Highways and Travel to Work: Evidence from Brazil

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RESUMO

Um relatório recente da Confederação Nacional de Transportes (CNT, 2017) afirmou que os investimentos na infraestrutura de transporte do Brasil estagnaram em níveis muito baixos desde a década de 1970. Isso é alarmante, pois soluções de transporte são essenciais para promover crescimento, especialmente para um país de tamanho continental como o Brasil. Entre os estudos sobre os determinantes do crescimento das cidades realizados para o Brasil, poucos tratam especificamente o impacto da infraestrutura de transporte. Portanto, utilizando dados do Censo e análise de regressão com variável instrumental, buscamos identificar como a proximidade de uma rodovia afeta de forma causal a migração pendular entre 2000 a 2010. Encontramos uma relação causal positiva entre a proximidade das rodovias e o deslocamento diário para uma cidade diferente, o que implica que a infraestrutura de transporte pode oferecer aos trabalhadores acesso a um mercado de trabalho mais amplo.

Palavras-chave: Rodovias, Infraestrutura de transporte, migração pendular

Área de submissão: Infra-estrutura, transporte, energia, mobilidade e comunicação

Códigos JEL: R11, R41

ABSTRACT

A recent report from the National Confederation of Transport (CNT, 2017) stated that investments in Brazil's transportation infrastructure have stagnated at deficient levels since the 1970s. This is alarming, as transportation solutions are essential for promoting growth, especially for a continental country like Brazil. Among studies that consider the determinants of city growth for Brazil, few treat the impact of transportation infrastructure specifically. Therefore, using Census data and regression analysis with instrumental variable, we investigate how proximity to a highway causally affects urban employment growth and travel to work from 2000 to 2010. We found a positive causal relationship between proximity to highways and daily commuting to a different city, which implies that transportation infrastructure can offer workers access to a broader labor market.

Keywords: Highways, Transportation infrastructure, Travel to work

JEL codes: R11, R41

1 Introduction

Daily commuting still is a central part of the day-to-day of many workers, even with the proliferation of teleworking opportunities (Sandow, 2011). For many who live in rural areas and in the fringe of large centers, the possibility to commute long distances is a valuable alternative to out-migration (Green et al., 1999, van Ham, 2002; Lück and Ruppenthal, 2010). As better transportation can offer workers access to a larger labor market (Bjarnason, 2014), it can be argued that the lack of investment in transportation infrastructure is an important obstacle to a better labor market matching. In fact, the literature has affirmed that better transportation network improves employment mainly in urban areas (Zenou, 2000; Coombes and Casado-Díaz, 2005; Bastiaanssen et al., 2022).

Much research has been done to show the interaction between long-distance commuting and workers' access to job opportunities for the develop world (Sandow, 2008; de Silva et al., 2011; Boussauw et al, 2012; Bergantino and Madio, 2016; Chen et al., 2021). Studies have found that workers are willing to face longer commutes to have better access to job opportunities, higher gains and cheaper rent.

There are strong reasons, however, to believe that these relationships are even more pronounced in developing countries. In South Africa, for instance, cities' shape has been largely affected by policies of segregation from before and during the Apartheid era. Work opportunities are often located far from worker's homes, particularly for black South Africans. This created high commuting costs, both in terms of expenses and travel time. According to the 2003 National Travel Survey, black South Africans spent almost double the average commute time of an american worker in 2002. A decade later, the 2013 South African National Travel Survey reported that the average commuting time had increased by an additional 14 minutes for both black and white South Africans (Kerr, 2015). In China, the past few decades were marked by fast urbanization and expansion of motorisation. Due to the rapid economic growth and large migration movements to China's metropolitan areas, the transport development gap has been widening between developed and underdeveloped areas. Investiment in transportation solutions in eastern China has been historically much higher than in the central and western regions. In addition, the income gap of Chinese residents resulted in a class-based stratification of housing choices in China, as igh-income workers are more likely to accept longer commutes in order to fulfill their residential preferences (Li et al., 2019). In Latin America, after a period of import-substitution policies and intense population growth from the 1930s to the 1970s, the new economic liberalization and export-oriented developments in the 1980s improved access to new technology in the areas of telecommunication and transport (Rowe and Bell, 2018). With an inflow of new international investiments, large-scale and mainly natural resource-based enterprises started to appear distant from the main metropolitan centers at the time (ECLAC, 2012). These developements provoked transformations that reshaped both the labor market and the infrastructure landscape of latin countries ever since.

