The Long and Winding Roads: Roads, Inequality, and Growth in Colombia.

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Abstract

We measure road improvement and road construction on production and inequality in Colombia from 1993 to 2012, taking into account network effects using a market access approach. We found that roads, by changing market access, have an important effect on GDP growth and all the sectors. We also find that GDP increases with distance to the intervention. We address endogeneity in multiple ways. We use exogenous variation based on the likelihood of receiving a road improvement based on pre-colonial (indigenous) roads least-cost cost path counterfactual road networks that use estimated construction costs; we also build alternative market access measures that focus on quasi-random market access changes stemming from exposure to markets of smaller cities. We find that roads concentrate the land close to that infrastructure in fewer hands. Also, roads have an important effect on municipal development indicators. Roads also seem to have important spillover effects on municipalities located at 35km or closer to the intervention.

1 Introduction

Transport infrastructure has been an important determinant for economic development. Effects of railroads, roads, and massive transportation systems on different variables have been largely studied, especially in developed countries. Between 1950 and 2014, Colombia built more than 86.000km of roads but only until 1993 the country started to bring private investment to the infrastructure sector, including roads, power generating plants, and telecommunications. For this purpose, a new regulatory and legal framework was implemented, allowing the nation to hire private companies to develop public infrastructure using competitive bidding. This allowed increasing the quality and availability of roads in order to prepare the country for trade openness. Since 1993 the country established concession contracts to start improving and building roads. Those contracts were released in different generations. Three generations were executed starting in 1994, 1997, and 2001. Besides the time they started, each generation has a different

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legal mainly to improve risk distribution between the government and the private.

The first generation of road concession started operations in 1996. Most of the roads intervened were close to the country's capital, with some exceptions on the Caribbean coast. The second-generation improved the sugar cane cluster of the country located in the southwest in the $ValledeCauca$. The third generation entailed more comprehensive roads connecting important regional production centers with internal markets and the ports. We use data on the universe of municipalities in Colombia from 1986 to 2014, in the context of an ambitious plan of road improvements and construction implemented through these three generations of concession intervening 4463 km of roads, 23% of the national road network. Besides, we include 2500km of roads built by the public sector directly since 1986.

We examine the impact of roads on the total GDP, the GDP by sector, and inequality using two treatments. The first one is related to changes in the market access, which allows accounting for network effects, and the second is related to distance to the nearest infrastructure. We also investigate the spillover effects that roads might have on neighboring towns, another understudied topic, especially for developing countries.

To estimate these effects, we faced several challenges. The first was to gather the historical information necessary for the study; we went through archival sources in different Colombian institutions and consolidated them. The second problem is that roads' true effects on output variables are given only after complex general equilibrium interactions generally not considered by using only the distance as treatment. We incorporate a market access measure using the initial population as a proxy of markets, capturing network effects. The third problem was endogeneity. Unfortunately, roads are not exogenous. On the contrary, they were developed to link important places(i.e., places with high GDP). For example, in Colombia, until 1960, most important roads were built to link demand centers; after that year, the country started to link supply centers by building new roads. That apparent endogeneity could bring biased and inconsistent results for our estimations. To deal with that, we first test the hypothesis that only economic growth determines the probability of building new roads by following Chandra and Thompson (2000), Moreover, we find no evidence of this. However, like road construction and improvements might not respond to observe. However, to expected growth, we also remove large cities from the analysis, *main cities*, and focus on the impact on incidental cities.

To deal with route selection endogeneity, we also calculated a hypothetical least-cost path between important locations in 1938 and used it as an instrument for distance to the infrastructure and. In addition, we use precolonial routes suggested by Duranton (2015). We also build two instruments for the market access measure. First, calculate the counterfactual market access for each location using the least cost path. Second, we built a market access instrument by subtracting the market access for main cities from the total market access. This exploits the specific changes in market access due to enhanced access to only incidental cities. By doing that, we are getting the quasi-random component of it. This instrument allows for the inclusion of main cities in the analysis.[1]. Through improvements in market access, results show that roads had an important positive impact on total GDP, industry GDP, and service GDP. Its effect on effect on agricultural GDP is not clear. Also, roads help diminish income inequality but increase the concentration of property in fewer owners. One explanation for that is that places near the infrastructure are good for developing big-scale agricultural projects, which implies the concentration of land. However, given the poor effect of roads on agricultural GDP, another explanation is that land concentration happened because of speculation purposes. Also, GDP has positive spillover effects on municipalities within 35 km of the infrastructure. However, that effect is uncertain or negative for adjacent municipalities directly affected by the road. Showing that might be a reallocation of economic activity from adjacent municipalities to those directly affected by the GDP.

1.1 Colombia as a case of study

In Colombia, around 80% of the freight is done using trucks, compared with 71.4% in the US or 76.7% in Europe or 57.7% in Mexico. This fact is striking for several reasons: 1. Colombia has a uniquely broken geography, which makes road transportation inefficient and costly. For example, while driving by car from Bogota to Cali in Colombia entails about the same distance as driving from Miami to Daytona Beach in Florida, US, at 65km/h, the first journey will take 9 hours second will take 3 hours 45 minutes. 2. Although in the '40s, almost 33% of the cargo was moved by rail, a transport model with economies of scale and cheaper operational costs. This transport model was abandoned in favor of trucks. 3. There have been several attempts to develop additional transportation modes for cargo like rail or river, but they never get

[1]Herzog (2020) follows a similar approach with planned roads, which we extend to use actually measured market access

the political capital funded and developed.

Despite the dominance of roads as a transport mode for freight and the big investments done, there are no studies about the effect of roads on economic development for Colombia. Such studies can be used, for example, as a tool to prioritize new roads or the maintenance of the existing ones.

Colombia is also an interesting study case, given its unique geography and its institutional arrangement. The country is crossed by three mountain chains which are the end of the Andes. This feature creates a diversified climate and soil qualities, from snow-capped mountains to multiple beaches and amazon jungle to extensive plain fields. This diversity is driven by the initial geography and directly impacts agricultural productivity; the highest agricultural productivity was obtained at the top of the mountains, in tempered climate. In this climate, there is a low incidence of tropical diseases and were natural protection from the local indigenous tribes[2]. One of the unwanted consequences of this natural division is that the country was fragmented from the start, and this division had long-term consequences for development. As regions are heterogeneous in different ways, we might expect that the effect of roads will reflect it by affecting unevenly different regions in the country.

1.2 Roads, Inequality and Growth

Literature on this topic is abundant for developed countries. However, for developing countries, it is much more scarce. DBerg et al. (2017) does a detailed summary of the latter. Studies have focused on the effects of transport infrastructure on trade (Duranton (2015) and Duranton and Turner (2012)) show that roads increase trade for Colombia and the US respectively. There is an extensive literature showing positive impacts of roads on output including Jedwab and Storeygard (2020) for Africa, Donaldson (2018) for India, and Donaldson and Hornbeck (2016) for the United States ,Banerjee et al. (2012) for China, and within this literature are some recent developments that allow seeing heterogeneous effects on different regions as in Chandra and Thompson (2000) Baum-Snow et al. (2017) and Herzog (2020) showing that the effects of transport infrastructure are not the same for all the geographic areas they affect. These contributions use several explanatory variables either, for example, the distance to new transport infrastructure, or an identifying dummy variable show places affected by the infrastructure or a version of the market access

[2] Safford et al. (2002) explains in great detail the implications of geography for Colombian economic development

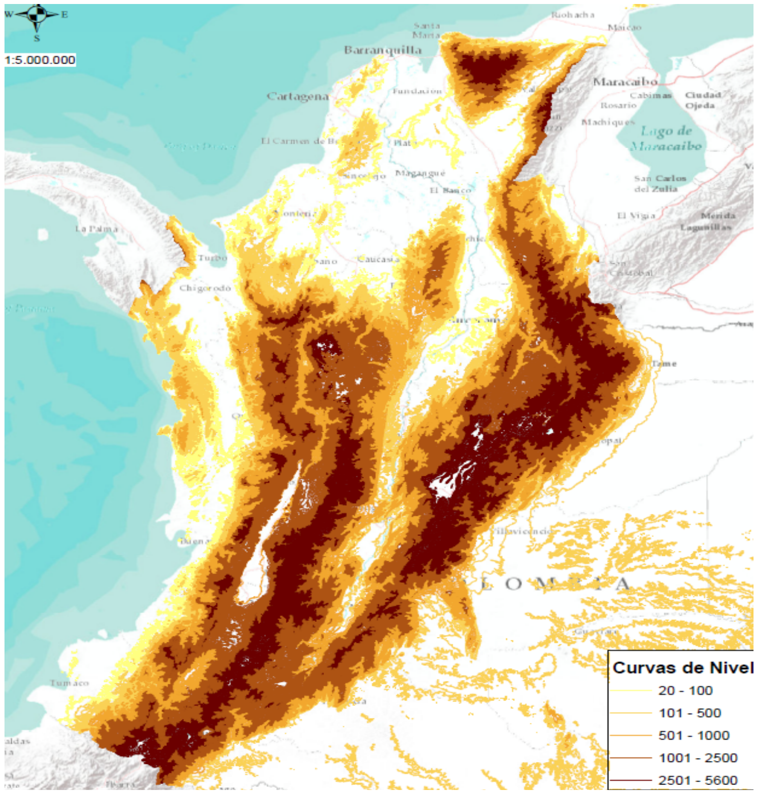

Figure 1: Uneven Colombian Geography

or, in some cases, the number of km of roads or railroads within an area. There is also a branch of the literature that measures welfare effects that imply general equilibrium settings, includes papers as Allen and Arkolakis (2019) for the total road network in the United States, Tsivanidis (2018) which measures effects for introducing a bus rapid transit system in Bogota, Colombia and Donaldson and Hornbeck (2016) the railroads developed in India. There is little research on the effect of roads on inequality, and even less so for Latin American countries. On the theoretical side, it Getachew and Turnovsky (2015) highlights that roads devoted to reducing the needs of the poorest agents tend to reduce inequality. However, roads favoring the wealthier owners of capital tend to increase inequality. According to their model, in the end, distributional consequences will depend on the substitutability between private and public capital in production. Also, Ferreira (1995), introduce credit constraints to show that long-term inequality might remain despite infrastructure investment. In this line of thinking, poor people do not have access to credit, therefore, can not have the required start-up capital necessary to invest in new projects. The middle class has partial access to credit and can start a new investment. However, only the richer people can take full advantage of the infrastructure and the resources necessary to develop wealth. Some of the empirical work in this area try to measure macroeconomic effects of infrastructure on inequality as in Barro (1990) and Calderón and Chong (2004).[3] Although we will use many of the measurement tools presented above, our work has distinctive tools worth mentioning. First, we developed a counterfactual road network using granular geographic information of the country, and we use it as a source of exogenous variation. This instrument, besides being innovative, also has a historical justification for its credibility. Cities linked by this least-cost path were important nodes before the current road system was in place. To make the estimation more exogenous, we take big cities out of the estimation, and municipalities near them are excluded. Our most exogenous results will only take into account incidental cities. However, we created an instrument that allows using big cities. Also, this is going to be explained later on. Finally, we use the common neighborhood effects as in List et al. (2019) estimation to account for spillover effects of infrastructure on nearby municipalities.

