1.042***	0.962***	1.009***	1.039***	1.049***	1.106***
Share Primary Sector	0.0909***	0.0443***	0.0809***	0.0774***	0.0913***	0.0661*
Indigenous Municipality	2.657***	3.319***	2.675***	2.476***	7.898***	7.280**
Urbanization in the municipalities[2]						
2,500-15,000 inhabitants	-0.257	-0.0133	-0.119	-0.165	-0.422	-0.640
15,000-99,999 inhabitants	-1.153**	-0.891	-0.986*	-1.037	-1.480**	-1.694**
More than 100,000 inhabitants	-6.167***	-6.334***	-5.957***	-5.804***	-6.879***	-6.935***
Regions[3]						
North	-12.99***	-14.75***	-14.13***	-13.63***	-12.01***	-11.18***
North-center	-6.698***	-7.818***	-7.359***	-7.077***	-6.191***	-5.663***
Center	-3.764***	-4.172***	-3.953***	-4.265***	-4.271***	-4.171***
Year dummies						
2000	11.63***		11.08***	24.18***	11.26***	17.35***
2010	1.327***		1.349***	8.659**	1.251**	5.503
Constant	17.26***	25.35***	19.36***	11.74***	15.77***	11.60**
Observations	7,261	7,261	7,261	7,261	7,261	7,261
R-squared	0.692	0.630	0.686	0.509	0.635	0.522

*** p<0.01, ** p<0.05, * p<0.1

1. In all models the category of reference year dummies is 1990.
2. The category of reference for urbanization is municipalities with less than 2,500 inhabitants.
3. The category of reference is South

Source: Author's elaboration.

Note: The IV models were using 2SLS. The postestimation tests showed that the instrument was significant (p=0.00), and strong enough with and F=56.587 (for being strong it should be greater than 10). Regressions were done using robust standard errors.