Specifically for Brazil, long-distance commuting is an important subject for four reasons. First, Brazil is a large developing country known for the high density of its urban areas (Ingram and Carrol, 1981; Da Mata et al., 2007; Fernandez-Maldonado et al., 2014). The Portuguese colonization produced a country with isolated cities across a great territory, which later hindered the development of transportation infrastructures (Natal, 1991). When compared to other countries (US, India, and China), Brazil has the largest percentage of inhabitants living in very small cities (100k to 250k people) (Chauvin et al., 2017). The insufficient supply of transport solutions, together with opportunities dispersed over a large territory, led to the development of a labor market significantly affected by spatial mismatch. Workers often need to travel long distances to reach their job. Poor workers are the most harmed by this configuration, as they face much longer commutes than richer workers (Haddad and Barufi, 2017a). Second, in the 2000 decade the country saw a lot of growth of its agricultural and mining industries, mainly in the Central-West region, North region and in the state of Minas Gerais. These developments took place far from major cities, forcing workers to travel further afield. Third, the Brazilian transportation infrastructure is notably inadequate for its size and economy. Investments in transport have stagnated at exceptionally low levels since the 1970s (CNT, 2017a). While the highway network had an expansion of 96.7% of its extension in the 1960s, it only grew 11% from 2000 to 2010. Historically, the federal government have failed to execute around 30% of the authorized road infrastructure annual budget, causing an investment deficit that is reflected in the accelerated process of wear and tear on the federal road network (CNT, 2017b). Fourth, long-distance commuting is a growing phenomemon in Brazil, despite the developement of information technology. Interestingly, the growth of people who travel to work or study in the 2000s was higher in percentage than the growth of the whole group of people who work or study. Actually, the number of workers who commute to a different city for working increased by 209% from 2000 to 2010 (from 7.4 million to 15.5 million) (Moura et al.; 2013), while the total number of workers grew 135% in the same period.

This research investigate if the availability of transportation infrastructure has a causal impact on inter-urban access to employment between brazillian cities. Specifically, we use instrumental variables regression to evaluate if being near a highway had a causal effect on the growth of workers who traveled daily between cities for working from 2000 to 2010 in Brazil. We analyze outbound commuting and we also investigate heterogeneous results by sex and education levels.

Among studies that consider the determinants of long-distance commuting (Sandow, 2008; de Silva et al., 2011; Boussauw et al, 2012; Cassel et al., 2013; Bergantino and Madio, 2016; Chen et al., 2021), we find several gaps that we aim to fill with the present study. First, despite the existence of a large literature that investigates the impact of transportation on employment and wealth (Holl, 2004a; Holl, 2004b; Banerjee, Duflo, and Qian, 2012; Duranton and Turner, 2012; Faber, 2014; Redding and Turner, 2014; Gibbons, 2019), no previous work treats the specific impact of transportation infrastructure on travel to work[1] patterns using causal inference. Second, there is little evidence for the role of transportation infrastructure in lessening spatial mismatch in developing countries. Third, the recent studies that examine the spatial mismatch hypothesis for Brazil only consider intra-urban access to the labor market, and not inter-urban access (Haddad and Barufi, 2017a; Duarte, 2020). Our study also contributes to expanding a growing literature that seeks to understand the historical process of metropolization and urban expansion in Brazil paying close attention to workers commuting patterns (Moura et al., 2005; Ojima et al.; 2010; Moura et al., 2013).