2 Roads and geography in Colombia and institutional background

2.1 Colombian Geography and its consequences for development

*"Colombia's history has been shaped by its spatial fragmentation, which has found expression in economic atomization and cultural differentiation".*Safford et al. (2002)

Colombian geography is unique given that the Andes is divided into three different mountain chains within it, from its border with Ecuador that goes in the north-northeast direction. This generates natural geographic divisions among regions that have consequences on economic and social outputs. The historical dispersion of most of its population in isolated mountain pockets delayed transport infrastructure and an integrated national market. Roads were created to connect these important but isolated hubs. In the first stages, they did not solve other areas with a smaller population and less access to markets. For example, about 56% of the country's territory represented mostly by the plain fields on the east part, and the Amazon region in the southeast do not have national-level roads to connect them to the rest of the country because construction cost there is high and the population is still low. This region accounts for less than 19% of

[3] Calderón and Servén (2014) contains a detailed review of this branch of the literature, including both empirical and theoretical developments

the total population, and also, the departmentos present show some of the lower per capita income in the country. Given that Colombia is in the tropic, it does not have proper seasons. However, there is a noticeable variation in weather from perpetual snow mountains to the Amazonian jungle to temperate weather regions where most of the country's GDP is generated. For example, only six of the departments (out of 32) located in tempered regions produce 67% of the national GDP. From the historical point of view, this result is that tempered weather regions had better agricultural productivity, less incidence of sickness, and are located in the high-but-plain parts of the mountain chains making construction and development easier than in extreme weather regions.

All these geographical features have made it more costly to integrate the country using transport infrastructure.

2.2 Road development in Colombia

At the beginning of the last century, Colombia had not developed a road system. The investments are made in the first half of the century allowed to increase the total national roads length from less than 1.000km in 1904 to 21.000km in 1950 with less than 2.500km of paved roads[4]. While the US had 24% of its roads paved, Colombia had only 0,24% (Bank (1994)). During the first half of the twentieth-century roads we poorly maintained and were only linking demand centers, without taking into account the natural corridors such as the main rivers and also were very dispersed; one factor that promoted dispersion was that the approval for building roads has to pass through the congress [5] Until 1950, given the money inflow to the country and the world recovery during the postwar period, the number of cars increased, and transport infrastructure started to be developed. At that time, the government tried to link the supply centers. Between 1950 and 1959, 4600 km of roads were maintained (60%) or built (40%). From 1960 to 1974, the emphasis was put on tertiary and state roads, which increased 7% annually. Finally, between 1975 and 1994, more than 5.600km of the national roads were paved while the tertiary and state roads were increased or maintained in an amount of 55.000km. Two institutions were fundamental for the expansion of the road system the *Fondo*

[4] Pachón and Ramírez (2006)pp 55-60 shows statistics about roads construction in those years, the distribution of roads was not even in the national territory, Antioquia, Cundinamarca, and Boyacá all of them important demand centers were places with a higher concentration of roads

[5] Also Pachón and Ramírez (2006) studies the development process of road infrastructure in Colombia during the last century, including political and geographical aspects.

Nacional de Caminos Vecinales and the *Fondo Nacional Vial* these institutions were replaced by the *Instituto Nacional de Vias* (INVIAS) that currently handles all national and state roads that are not under concession. However, by 1994 Colombia was still one of the less developed countries in terms of road infrastructure, and several studies have identified that as a barrier to economic growth.

The country started an institutional change in 1990 to bring private investment to the public roads sector, following other countries such as Mexico and Chile and making the country more competitive for exports. The government of *Cesar Gaviria Trujillo (1990- 1994)* established the legal and institutional bases for private participation in infrastructure using concession contracts that were first released in 1993. Due to the lack of experience of the public sector, the first generation of contracts suffered a lack of planning, insufficient information, and had many re-negotiations. In order to bring private players to the infrastructure market, the government assumed almost all the risks for those contracts which were developed until 1998. The next *Ernesto Samper (1994-1998)* continued with the structuring of the second generation of roads concessions released in 1996, including a better risk-sharing with the private sector and better planning in the environmental and technical areas[6]. These two generations were concentrated around the capital city and the sugar cluster of the country, respectively. In 2004 it was started the third generation, which covered a wider area and contractually was better in terms of risk-sharing for the government.

Finally, in 2014 the fourth generation of roads concession started. For that generation, the government created independent agencies to develop the projects' technical, financial, and environmental dimensions.[7] Effects of this last wave of concessions will not be taken into account for this research given that some of those projects are still unfinished. The figreffig: interventions shows the location of the national road network and the different interventions done by INDIAS and during the concession waves. Red segments are concession roads; green segments are roads improved by INVIAS. The clear blue lines are the rest of the road network.

[6]The national department of planning of Colombia coordinates a national council for economic and social policy, and the documents that are produced for such a council are called *CONPES* documents which generates policy briefs for nationwide topics, including the presentation of the detected problem, the policy suggested and the guideline for the implementation and evaluation of the programs, this council includes members of different areas of the government that will have to implement the respective policy. The first generation of concessions is ruled by the *CONPES* 2597 of 1992 starts *CONPES* 2775 of 1995 that clarifies the rules for private participation in roads concession and third generation was established in the *CONPES* 3045 of 1998. Each document builds on learning the immediately previous experience, making the risk-sharing fairer for both parts

[7]The Agencia Nacional de Infraestructura (ANI) and the Agencia Nacional de Licencias Ambientales (ANLA) were created in 2012 to expedite road building by providing investors with up-to-date studies in these areas. The government also was committed to providing bank warranties for the project to make the funding easier

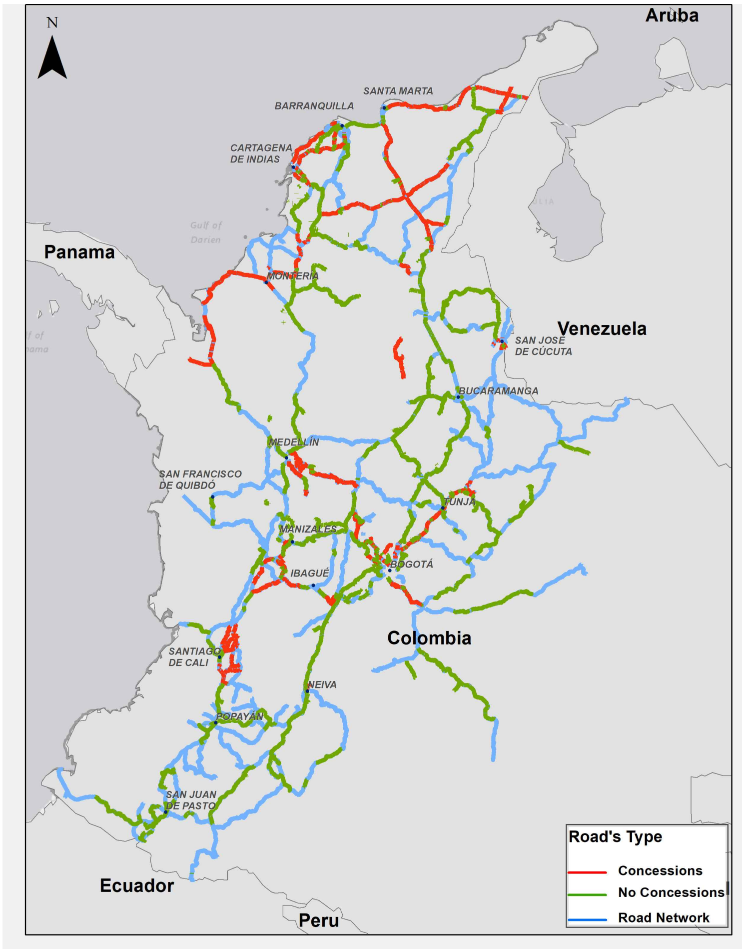

Figure 2: National road network vs roads concessions waves

To better understand the distribution of interventions across time, the Figure3 shows the number of municipalities affected by a road between 1990 and 2012. Peaks in construction are seen in 1995-98 in 2004 and 2008. Each peak corresponds to a different generation of concessions.

Finally, in the Table,1 we can see the distribution of the road interventions by type. Out of 617 road segment interventions, rehabilitation plays a big role, and divided highways are the second most important intervention.

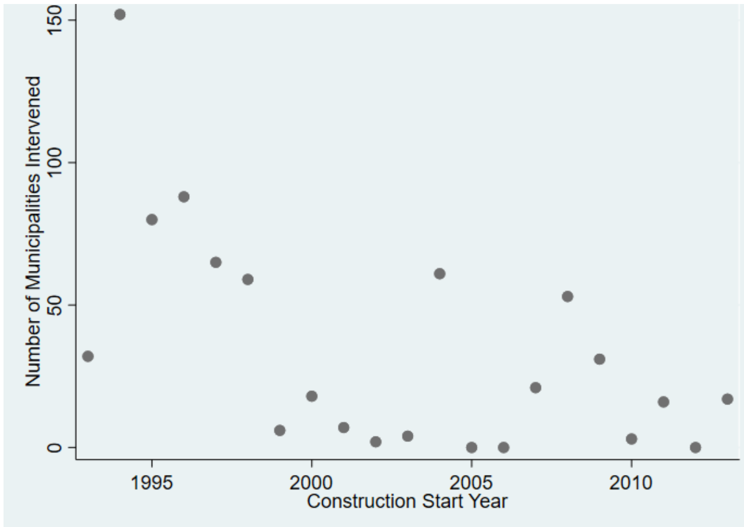

Figure 3: National road network vs roads concessions waves

	Invias	1G	2G	3G
Divided Highway	4%	19%	39%	25%
Rehabilitation	51%	64%	50%	36%
3 Lane Road	3%	4%	-	29%
New Road	33%	7%	-	8%
Bridge/Variant	10%	6%	-	2%
Total	617	96	18	131

Table 1: Interventions divided by type

3 Data

Colombia has 1102 municipalities which are our unit of observation. From those, 64 were created after 1993, which was taken into account for the econometric implementation. These municipalities belong to 32 departamentos that are equivalent to states in the US. [8]. We built a database with the universe of the municipalities for 1986-2014, using different sources. One was the municipality panel from CEDE of the University of Los Andes. [9]. GDP variables are calculated from the municipality tax revenues reported to the National Planning Department(DNP) since 1990. Given that the DNP does not report the GDP by the municipality, we used the total tax figure to calculate the participation of each municipality within the

[8]Besides, some of the municipalities are not connected to the national road network because they are located in the Amazon region or islands, so they are excluded from the estimation

[9]In this database, we got total and sectoral GDP from the national bureau of statistics from 2000 to 2009, income inequality for 1993 and 2005 using census data. Land and owners inequality using Agustin Codazzi Institute data between 2000 and 2012, average results in standardized high school test (Saber 11), altitude above the sea level as a geographic variable, homicide rates, and as a proxy of historical human capital, we use the number of literate people in each municipality in 1951

total tax revenue of the departamento (state), and this proportion is applied to the GDP by departamento, which is reported, to calculate the municipal GDP. This allows us to have a GDP series from 1990 until 2012. We also used the GDP figure calculated by the municipal panel by CEDE, which includes total GDP and GDP by sector (industrial, services, and agricultural) from 2000 to 2009. The owner's Gini considers the owner and valuation of all estates registered to the same owner in rural areas of each municipality, measuring property concentration. The income Gini from the CEDE database is calculated using income from the censuses in 1993 and 2005. Land Gini takes into account the size and valuation of all estates in rural areas of each municipality. Measuring land concentration. As controls, we have the average score in end-of-highschool standardized test *Saber 11* that works as a proxy of education quality; we also are controlling for the number of homicides per capita from CEDE as a proxy of institutions, we include altitude above the sea level as the geographic variable to control for the fact that geography is correlated with economic development; we include the literate population in 1951 to control for the fact that the distribution of human capital in the past was driving economic growth in the present. Finally, we are controlled by the rurality index that measures the percentage of the population that lives in rural areas in each municipality[10].

From the national planning department, we got a measure of GDP based on aggregate value for a longer period from 1990 to 2012 and the municipal development index, which includes social and financial variables of each municipality not related to roads[11]. The urban population density was calculated by using projections and census urban population from DANE and the area of each municipality calculated using night lights which allows accounting for area growth [12]. The road network is the one reported by Agustin Codazzi for 2018; it is possible to differentiate primary, secondary and tertiary roads, each type of road implies a different maximum speed according to its engineering design [13]. This map was used to identify infrastructure in the space and to calculate distances used for regressions. To build market

[10]We also controlled for different proxies of human capital like math tests or language test, average years of education by a municipality, proxies of geography like temperature or annual rainfall and historical variables to see the effect on coefficients of interest but results did not have noticeable changes.

[11]This index includes information about population, access to public services, municipal investment per person, municipal tax per person, poverty, illiteracy, and percentage of the population attending to school

[12]Data on night lights are available in Nightlights

[13]The main difference besides the wide, the traffic and the municipalities they link is which administrative entity has to maintain them, primary roads are under the responsibility of the country, secondary roads under the departmentos and tertiary roads under the municipalities

access, we generated data on distances between municipalities using the road network. We combined it with geography to obtain an asymmetric matrix of traveling times that will be used to calculate the market access as told before the population was set in 1985 to isolate the effect of changes in the traveling speed given by transport improvements. We also used archival information provided by the *Instituto Nacional de Vias* INVIAS about roads developed directly by the nation before 2000. This information was in hard copies, and we transfer it to the digital format. The least-cost path was built by calculating the least construction cost to link main cities in the country in 1938 by pairs from south to north, using detailed information on Colombian geographies such as body waters (lagoons, swamps, rivers, etc.), terrain roughness, protected areas and dense jungle among other geographic characteristics. Engineering information would give us the difficulty of each of these features for construction. In the table,2 we can see the heterogeneity present among Colombian municipalities in different aspects. GDP variables are all in logarithms, but standard deviations are big. We can see that some municipalities have their rural land highly concentrated regarding land and owners inequality, getting up to 99%. In contrast, others have an almost perfect distribution of land. The average in those values is 0.69 and 0.71, respectively, showing a high concentration of land in the country. The different market access measures are calculated with the decay parameter we found (e) and Duranton (2015) parameter (D). Data on interventions allow us to see that about 15.6% of the municipalities were directly in contact with improvements, and 35% were in those neighborhoods.

VARIABLES	N	mean	sd	min	max
Deflated_GDP	27,861	7.382	3.070	-2.718	19.27
Constant94_GDP	15,604	8.692	1.809	-2.304	16.43
Constant05_GDP	13,922	3.728	1.689	-7.755	11.21
Aggregate_Value	19,074	4.114	1.516	-6.208	11.77
GDP_CEDE	10,970	11.24	1.289	6.816	18.48
Agr_GDP	10,967	9.437	1.292	2.533	12.88
Ind_GDP	10,970	9.632	1.640	4.822	16.95
Serv_GDP	10,970	10.24	1.529	4.549	18.10
Gini	2,086	0.455	0.0361	0.357	0.568
Land_Gini	12,977	0.690	0.106	0.0184	0.998
Owners_Gini	12,361	0.713	0.0962	0.0184	0.985
DevelopmentIndex	12,070	39.96	19.36	0.0478	94.53
Altitude	26,928	1,140	1,155	2	25,221
Population_Density	36,833	128.8	536.3	0	13,794
Saber11 score	16,472	47.49	3.231	32.13	81.16
Homicides per capita	13,025	0.000372	0.000496	0	0.0122
Literacy 1951	23,562	4,734	23,321	0	431,654
Interventions	36,888	0.156	0.363	0	1
BoarderNeighbors	36,888	0.0697	0.255	0	1
Neighbors35k	36,888	0.354	0.478	0	1
Distance to Infrastructure	37,953	3.713	1.853	-8.012	7.263
Market access (e)	24,288	14.91	0.801	7.177	15.31
Market access (D)	24,288	13.30	0.744	6.008	14.05
Market access Turner (e)	23,856	14.24	0.137	13.87	14.69
Market access Turner (D)	23,856	12.64	0.263	11.93	13.57
MAnoCloseMunicip (e)	24,120	14.92	0.731	6.297	15.25
MAnoCloseMunicip (D)	24,120	13.29	0.715	4.793	13.90

Table 2: Descriptive statistics

4 Methodology

4.1 Research Design

We will estimate different version of the following equation:

$$Y_{it} = \alpha * \text{Treated}_{it} + \beta * X_{it} + a_i + c_t + \varepsilon_{it} \tag{1}$$

Y_{it} denotes the output variables in our case will take the logarithms of total GDP, agricultural GDP, industry GDP service GDP, land GINI, owners GINI, and the income GINI and the municipal development index. The vector X_{it} includes our set of controls includes geographic, historical, socio-economic, and institutional variables that might determine GDP. a_i, c_t are the time and departamento fixed effects of accounting for unobserved location-specific characteristics and time trends. Treated_{it} is the main treatment variable, either the logarithm of market access or the logarithm of distance to the infrastructure. In this case, α will capture the effect of the treatment on the output variable, which can be interpreted as a semi-elasticity. Treated are our problematic variables because they might be simultaneously determined with the output. For that, we use different instruments. To deal with this endogeneity, we also excluded from some regressions capital cities and cities within 25km of them. To estimate spillover effects, we will estimate the following difference-in-difference type panel equation.

$$Y_{it} = \beta * \text{treated}_{it} + \gamma * Border_{it} + \zeta * Neighbor35_{it} + d_i + f_t + \varepsilon_{it} \tag{2}$$

Where $treated$ are all municipalities with direct contact with the new infrastructure, borders are municipalities adjacent to the ones treated, and neighbors35 represent the rest of neighboring municipalities within a range of 35km from the infrastructure. Variables d_i and f_t represent location-specific and time-specific fixed effects respectively. Given that we keep the whole sample in this regressions, β will be the average effect of taking a municipality in the control group and putting it on the road.

4.1.1 Market Access

We use a continuous measure of treatment using a market access gravity equation as in Henderson and Wang (2007):

$$MA_{it} \equiv \sum_{k \in j | j \neq i}^{N_j - 1} \frac{n_{k85}}{t_{ik}^{\alpha}}. \tag{3}$$

n_{kt} measures market size.[14] Population in each municipality was left fixed as in 1985's census. To calculate commuting times among pairs of municipalities, in the denominator, we calculate a matrix of distances using the actual road network and use the maximum commuting speed and geography to calculate times. Using details from the concession contracts, we build a national road network with estimated speeds for every year since 1993 and each road section depending on road structure and quality. Interventions considered as affecting speeds are pavement, construction of second or third lane, road expansion to become a dual highway, construction of a new bridge, new ring road, and new roads. That way, it will be possible not only to calculate the effects of the road improvement in general but also it will be possible to differentiate for the heterogeneous effects of different interventions which have not been studied either—additionally,

[14]We use population for market size for all other locations, but we fixed it in 1985 before the intervention, and the local population will be included as a control in the regressions

speed changes due to terrain ruggedness, as inNunn and Puga (2012). Therefore, we include geography in this calculation through the slopes faced by the road connecting pairs of municipalities to have a better adjustment in commuting times. Geography makes that the time-traveling from A to B differs from B to A. Using these estimated speeds, we determine a panel of travel times between all municipalities. We test these estimated travel times using actual GPS data for trips in recent years from HERE technologies and find that the estimates are satisfactory, with differences between the estimated and observed times of less than 10% in most trips. Differences in relative times across trips are even smaller across methods. The figure 7shows the distribution of errors.[15]

To calculate the decay parameter α in the denominator, which is the elasticity of trade concerning distance, following Duranton (2015) and Duranton et al. (2014) we use the Commodity Flow Survey (CFS) for Colombia ('Encuesta Origen – Destino a Vehículos de Carga') from the Colombian Ministry of Transport which measures bilateral trade flows among Colombian municipalities[16]. The advantage of using market access is that the change in one road segment can affect the commuting times between many cities that use that segment. Hence, it allows incorporating network effects during the calculations. The figreffig:chMA shows the percentage change in market access from 1993 to 2016. This gives an idea of the main winners with infrastructure during the period of study. Although the center of the country has important changes, the Caribbean coast in the north and some places in the east also present big changes in their market access. Also, there are areas of the country that are unconnected to the national road and stayed that way.

4.2 Endogeneity concerns

Teallen2019welfare there are three concerns to measure welfare effects of infrastructure: The routing problem, which highlights the fact that routes chosen by agents are not exogenous and changes in one segment

[15] Here.com data are given by GPS installed in trucks mostly, and some trucks do not follow the shorter way to get from one point to another because they follow certain routes. We identify that some of these unusual results were given by truck routes meant to cover several regions instead of going straight away from point A to point B.