We found that, on average, Brazillian cities that had access to a highway saw their outbound commuting grow 49.6% over ten years more than their counterparts. When we analyze specific groups, we obtain statistical significance for men but not for women, indicating that women have more restrictions to accept distant jobs than men. Access to highways had no significant impact on workers with no education attainment, while it was most significant for workers with at least primary education. These results provide strong evidence that Brazilian workers – mainly skilled men – take advantage of highways to find better job opportunities in adjacent employment centers.

The combination of poor transportation infrastructure and low-income population produced, over the years, a pattern of cities with very high density and remarkably high commuting costs (Ingrad and Carrol 1981, Fernandez-Maldonado et al. 2014, Silveira-Neto et al. 2015). Better access to transportation infrastructure, thus, can be a solution to counterbalance the hardships imposed by such a spatially concentrated job market. Moreover, when transport infrastructures are underdeveloped, as in the Brazillian case (CNT, 2017b), even small expansions should promote big gains in terms of job allocation and employment. Given the scarcity of public resources, investing in transport is also a matter of better resource allocation for promoting equality and growth.

This paper is organized as follows. In the second section, we present a review of the literature; in the third section we give the historical context of transport in Brazil; in the fourth section we present our empirical strategy and data; in the fifth section we present the results; and the last section brings our conclusions.

2 Literature Review

Many studies examined commuting patterns of workers empirically, exploring how far they are willing to travel and for what reasons. Sandow (2008) used logistic regression with data for northern Sweden to study commuting behavior in low-density areas. He found a positive relationship of longer commuting with living in low-density regions, being male, and being

[1] In this study, we use the term *travel to work* to refer to the daily commute of workers who work in a city different than the one where they live. In the literature, this movement is also known as *long-distance commuting* (Öhman, Lindgren; 2003), *pendulum migration* (Zaslavsky, Goulart; 2017), or *daily migration* (Silva, Freitas; 2020).

younger. For Australia, de Silva et al. (2011) analysed commuting patterns and found that the difference in income and education levels between origin and destination of commuters were determinant for the number of workers who traveled to work. Boussauw et al (2012) assessed the relationship between spatial aspects with commuting distance for Flanders, Belgium, using spatial regression models. They found that high residential density, high degree of spatial diversity, and elevated level of job accessibility were all related to short commute distances. Bergantino and Madio (2016) studied inter-regional mobility in the UK. They used multinomial logit to examine if monetary incentives affect the likelihood of moving to other regions and found a positive relationship that is larger for males than for females workers. Chen et al. (2021) explored inter-city commuting data for Germany between 1994 and 2018 using Machine Learning algorithms. They found that income is a determinant factor for travel to work: cities with a lower average income have more outbound commute towards higher income cities. Housing prices is also related with travel to work, as expensive apartments and higher rent prices are related to more inbound commuting from workers who live elsewhere. They also found that long-distance commute is more intense in the secondary and tertiary sectors, while farmers from the primary sector tend not to commute. Summarizing, authors argue that those who are willing to face longer commutes do it because they expect higher gains. They have access to more job opportunities (for those who live in low-density areas), receive a better salary (for the more skilled), and pay less rent (as they avoid moving to an high-rent metropolis).

For Brazil, specifically, Moura et al. (2005) produce a rich review of the concept of pendulum migration and its applications in the literature, along with a survey of earlier empirical studies in the subject. Brito and Souza (2005) study the travel to work movement in the Metropolitan Region of Belo Horizonte, in the southeast of Brazil. Using data from 2002, they found an interesting fact: almost 70% of those who travel to work to the capital city of Belo Horizonte used to live in the capital. This suggests that the peripherization of the region was caused by pressures from the real estate market, a phenomenon also observed in other parts of Brazil in the 1970s (Ojima et al.; 2010). Moura et al. (2013) examine the travel to work movement in Brazil by proposing a typology to differentiate cities in terms of direction flow and size. They found that aproximately 51% of cities fall in the ”small-evader” category[2]. Silva and de Freitas (2020) examined the characteristics of those who travel to work in the southeast of Brazil using Logit models applied to Census data of 2010. They found that men, urban dwellers, and high-income workers are more prone to live and work in different cities. Meanwhile, being white and having more children are factors that reduce the chance of daily migration.