[16] This is a survey of trucks on major Colombian roads. They have pulled aside the road, weighted, and asked about the origin, destination, and nature of the cargo, including products and their value. The result was -0.34, which means that distance between municipalities is a big impediment to trade. Duranton (2015) Calculates this elasticity using the 2011 version of the survey and the estimate was -0,60. The 2013 version includes about 90.000 additional observations. Results presented hereby do not change dramatically when we use either elasticity

[17] We have pre-colonial roads as additional instruments, as in Duranton (2015)

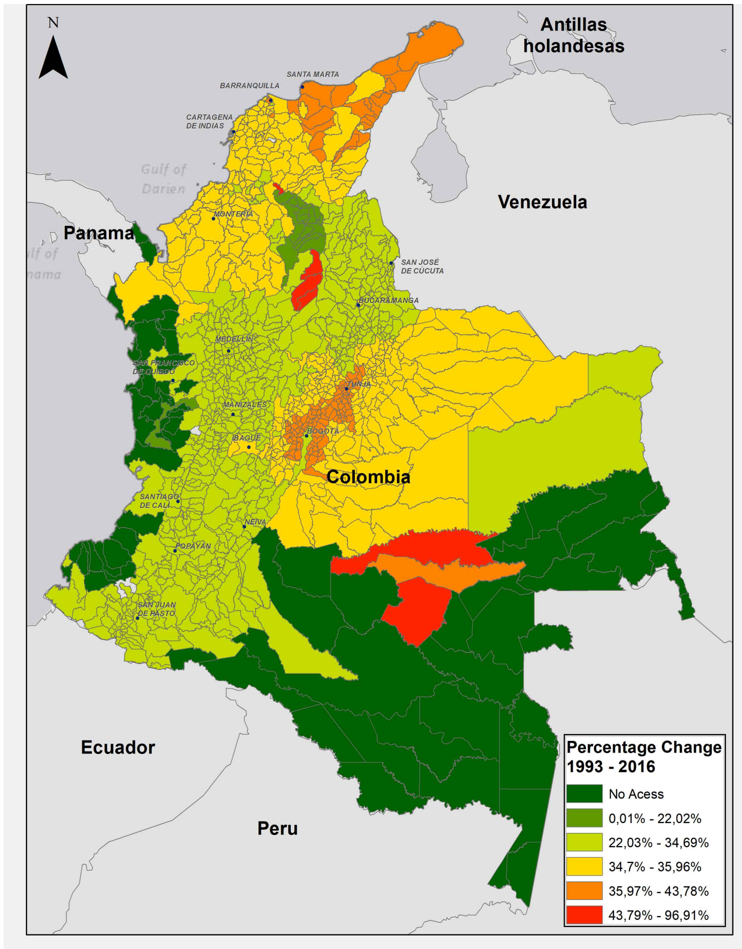

Figure 4: Percentage Change in Market access from 1993 to 2016 by municipalities

can change the trade cost in the entire network. The second is the economic problem because road improvements by changing trade costs can also change the location of economic activity, generating winners and losers through general equilibrium relationships. The third is traffic, which also changes endogenously with road improvement and trade costs. Fortunately, we deal with all three problems. For the routing problem, we have counterfactual least-cost path roads connecting the country's main cities in 1938, using it as an instrument for actual roads. We also use precolonial (indigenous) roads for that purpose. Furthermore, we calculate the market access that takes into account network effects. This market access network is helping us to account for the economic issue also. Finally, we incorporate changes in traveling times due to transport improvements in our empirical exercise to account for traffic congestion.

Another common endogeneity concern is that new roads are not exogenous. In general, they are built to

Endogeneity Concern	**Empirical Strategies**
1.Road network designed to benefit main cities	A. Selection tests á la Chandra and Thompson (2000) B. Estimation of impact using only incidental cities C. Our main IV, the quasi-random component of market access as an instrument (eq 4).
2.Road Network path is chosen endogenously	A.Least-cost-path counterfactual roads based on topographical construction costs criteria solve it.[17] B.Analogously, use the least-cost-path roads to calculate exogenous counterfactual dynamic and static market access
3.Road improvements are chosen endogenously	A.Use static market access as instruments (see 2B above) B. Use construction costs (see 2A) as IV for upgrades
4.Spillovers between local municipality market effects and market access effects	A.Calculate market access only with municipalities that are farther than 50 km from the focal location

Table 3: Summary of Endogeneity concerns and estimation strategies

link important places, but they affect unimportant places. This will be one of the key problems facing the result, and we deal with it in several ways. First, we took out of the estimation the capital and the second biggest cities in all departamentos. These cities are the ones that might be generating endogeneity in both the distance to the infrastructure and the market access. So we were left with only small and intermediate cities, sometimes called incidental cities, that are supposed to be exogenous for the decision of building roads. A similar concern is that only faster-growing cities will be assigned roads meaning that the growth was generating the roads and not the other way around. To understand that that was not the case, we did the test similar to the one proposed by Chandra and Thompson (2000) obtaining no evidence that that was the case.[18]. In a different way of dealing with the endogeneity of big cities, we also developed a market access instrument that subtracts from the regular market access built only using big cities. A form that it is expected that only the semi-random component of the market access remains. These methodologies are supported by current literature, Redding and Turner (2015) show some ways to address endogeneity concerns using instrumental variables. These can be summarized in planned route IV as it was proposed by Baum-Snow (2007) for the US and Baum-Snow et al. (2017) China and also used in Herzog (2020) and in a similar setting Hsu and Zhang (2014) for Japan; they also include the historical route IV, which is used in Duranton (2015) which proposed indigenous roads for Colombia and the road system in 1938 or Duranton and Turner (2012) which uses both 1947 planned roads and 1898 map of railroads. Finally, they mention the inconsequential places approach based on the selection of sub-samples that are exempt from endogeneity, given that the presence of new infrastructure in these locations can be considered random.

[18]We test the probability of getting a highway as a function of lags of the first differences in GDP between three consecutive years before the intervention, using the following specification $Pr(Road_{it}) \equiv \Lambda(\sum_{t=1}^{3} \psi^i \Delta GDP_{t-(t-1)})$ we found that road development were not directly related with lagged municipality growth

Faber (2014) Uses this kind of variation to explain the effect of new highways on the production of Chinese cities as is also done Banerjee et al. (2012) which uses inconsequential places to measure the effect of new roads in economic development in China. A more traditional contribution Chandra and Thompson (2000) also uses this approach to account for the effects of the highway system in the United States on profits. Jedwab and Moradi (2016) and Jedwab and Storeygard (2020) Used instrumental variables approach to calculate effects of transportation infrastructure on Ghana and other 39 African countries from 1950 to 2015. A different strand of the literature uses structural models to estimate welfare effects, such as Allen and Arkolakis (2019) calculating the welfare effects of road interventions for the US road network.Donaldson and Hornbeck (2016) Also, calculate welfare effects of railroads on agricultural productivity for the US, updating well-known results by Fogel (1964). Our work uses elements of several of these methodologies to allow for more reliable identification of the effects of road interventions on output and inequality. We used indigenous routes suggested by Duranton (2015) Colombia, and we built a hypothetical transport infrastructure to link main Colombian cities in 1938 Donaldson and Hornbeck (2016), by finding the least cost path using Colombian geography and used it as an instrument for actual infrastructure. We also take out of the estimation the big cities however it takes into account two novel interventions.

4.3 Instruments for distance to the infrastructure

Distance to the infrastructure was the pioneer treatment measure for infrastructure. However, this measure does not consider the effects that the improvement of a road segment or the establishment of a new road might have on places that are not close to the improvement because of network effects. This restriction makes the interpretation of distance results limited, but we calculate it to contrast our more believable estimate using market access.

Given that distance to the infrastructure is endogenous, we use two instruments as a source of exogenous variation: The distance to the calculated least cost path network and the distance to the pre-colonial (indigenous) roads.

4.3.1 Least cost path

To develop our counterfactual least-cost path road network, we use granular geographical information available and the information on the main cities in each department to the 1938 census. Back in 1938, the country was divided into administrative units ordered by their importance and were *departamentos*, *tendencies*, and *comisarías*. All these units contained smaller units called municipalities. Departamentos contained around 97% of the country's population, and their city capitals were the main economic agglomerations in that area. There were 15 departments: Antioquia, Atlántico, Bolivar, Boyacá, Caldas, Cauca, Cundinamarca, Choco, Huila, Magdalena, Nariño, Norte de Santander, Santander, Tolima y Valle del Cauca. To build this counterfactual, we took the capital and second main city according to census information. This instrument has two arguments for its validity. The first one is historical. The current road system started construction in 1951. Thus, picking the population in 1938 to determine the main cities could diminish endogeneity concerns. The second argument is geographic information and technology to calculate the least-cost path, which is more exogenous than the actual roads but is related to it. The least-cost path is a beneficial instrument if geography is not related to our outcome variables, unfortunately in our case, it is related to main cities. That is why we take them out of the econometric analysis. However, small towns that are crossed by the least cost path are exogenous to the infrastructure assignment because the hypothetical road was not built to link them with anything.

The figure8 shows the comparison of the least-cost path in green versus actual roads in red. In this closeup, we can see that the least-cost path in many regions of the country is fairly exogenous, even though the first stage statistic confirms that it is a good predictor for actual roads. The least-cost path tool in ArcGis determines the least cost way to get from a destination point to a source, taking into account different rasters containing relevant information to improve the accuracy of the calculation, and each raster has to be weighted according to their impact on the cost. This allows the researcher to include various features to make the calculation either more realistic or adjusted to the theoretical model.

Technically, the least-cost path analysis in GIS means that the eight neighbors of a raster cell are evaluated. The generated path moves to the cells with the smallest accumulated or cost value. This process is repeated multiple times until the source and destination are connected. The completed path is the smallest sum of raster cell values between the two points, and it has the lowest cost. The figreffig:lcppath shows an ex-

Type	Weight
Slope 0-3%	1
Slope 3-7%	2
Slope 7-12%	3
Slope 12-25%	4
Slope 25-50%	5
Slope 50-75%	6
Slope $> 75\%$	7
Bog	6
River	9
Slope 6	9
Protected Area	∞
Reservoir	∞
Wetland	∞
Swap	∞
Lagoon	∞

Table 4: Least cost path determinants with weights given by engineering information

ample of the mechanism of the least-cost path linking two places. For this calculation, we are considering terrain slopes because the steeper the slope, the harder it is to build roads. For that, we use level curves to the scale of 1:100.000. Water bodies such as rivers, lakes, lagoons, swamps, reservoirs, and wetlands. In general, the presence of these areas implies a higher construction cost for roads or the impossibility of construction. We also take into account protected areas because of environmental reasons. In general, current protected areas are thick forests or jungles that were hard to cross in the past. Once we have identified, and geo-referenced these areas within the national geography, assigning weights to each of them gives a higher score to the harder places to build. Infinite implies the impossibility of construction, and the scale is measured from 1 to infinity, where 1 is easy to build, and infinity is really hard.

In practical terms, protected areas, reservoirs, wetlands, lagoons, and swamps will make the road deviate from surrounding these areas, increasing the construction cost. At the same time, rivers and moderately and strongly steep slopes are still an option but at a higher cost. The tareftable:lcpweights shows the geographic features taken into account and their respective weights. We also use this least-cost path to build counterfactual market access for each municipality used as the source of exogenous variation for the market access.

4.3.2 Indigenous roads

This instrument was first used Duranton (2015) as an instrument for Colombian roads. Its validity relies on the fact that native indigenous were circulating across the country long before the Spanish colonization. It

Figure 5: Calculated least cost path connecting main cities

is expected not to have any influence on current GDP or inequality. However, given Colombian geography, these corridors for natives are a good predictor for actual roads. The figreffig:indigenous shows the indigenous roads in the country. These roads belong to different indigenous tribes that were separated because of geography. These also included rivers and were not necessarily used by the Spanish after the conquer, giving additional endogeneity to the variable. We use the distance to indigenous roads as an instrument for current roads.

4.3.3 Quasi-random component of market access

Endogeneity inroads are generally assumed to come from important cities. As said, infrastructure is built to connect cities with high production, and therefore any estimation of the effect of the infrastructure on

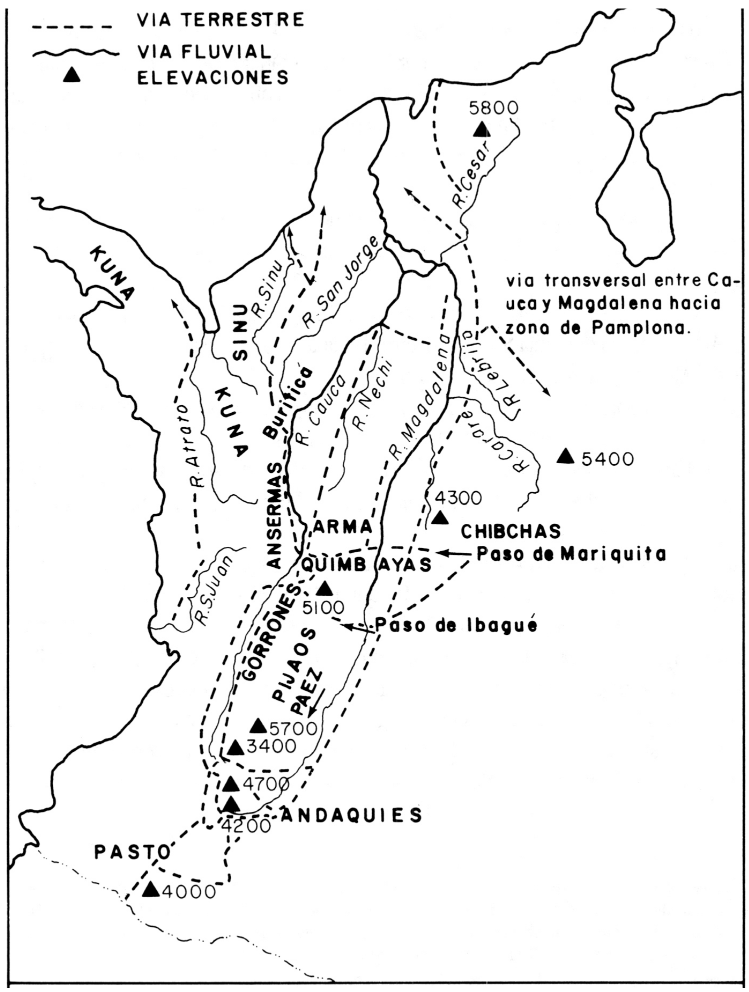

Figure 6: Pre-colonial (indigenous) roads in the country including river transportation

those cities' output will be biased and inconsistent. So far, we have used suitable instruments to solve this problem, one historical (indigenous roads) and one self-created using the country's geography (least cost path). In both cases, most trusted results do not include big cities. In order to regain the ability to say something about the impact of roads on the main cities or nodes, we look at the change in market access experienced by the main cities that correspond to the unplanned access to incidental cities gained or increased from new roads or upgrades. We calculate it as a difference between MAs:

$$z_{it} = MA_i - MA_{\text{Main},\, i} \quad (4)$$[19]

[19] $MA_{\text{Main}i}$ is the market access calculated without incidental cities. This strategy is a novel contribution that builds on a strategy ?.

This measure will take out from the market access the endogenous component, which is the effect of big cities, allowing us to use it as an instrument for market access.

5 Results

5.1 Impact of roads on total and sectoral GDP

The tareftable:sumGDP summarizes the results of the GDP and its components, including two market access instruments and distance regressions. In this case, the main cities are excluded from the analysis, and cities surrounding them in a radius of 25km are also excluded. Each coefficient represents one regression including saber 11, altitude, homicides per capita, population density, rurality index as controls, and also all regressions include municipality and year fixed effects. Market access positively determines GDP, and coefficients look robust to the different specifications regarding the instruments used. In tables 7 and 8we show the full regressions of the effects of distance to the infrastructure on GDP. In this case, the variables distance to the infrastructure included refers to bridges, ring roads, double lane, third lane, and new roads, which are considered main interventions[20]. It is clear that once we take municipal level fixed effects, total GDP increases with distance to transport infrastructure, giving a counterintuitive result. This, however, is consistent in all specifications even when we do not take into account big cities. The total GDP's elasticities to distance are 0.867 if we exclude big cities and 0.940 for the full sample. These estimates include both instrument's indigenous roads and distance to the least cost path. Also, geographic and historic controls stop being significant as expected. Two main conclusions arise. First, the effects are important on total GDP and agricultural, service, and industrial GDPs. Second bigger cities can take more advantage of the benefits of the improved infrastructure.

However, these results are not taking into account any network effects that might affect many cities in a more complex way. To measure network effects, there is our measure of market access. This is consistent becauseBaum-Snow et al. (2016) where prefecture's primate cities in China benefited more from highway intervention. We can also conclude from the table 10 market access without considering big cities has an important impact on GDP and all the sectors. The fact that agricultural GDP grows more further away from

[20]This specific measure does not include replacement which is a minor intervention. Results are robust when repaving is taken into account

the roads could be explained because places that benefited from better market access are not necessarily pursuing agricultural activities. The sector that increased the most because of that market access was serviced. Agriculture in Colombia is really expensive because of geography, which makes more expensive seeding and harvesting. Most of the inputs necessary for production are imported and change their price with the exchange rate. Only people without credit constraints, which are the minority in rural areas, can take advantage of big-scale agricultural projects. With better infrastructure, the economy could easier develop improvements in the service sector than in the agricultural sector. The tablereftable:IVGDPproxies we include all different proxies of GDP available, which allows us for longer time series. These proxies include GDP from CEDE, the Aggregate value from DNP, constant GDP with 1994 base and 2005 base, and a tax called industry and commerce, which is a good proxy of formal economic activity. In terms of the sign, the results are consistent. In the table,13 We also hoped to find a certain pattern of spatial fadeout in the strength of the effect, so we calculated the results of market access regressions for municipalities subsample between 20 to 40kms of the intervention. The spatial pattern, at least up to that distance, does not show any spatial fadeout. The coefficient is positive and robust.

Finally, we test for different subsamples using a conventional division of the country into *natural regions* that divide the country using geographic features. According to these criteria, the country is divided into 5 regions *Andina*, which gather all municipalities on top of the Andes, *Caribe* composed by all municipalities next to the Caribbean ocean, *Pacífica* composed by the municipalities next to the pacific ocean in the west part of the country, the *Orinoquía* where all the plain field in the east of the country are included and finally the *Amazonía* which is basically the amazon jungle with few municipalities. Once we run the regression for these natural regions, we see big heterogeneity among them. As expected, in the *Andina* region, where most of the country's economic activity is located, the coefficient is positive, highly significant, and is bigger in size. It is, however, surprising that in the Caribe region, the relationship between market access and GDP turns negative and significant. It is the only region where that happens. Also, there are the biggest differences between the least cost path and actual roads in this region, hinting that roads might not be assigned in an optimum fashion. The other two regions keep the positive sign and significance, but their size is much smaller. These results can be found in the table 14.

5.2 Impact of roads on inequality and municipality development

The tareftable:sumgini summarizes the results of the Gini indexes and the municipal development index, including two market access instruments and distance regressions. In this case, the main cities are excluded from the analysis, and cities surrounding them in a radius of 25km are also excluded. Each coefficient represents one regression including saber 11, altitude, homicides per capita, population density, rurality index as controls, and also all regressions include municipality and year fixed effects. Again increases in market access increase land and owners inequality. The effect on income inequality once we include municipal fixed effects are not significant. Tables 15 and 16 show that land Gini and owners Gini reduce with distance to the infrastructure, and that result is consistent in the full sample and excluding big cities. The concentration of big pieces of land in few hands close to the improved infrastructure is an anecdotal feature of this process, but this data supports that idea. Income inequality is reduced only when we analyze the reduced sample. According to tables 17 and 18 roads measured through the market, access has an impact on income inequality. Regardless of the proxy of market access and instrument used for these tables, we exclude main cities from the analysis. Here we are using two different proxies of market access, and results do not seem to change much. In this regression, we exclude also exclude main cities. Income inequality improves with better market access, which is consistent with results obtained in the GDP section. Economic growth generated by improved infrastructure trickles down to reduce income gaps in the population. It is also evident that land is getting concentrated in fewer owners (increase in owners Gini), and estates are getting bigger(increase in land Gini) The municipal development index has a direct relationship with market access, and its magnitude is significant. Having better market access improves the financial capacity of the municipality.

5.3 Spillover effects

Tables 19 and 20 show the spillover effects for GDP and Gini-municipal development index, respectively. Spillover effects have an interesting behavior, there are important and positive spillovers to municipalities within 35km from the infrastructure, but that effect does not cover the adjacent municipalities. Surprisingly adjacent municipalities show a negative spillover effect but are not significant. One possible explanation is that industrial and service production could be moving from adjacent municipalities to the intervened ones, generating a negative effect on the production of the former. Effects in municipalities within 35km from the intervened are about significant and smaller in size (about 50% from the original effect). The last column shows of the table 19show a longer series for GDP. In that case, the result is not negative for adjacent municipalities, but it is minimal compared with other municipalities within 35km. Owners Gini presents important spillover effects on all the subsets analyzed. The concentration of property is not only happening on the intervention but also in nearby municipalities.