An important source of heterogeneity in commuting distances is gender. Empirical evidence suggests that women have more restrictions to accept longer-hours work due to household and childcare responsibilities, which is known as the ”household responsibility hypothesis” (Turner and Niemeier, 1997). The studies reviewed above in this section largely support this hypothesis for developed regions (see Mcquaid et al., 2001; Shearmur, 2006; Sandow, 2008; Cassel

[2]This number is based on the subset of cities where the daily flow is at least a thousand people.

et al. 2013; Bergantino and Madio, 2016), but there is also important evidence for developing countries. Silveira-Neto et al. (2015) examined data for the Metropolitan Region of São Paulo using ordinal probit models. They inferred that being a married female implied an increase of about 7% on the probability of having shorter commuting times. Additionally, they found that single or divorced women have a shorter commute than their male counterparts. Olivieri and Fageda (2021) also found support for the household responsibility hypothesis in Montevideo, Uruguay. Through multilevel regression models, they obtained evidence that, on average, women make fewer trips and travel shorter distances. In the presence of children, the female breadwinner reduces their travel distance while the male breadwinner increases it. Also, women make more use of transit, thus residential areas with less access to public modes will negatively affect women's mobility.

The long-distance commuting also appears associated with education level. de Silva et al. (2011) found that higher skills are a dominant factor prompting long-distance commuting. Cassel et al. (2013) found that more skilled people in Dalarna (Sweden) were more willing to travel for a longer duration. Similarly, Silva and de Freitas (2020) found that lower levels of education is associated with less daily migration in Brazillian cities. These findings suggest that more skilled people benefit more from a larger job market, both in developed and developing countries. This is an important result for Brazil. As the country sustain high levels of inequality, it is expected that infrastructure will affect people differently according to their qualification. As an example, access to transportation can help a computer scientist from a small town to find a much better-paying job in a bigger city. If this worker lives in a big city, he can also travel daily to another big city without having to incur migration costs. However, for a low-skilled worker, like a plumber, the prospect of gains is much smaller. The costs of commuting probably will not compensate the benefits. The worker needs to have a minimum qualification to take advantage of the long-distance commuting.

3 Travel to work and transport infrastructure in Brazil

3.1 Evolution of land transportation in Brazil

Natal (1991) wrote that there is often a relationship between the occupation of a country and its transportation infrastructure. In this regard, Brazil's occupation process is an interesting case. For early colonizers, a common occupation strategy was to first settle on the coast and then move to the interior regions of the country. That was the case, for instance, in the colonization process of North America. After arriving in Brazil in 1500, the Portuguese logic, however, was to rapidly penetrate the interior of the country to take profit from its abundant natural resources (Natal, 1991). Throughout the colonial period, Brazilian spatial occupation was based on the exploration of primary exportation products (basically: sugar cane, gold, and coffee). This approach generated Brazilian first important cities, but also produced "economic islands": highly specialized cities isolated and distant from each other (Furtado, 1968). In the first centuries, there were no economic connections between Brazilian cities or regions as the transport infrastructure was poorly developed (Natal, 1991).