6 Conclusion and policy recommendations

The importance of transport infrastructure for Colombia is shown and calculated in this research. Results show that total GDP, services GDP, and industrial GDP increase with improvements in market access and increase with distance to the infrastructure. This result is robust to all our specifications. This is not the case for agricultural GDP, which shows a much erratic pattern. One possible explanation is that the apparent concentration of land near the infrastructure that can be seen through the Gini results could have been done with speculation purposes but not necessarily to developed big agricultural projects. This is one issue that comes with the political process of assignment of new infrastructure and requires more study. As expected, effects are much stronger when we take the full sample that includes all cities. Those big cities are dragging between 25% and 50% some times more! Of the total effect of infrastructure on economic growth.

Regarding inequality, income Gini improves with market access and decreases with distance to the infrastructure. Places closer to the infrastructure reduced inequality improved their income. We also found that the effect of roads is bigger the most to places that were important before because those could take better advantage of them. Another important finding is that the effect of this research is that the type of improvement or infrastructure matters. New roads, third lanes, double lanes, bridges, and variants have bigger and stronger impacts on output variables than those obtained, including rehabilitation. Spillover effects of GDP on neighboring municipalities show an interesting pattern, adjacent municipalities to the ones directly affected by the infrastructure show no significant effect; however, in municipalities within 35 km, the effect has the same sign that in Additional analysis of these results' heterogeneity shows that regions within the country have bigger effects than others. According to its geography, the country is divided into five regions: *Andina, Pacífica, Caribe, Orinoquía, and Amazonía.* The Andina region takes its name because it includes what is on top of the Andes, including most of the bigger, most prosperous cities in the country. In size, effects of distance to infrastructure on total GDP, controlling for endogeneity, are almost 28 times in the Andina region compared to de Amazonía, almost 10 times compared to the orinoquía, almost 3 times compared with the Pacifica region, and twice the effect of the Caribe region. Meaning that it is much more important to be close to a road in the Andina region than in all others. From our view, infrastructure does generate bigger effects if the area has better conditions to take advantage of it.

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A Appendix

Figure 7: Distribution of errors between HERE data and out data

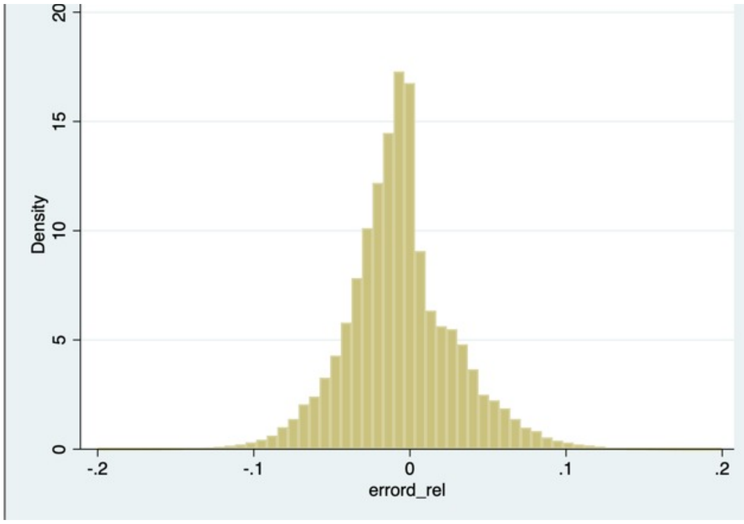


Figure 8: Zoom of the comparison between the least cost path (green) vs actual roads(doted red)

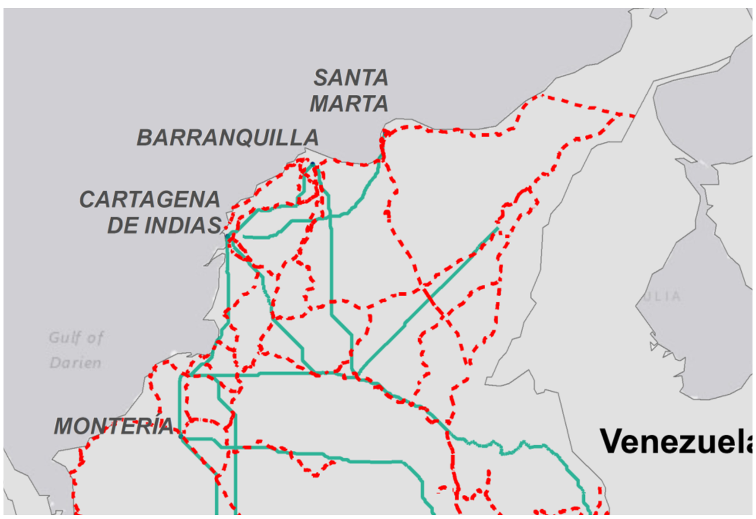


Table 5: Summary results table GDP

Variables	GDP_CEDE	Agr_GDP	Serv_GDP	Ind_GDP
MA Population 85 (IV)	2.530***	2.927***	2.956***	2.620***
	(0.104)	(0.127)	(0.120)	(0.165)
MA Q-Random (IV)	2.392***	2.767***	2.795***	2.478***
	(0.0979)	(0.121)	(0.112)	(0.155)
Observations	6,491	6,491	6,491	6,491
Distance to Infrastructure (IV)	0.867***	1.035***	0.720***	0.701***
	(0.102)	(0.119)	(0.0989)	(0.113)
Observations	7,147	7,147	7,147	7,147

Note: $***p < 0.01, **p < 0.05, *p < 0.1$ In this table, each coefficient represents an IV regression with the historic geographic, social, and institutional controls, in this case, we exclude main cities their surrounding cities in a radius of 25km from the analysis for GDP and its components. The first market access regression keeps the population fixed in 1985 and uses as an instrument the MA derived from the least cost path. The second MA regression uses the quasi-random component of the least-cost path as an instrument. Distance regressions use distance to least cost path and distance to the indigenous road as instruments. All regressions include municipality and year fixed effects. Standard errors are in parenthesis

Table 6: Summary results table Inequality and development index

Variables	Gini	Land_Gini	Owners_Gini	DevelpmentIndex
MA Population 85 (IV)	-0.0578	0.122***	0.173***	28.38***
	(0.0370)	(0.0132)	(0.0145)	(1.791)
MA Q-Random (IV)	-0.0550	0.115***	0.165***	26.83***
	(0.0352)	(0.0124)	(0.0138)	(1.690)
Observations	101	8,682	8,116	7,421
Distance to Infrastructure (IV)	-0.00858	-0.0924***	-0.0173**	3.689***
	(0.0143)	(0.0101)	(0.00780)	(1.046)
Observations	119	9,494	8,900	8,174

Note: $***p < 0.01, **p < 0.05, *p < 0.1$ In this table, each coefficient represents an IV regression with the historic geographic, social, and institutional controls, in this case, we exclude main cities their surrounding cities in a radius of 25km from the analysis. The first market access regression keeps the population fixed in 1985 and uses as an instrument the MA derived from the least cost path. The second MA regression uses the quasi-random component of the least-cost path as an instrument. Distance regressions use distance to least cost path and distance to the indigenous road as instruments. All regressions include municipality and year fixed. Standard errors are in parenthesis effects.

Table 7: IV regressions of the effect of distance to infrastructure on GDP full sample

Variables	GDP_CEDE	Agr_GDP	Serv_GDP	Ind_GDP
Distance to Infrastructure	0.940***	1.176***	0.938***	0.771***
	(0.107)	(0.129)	(0.114)	(0.115)
Altitude	0.254***	0.237***	0.253***	0.244***
	(0.0168)	(0.0201)	(0.0178)	(0.0181)
Population_Density	0.00146***	0.000570***	0.00146***	0.00190***
	(0.000112)	(0.000135)	(0.000119)	(0.000121)
RuralityIndex	-3.838***	-2.678***	-4.770***	-3.785***
	(0.248)	(0.298)	(0.263)	(0.267)
Saber11 score	0.152	-0.247	-0.373**	0.780***
	(0.178)	(0.214)	(0.189)	(0.192)
Homicides per capita	-38.40**	-29.10	-30.69*	-31.53*
	(15.07)	(18.11)	(16.00)	(16.23)
Literacy 1951	8.49e-06***	-8.61e-06***	-1.57e-06	1.98e-05***
	(1.97e-06)	(2.37e-06)	(2.09e-06)	(2.12e-06)
Constant				
Observations	7,532	7,532	7,532	7,532
R_squared	-1.458	-2.158	-0.916	-0.574

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

Note: Instruments used are distance to pre-colonial roads and distance to the least cost path. All regressions include municipality and year fixed effects. Population density is obtained using population overnight lights area. Standard errors are in parenthesis.

Table 8: IV regressions of the effect of distance to infrastructure on GDP reduced sample

Variables	GDP_CEDE	Agr_GDP	Serv_GDP	Ind_GDP
Distance to Infrastructure	0.867***	1.035***	0.720***	0.701***
	(0.102)	(0.119)	(0.0989)	(0.113)
Altitude	0.234***	0.210***	0.220***	0.225***
	(0.0154)	(0.0180)	(0.0150)	(0.0171)
Population_Density	0.00180***	0.000793***	0.00178***	0.00224***
	(0.000112)	(0.000131)	(0.000109)	(0.000124)
RuralityIndex	-3.053***	-1.825***	-3.721***	-3.170***
	(0.219)	(0.256)	(0.213)	(0.243)
Saber11 score	0.124	-0.267	-0.444***	0.741***
	(0.169)	(0.198)	(0.164)	(0.187)
Homicides per capita	-32.57**	-21.00	-19.29	-28.27*
	(14.28)	(16.71)	(13.90)	(15.82)
Literacy 1951	1.36e-05***	-5.23e-06**	3.31e-06*	2.05e-05***
	(2.05e-06)	(2.40e-06)	(1.99e-06)	(2.27e-06)
Constant				
Observations	7,147	7,147	7,147	7,147
R_squared	-1.281	-1.746	-0.514	-0.447

Note: $***p < 0.01, **p < 0.05, *p < 0.1$ standard errors are in parenthesis. In this table, we exclude big cities and cities surrounding them in a 25km radius. Instruments are pre-colonial roads and distance to the least cost path. Distance to the infrastructure, altitude and saber 11 are in logarithms

Table 9: IV regressions of the effect of market access on GDP full sample

Variables	GDP_CEDE	Agr_GDP	Serv_GDP	Ind_GDP
Market Access	2.452***	2.744***	2.816***	2.559***
	(0.104)	(0.127)	(0.120)	(0.158)
Altitude	0.113***	0.0105	0.0963***	0.131***
	(0.00887)	(0.0108)	(0.0102)	(0.0134)
Population_Density	0.00126***	0.000601***	0.00123***	0.00178***
	(5.53e-05)	(6.71e-05)	(6.33e-05)	(8.35e-05)
RuralityIndex	-1.579***	0.436***	-2.286***	-1.946***
	(0.0635)	(0.0770)	(0.0727)	(0.0958)
Saber11 score	0.0993	-0.436***	-0.573***	0.837***
	(0.0937)	(0.114)	(0.107)	(0.141)
Homicides per capita	2.566	12.21	15.07*	1.630
	(7.403)	(8.981)	(8.474)	(11.17)
Literacy 1951	-3.06e-06***	-2.17e-05***	-1.43e-05***	1.03e-05***
	(8.82e-07)	(1.07e-06)	(1.01e-06)	(1.33e-06)
Constant				
Observations	6,834	6,834	6,834	6,834
R_squared	0.324	0.154	0.354	0.246

Note: $***p < 0.01, **p < 0.05, *p < 0.1$. These regressions include the main cities instrument: the market access generated with least cost path times and keeping population constant 1985. Market access, altitude, and saber 11 are in logarithms. Standard errors in parenthesis

Table 10: IV regressions of the effect of market access on GDP reduced sample

Variables	GDP_CEDE	Agr_GDP	Serv_GDP	Ind_GDP
Market Access	2.530***	2.927***	2.956***	2.620***
	(0.104)	(0.127)	(0.120)	(0.165)
Altitude	0.0971***	-0.00722	0.0784***	0.115***
	(0.00867)	(0.0106)	(0.0100)	(0.0137)
Population_Density	0.00155***	0.000786***	0.00153***	0.00206***
	(5.65e-05)	(6.91e-05)	(6.53e-05)	(8.94e-05)
RuralityIndex	-0.994***	0.936***	-1.686***	-1.541***
	(0.0653)	(0.0799)	(0.0756)	(0.103)
Saber11 score	0.129	-0.376***	-0.533***	0.850***
	(0.0908)	(0.111)	(0.105)	(0.144)
Homicides per capita	8.494	18.15**	21.96***	4.715
	(7.180)	(8.778)	(8.302)	(11.37)
Literacy 1951	3.62e-06***	-1.60e-05***	-7.12e-06***	1.24e-05***
	(9.84e-07)	(1.20e-06)	(1.14e-06)	(1.56e-06)
Constant				
Observations	6,491	6,491	6,491	6,491
R_squared	0.320	0.157	0.319	0.241

Note: $***p < 0.01, **p < 0.05, *p < 0.1$. In These regressions, we exclude main cities and cities surrounding them in a radius of 25km. The instrument is the market access generated with the least cost path times and keeping population constant 1985. Market access, altitude, and saber 11 are in logarithms. Standard errors in parenthesis

Table 11: IV regressions of the effect of market access on GDP, quasi-random component

Variables	GDP_CEDE	Agr_GDP	Serv_GDP	Ind_GDP
Market Access	2.321***	2.597***	2.666***	2.422***
	(0.0985)	(0.121)	(0.112)	(0.148)
Altitude	0.117***	0.0146	0.101***	0.134***
	(0.00877)	(0.0107)	(0.00998)	(0.0132)
Population_Density	0.00124***	0.000572***	0.00120***	0.00175***
	(5.50e-05)	(6.74e-05)	(6.26e-05)	(8.29e-05)
RuralityIndex	-1.538***	0.481***	-2.240***	-1.904***
	(0.0635)	(0.0778)	(0.0722)	(0.0956)
Saber11 score	0.0780	-0.460***	-0.597***	0.815***
	(0.0932)	(0.114)	(0.106)	(0.140)
Homicides per capita	4.072	13.90	16.80**	3.202
	(7.367)	(9.030)	(8.385)	(11.10)
Literacy 1951	-3.07e-06***	-2.17e-05***	-1.43e-05***	1.02e-05***
	(8.78e-07)	(1.08e-06)	(9.99e-07)	(1.32e-06)
Constant				
Observations	6,834	6,834	6,834	6,834
R_squared	0.330	0.144	0.368	0.255

Note: $***p < 0.01, **p < 0.05, *p < 0.1$. These regressions include the main cities instrument is a quasi-random component of the market access. Distance to the infrastructure, altitude and saber 11 are in logarithms. Standard errors in parenthesis

Table 12: IV regressions all GDP proxies Market access

Variables	GDP_CEDE	Aggregate Value	Constant05_GDP	IndComTax	Constant94_GDP
Market Access	2.392***	1.674***	0.694***	3.809***	1.123***
	(0.0979)	(0.143)	(0.164)	(0.271)	(0.319)
Altitude	0.101***	0.0344***	0.178***	0.0540**	0.144***
	(0.00857)	(0.0124)	(0.0144)	(0.0236)	(0.0281)
Population_Density	0.00153***	0.00118***	0.00157***	0.00126***	0.00175***
	(5.62e-05)	(7.51e-05)	(9.01e-05)	(0.000147)	(0.000196)
RuralityIndex	-0.950***	-1.268***	-2.322***	-3.253***	-2.356***
	(0.0652)	(0.0925)	(0.108)	(0.177)	(0.219)
Saber11 score	0.106	-0.286**	0.187	-0.564**	0.705**
	(0.0903)	(0.129)	(0.150)	(0.247)	(0.328)
Homicides per capita	9.956	42.08***	-20.82	55.47***	-54.56**
	(7.140)	(11.27)	(12.85)	(21.10)	(22.00)
Literacy 1951	3.40e-06***	-4.48e-06***	1.56e-05***	1.01e-05***	1.44e-05***
	(9.80e-07)	(1.43e-06)	(1.65e-06)	(2.69e-06)	(3.19e-06)
Observations	6,491	10,223	9,230	9,147	2,743
R_squared	0.327	0.090	0.152	0.107	0.186

Note: $***p < 0.01, **p < 0.05, *p < 0.1$ In this table show the different GDP proxies that we have managed, from CEDE, Aggregate Value from DNP, constant prices 0f 2005 and 1994, also the industry and commerce tax which is a proxy of municipal economic activity. All regressions include municipality and year fixed effects.

Table 13: IV regressions of the effect of Market access on GDP for different distances to the infrastructure

Variables	GDP(20km)	GDP(25km)	GDP(30km)	GDP(35km)	GDP(40km)
Market Access	1.815***	1.359***	1.642***	1.420***	1.452***
	(0.265)	(0.203)	(0.203)	(0.187)	(0.193)
Altitude	0.178***	0.289***	0.328***	0.249***	0.436***
	(0.0315)	(0.0283)	(0.0244)	(0.0203)	(0.0191)
Population_Density	0.000453***	0.000451***	0.000582***	0.000695***	0.000963***
	(9.49e-05)	(9.29e-05)	(9.09e-05)	(7.70e-05)	(7.95e-05)
RuralityIndex	-5.115***	-5.072***	-4.255***	-4.568***	-3.928***
	(0.214)	(0.181)	(0.148)	(0.112)	(0.113)
Saber11 score	-0.444**	-0.278	-0.0459	-0.103	0.0829
	(0.225)	(0.201)	(0.184)	(0.170)	(0.169)
Homicides per capita	-40.76**	-60.60***	-56.78***	-58.09***	-45.33***
	(18.53)	(16.92)	(16.03)	(14.62)	(14.55)
Literacy 1951	-7.48e-06	7.16e-06***	4.11e-06***	1.05e-05***	9.65e-06***
	(9.09e-06)	(1.62e-06)	(1.57e-06)	(1.31e-06)	(1.36e-06)
Observations	4,220	5,048	5,892	6,713	7,226
R_squared	0.270	0.236	0.213	0.302	0.266

Note: $***p < 0.01, **p < 0.05, *p < 0.1$ In this table we show regressions including municipalities in a range of 20 to 40km. All regressions include municipality and year fixed effects. The instrument is the market access generated with the least cost path times and keeping population constant 1985. Market access, altitude, and saber 11 are in logarithms. Standard errors in parenthesis.

Table 14: IV regressions of the effect of Market access on GDP for natural regions

Variables	GDP(Andean)	GDP(Caribbean)	GDP(Pacific)	GDP(Orinoquia)
Market Access	8.249***	-14.63***	3.476***	4.371***
	(0.476)	(2.912)	(0.640)	(1.291)
Altitude	-0.222***	-0.0374	-0.0913***	-1.118***
	(0.0157)	(0.0277)	(0.0296)	(0.0851)
Population_Density	0.000568***	0.000512***	0.00126***	0.00949***
	(2.39e-05)	(4.99e-05)	(0.000102)	(0.00116)
RuralityIndex	-3.774***	-1.974***	-3.347***	-2.672***
	(0.0715)	(0.178)	(0.164)	(0.307)
Saber11 score	3.756***	7.672***	1.999***	-1.028
	(0.292)	(0.686)	(0.651)	(1.114)
Homicides per capita	12.64	139.6	-115.3	15.79
	(33.20)	(106.7)	(71.32)	(53.96)
Literacy 1951	-1.22e-06	-2.05e-06***	2.63e-05***	-4.76e-06**
	(7.75e-07)	(6.95e-07)	(8.86e-06)	(1.89e-06)
Observations	5,973	1,650	1,282	556
R_squared	0.483	0.374	0.406	0.527

Note: $***p < 0.01, **p < 0.05, *p < 0.1$ Dependent variable is total GDP from the national planning department. In this table, we show regressions, including natural regions of the country. All regressions include municipality and year fixed effects. The instrument is the market access generated with the least cost path times and keeping population constant 1985. Market access, altitude, and saber 11 are in logarithms. Standard errors in parenthesis.

Table 15: IV regressions of the effect of distance on land, owners and income GINI full sample

Variables	Gini	Owners_Gini	Land_Gini	DevelopmentIndex
Distance to Infrastructure	-0.0162	-0.0217***	-0.0905***	5.354***
	(0.0188)	(0.00734)	(0.0114)	(1.110)
Altitude	-0.00187	-0.00452***	-0.00188	2.770***
	(0.00413)	(0.00121)	(0.00175)	(0.170)
Population_Density	-1.83e-05	2.91e-05***	5.31e-05***	-0.00223**
	(2.81e-05)	(9.30e-06)	(1.17e-05)	(0.00106)
RuralityIndex	0.0595	0.0725***	0.166***	-41.12***
	(0.0475)	(0.0129)	(0.0246)	(2.521)
Saber11 score	-0.0665	-0.0274***	-0.0931***	5.363***
	(0.0898)	(0.0104)	(0.0168)	(1.743)
Homicides per capita	21.57**	0.880	-0.953	-630.3***
	(10.32)	(0.982)	(1.469)	(149.7)
Literacy 1951	-3.18e-08	2.12e-07	-1.21e-06***	0.000158***
	(1.88e-06)	(1.38e-07)	(1.88e-07)	(1.96e-05)
Constant				
Observations	124	9,377	9,990	8,613
R_squared	-0.284	-0.018	-0.888	-0.049

Note: $***p < 0.01, **p < 0.05, *p < 0.1$ In this table we show regressions including municipalities in a range of 20 to 40km. All regressions include municipality and year fixed effects. The instrument is the market access generated with the least cost path times and keeping population constant 1985. Market access, altitude, and saber 11 are in logarithms. Standard errors in parenthesis.

Table 16: IV regressions of the effect of distance on land, owners and income GINI reduced sample

Variables	Gini	Owners_Gini	Land_Gini	DevelopmentIndex
Distance to Infrastructure	-0.00858	-0.0173**	-0.0924***	3.689***
	(0.0143)	(0.00780)	(0.0101)	(1.046)
Altitude	-0.00109	-0.00417***	-0.00122	2.565***
	(0.00339)	(0.00112)	(0.00160)	(0.156)
Population_Density	-2.54e-05	2.95e-05***	4.93e-05***	-0.000644
	(2.40e-05)	(9.77e-06)	(1.09e-05)	(0.00108)
RuralityIndex	0.0381	0.0679***	0.133***	-36.16***
	(0.0365)	(0.0114)	(0.0206)	(2.217)
Saber11 score	-0.0432	-0.0294***	-0.0917***	4.953***
	(0.0791)	(0.0102)	(0.0167)	(1.658)
Homicides per capita	20.88**	0.996	-1.338	-570.7***
	(9.314)	(0.984)	(1.482)	(142.6)
Literacy 1951	-6.09e-07	1.04e-06	-1.48e-06***	0.000162***
	(1.53e-06)	(6.62e-07)	(2.30e-07)	(2.03e-05)
Constant				
Observations	119	8,900	9,494	8,174
R_squared	0.029	-0.001	-0.913	0.048

Note: $***p < 0.01, **p < 0.05, *p < 0.1$

Table 17: IV regressions for the effect of market access on land, owners and income GINI reduced sample

Variables	Gini	Land_Gini	Owners_Gini	DevelopmentIndex
Market Access	-0.0578	0.122***	0.173***	28.38***
	(0.0370)	(0.0132)	(0.0145)	(1.791)
Altitude	0.00242	0.00978***	0.00445***	1.354***
	(0.00304)	(0.00110)	(0.00103)	(0.149)
Population_Density	-3.17e-05	-4.56e-05***	5.80e-05***	-0.00237**
	(2.03e-05)	(7.73e-06)	(1.37e-05)	(0.000953)
RuralityIndex	-0.0155	-0.0644***	0.0288***	-26.79***
	(0.0225)	(0.00840)	(0.00853)	(1.117)
Saber11 score	-0.0390	-0.0378***	-0.0211**	3.802**
	(0.0755)	(0.0115)	(0.0103)	(1.558)
Homicides per capita	14.66**	2.732***	3.095***	-346.8***
	(7.182)	(1.025)	(0.918)	(126.3)
Literacy 1951	-3.22e-07	-1.27e-06***	-1.97e-06***	9.74e-05***
	(1.09e-06)	(1.48e-07)	(6.39e-07)	(1.69e-05)
Constant				
Observations	101	8,682	8,116	7,421
R_squared	0.178	0.038	0.034	0.147

Note: $***p < 0.01, **p < 0.05, *p < 0.1$. The instrument is the market access derived from the least-cost path times. Standard errors in parenthesis

Table 18: IV regressions of the effect of market access on land, owners and income GINI reduced sample

Variables	Gini	Land_Gini	Owners_Gini	DevelopmentIndex
Market Access	-0.0550	0.115***	0.165***	26.83***
	(0.0352)	(0.0124)	(0.0138)	(1.690)
Altitude	0.00239	0.00998***	0.00485***	1.395***
	(0.00303)	(0.00109)	(0.00102)	(0.148)
Population_Density	-3.13e-05	-4.71e-05***	5.54e-05***	-0.00266***
	(2.03e-05)	(7.70e-06)	(1.36e-05)	(0.000950)
RuralityIndex	-0.0169	-0.0626***	0.0291***	-26.29***
	(0.0227)	(0.00840)	(0.00852)	(1.118)
Saber11 score	-0.0356	-0.0385***	-0.0217**	3.562**
	(0.0753)	(0.0115)	(0.0103)	(1.554)
Homicides per capita	14.12*	2.773***	3.116***	-331.8***
	(7.189)	(1.022)	(0.916)	(126.0)
Literacy 1951	-2.85e-07	-1.28e-06***	-2.12e-06***	9.48e-05***
	(1.09e-06)	(1.47e-07)	(6.45e-07)	(1.69e-05)
Constant				
Observations	101	8,682	8,116	7,421
R_squared	0.177	0.044	0.038	0.151

Note: $***p < 0.01, **p < 0.05, *p < 0.1$.Instrument is the quasi-random component of the market access, standard errors in parenthesis

Table 19: GDP Spillover effects

Variables	GDP_CEDE	Agr_GDP	Ind_GDP	Serv_GDP
Interventions	0.331***	0.257***	0.500***	0.250***
	(0.0216)	(0.0197)	(0.0437)	(0.0137)
BoarderNeighbors	-0.00690	0.0406	-0.0159	-0.0100
	(0.0341)	(0.0288)	(0.0709)	(0.0210)
Neighbors35k	0.181***	0.160***	0.300***	0.136***
	(0.0142)	(0.0157)	(0.0292)	(0.0101)
Constant	10.92***	9.239***	9.201***	9.945***
	(0.0116)	(0.0116)	(0.0257)	(0.00774)
Observations	10,420	10,420	10,420	10,420
R_squared	0.021	0.021	0.020	0.018
Number of Municipalities	1,042	1,042	1,042	1,042

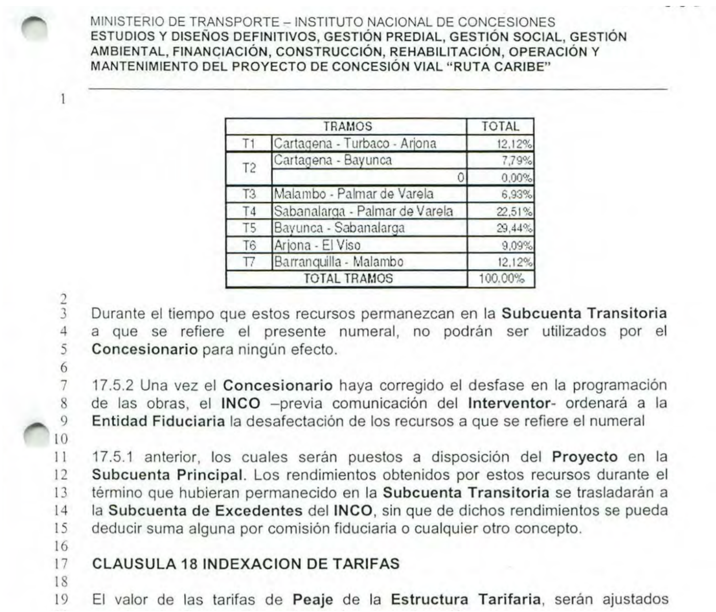
Note: $***p < 0.01, **p < 0.05, *p < 0.1$. Interventions are dummies on all municipalities that have direct contact with the road. Border neighbors are dummies signaling adjacent municipalities to the intervened, and Neighbors are municipalities beyond the adjacent distance of 35km from the infrastructure. All regressions include fixed effects by departamento and year. Standard errors in parenthesis

Table 20: GINI spillover effects

Variables	Gini	Owners_Gini	Land_Gini	DevelopmentIndex
Interventions	-0.000210	0.0137***	0.00427	-7.272**
	(0.00300)	(0.00289)	(0.00372)	(2.974)
BoarderNeighbors	0.00408	0.0144***	0.00771	0.291
	(0.00464)	(0.00317)	(0.00533)	(3.992)
Neighbors35k	-0.0161***	0.00488**	0.00311	1.830
	(0.00226)	(0.00244)	(0.00295)	(2.117)
Constant	0.461***	0.703***	0.684***	40.07***
	(0.000818)	(0.00179)	(0.00253)	(1.630)
Observations	1,992	11,747	12,344	11,466
R_squared	0.050	0.001	0.000	0.002
Number of Municipalities	996	916	1,035	1,046

Note: $***p < 0.01, **p < 0.05, *p < 0.1$. Interventions are dummies on all municipalities that have direct contact with the road. Border neighbors are dummies signaling adjacent municipalities to the intervened, and Neighbors are municipalities beyond the adjacent distance of 35km from the infrastructure. All regressions include fixed effects by departamento and year. Standard errors in parenthesis

Figure 9: Sample of Colombian road contract



MINISTERIO DE TRANSPORTE – INSTITUTO NACIONAL DE CONCESIONES
ESTUDIOS Y DISEÑOS DEFINITIVOS, GESTIÓN PREDIAL, GESTIÓN SOCIAL, GESTIÓN AMBIENTAL, FINANCIACIÓN, CONSTRUCCIÓN, REHABILITACIÓN, OPERACIÓN Y MANTENIMIENTO DEL PROYECTO DE CONCESIÓN VIAL "RUTA CARIBE"

TRAMOS		TOTAL
T1	Cartagena - Turbaco - Arjona	12,12%
T2	Cartagena - Bayunca	7,79%
	0	0,00%
T3	Malambo - Palmar de Varela	6,93%
T4	Sabanalarga - Palmar de Varela	22,51%
T5	Bayunca - Sabanalarga	29,44%
T6	Arjona - El Viso	9,09%
T7	Barranquilla - Malambo	12,12%
TOTAL TRAMOS		100,00%

Durante el tiempo que estos recursos permanezcan en la **Subcuenta Transitoria** a que se refiere el presente numeral, no podrán ser utilizados por el **Concesionario** para ningún efecto.

17.5.2 Una vez el **Concesionario** haya corregido el desfase en la programación de las obras, el **INCO** –previa comunicación del **Interventor**- ordenará a la **Entidad Fiduciaria** la desafectación de los recursos a que se refiere el numeral

17.5.1 anterior, los cuales serán puestos a disposición del **Proyecto** en la **Subcuenta Principal**. Los rendimientos obtenidos por estos recursos durante el término que hubieran permanecido en la **Subcuenta Transitoria** se trasladarán a la **Subcuenta de Excedentes** del **INCO**, sin que de dichos rendimientos se pueda deducir suma alguna por comisión fiduciaria o cualquier otro concepto.

CLAUSULA 18 INDEXACION DE TARIFAS

El valor de las tarifas de **Peaje** de la **Estructura Tarifaria**, serán ajustados

Figure 10: Least cost path mechanism