With the Industrial Revolution came a demand for faster transportation in western countries, which in the 19th century was solved by the construction of railways. The dispersed occupation of Brazil, however, imposed a challenge, as it was difficult and expensive to build an integrated system throughout its great territory (Natal, 1991). Despite the large system of navigable waterways concentrated in Brazil's north and west, they could not substitute railway development as most production and commerce was located in regions that required land transportation (Summerhill, 2018). Natal (1991) writes that the answer was to build a radial railway system connecting the main cities in the interior to ports on the coast. The railroads in this system were rarely interconnected, which was not a problem initially as the Brazilian economy was export-oriented. However, as the internal markets started to develop in the later 19th century, the limited transportation structure turned out to be insufficient due to the lack of interregional connections. It was in this context that highways started to appear, often near important railways (Nazareth, 1978). Paved roads were a cheaper way to connect different regions of the country and supply transportation from the train stations to cities nearby. Despite that, highway construction developed slowly until the mid-20th century, when it became the most important mode of transportation in Brazil (Natal, 1991). The inflection point occurred when the Brazilian capital was transferred to a new city built from the ground up in the center of the country: Brasília. As a result, a new highway system was constructed to connect the new capital with all the other capitals of the country (Morten and Oliveira, 2018).

According to Nazareth (1978), because of increased investments in road systems and lack of maintenance of railways and navigation infrastructure, the 1960s ended with 95% of passengers and 73% of goods being transported by roads. The 1960s started a period of major changes in the population geography of Brazil. The urban centers of the country were going through an intense process of industrialization, and many Brazilians migrated from rural regions to urban cities looking for better working conditions. In the second half of the 20th century, the urban population of Brazil increased 7.3 times – from 19 million to 138 million. This movement was strikingly fast compared to capitalist countries (European countries, US, and Japan) (Brito, Souza; 2005). According to Heidrich (2005), this rapid expansion of the urban landscape was possible, among other reasons, by the declining costs of transportation.

The 1970s brought a world oil crisis that severely damaged the Brazilian economy. As transportation infrastructure had been mainly financed with public money, the Brazilian transportation system started to deteriorate (Natal, 1991). Since then, investments in transportation infrastructure have stagnated at extremely low levels (CNT, 2017a). The federal government have failed to execute around 30% of the authorized road infrastructure annual budget, causing an investment deficit that is reflected in the accelerated process of wear and tear on the federal road network (CNT, 2017b). Table 1 shows the extension of paved national highways from

1960 to 2010 and its growth per decade.[3]

Table 1: Paved highways extension growth from 1960 to 2010 (Km)

Period	Extension	Relative to past decade
1960	8,675	-
1970	24,146	178.34%
1980	47,487	96.67%
1990	50,372	6.08%
2000	56,097	11.37%
2010	62,351	11.15%

Data from the Ministry of Transport, Ports and Civil Aviation.

The combination of quick industrialization, poor transportation infrastructure and low-income population produced, over the years, a pattern of cities with very high density and remarkably high commuting costs (Ingrad and Carrol 1981, Fernandez-Maldonado et al. 2014, Silveira-Neto et al. 2015).

3.2 Travel to work in Brazil

According to Moura et al. (2013), of the almost 110 million people who worked or studied in 2000, 6,7% performed this activity outside their municipality of residence. This percentage rose to 10,6% in 2010, and the number of people more than doubled: it went from 7,403,456 to 15,472,863 people. Of the 5.565 municipalities in Brazil in 2010, 56,7% had a daily inbound and outbound flow of at least a thousand people. The authors affirmed that the growth of people who traveled to work or study in the 2000s was even higher in percentage than the growth of the whole group of people who worked or studied.

The evolution of travel to work numbers is consistent with key policies that took place at the same period in Brazil. First, a government program provided some public services to remote areas of the country, such as public universities. Many new jobs were created because of those universities, which imediately improved the lives of the city residents (Carazza and Silveira-Neto, work in progress); and students that lived in the city and in neighbouring towns now had an incentive to commute to the university in search of better education opportunities. Second, the 2000 decade saw an expansion of industrial activities outside of the traditional urban centers of the country. The North and Northeast regions of Brazil received both public and subsidized foreign investiments for the construction of refineries, automotive assembly plants, and port and shipping industry. As those investiments were mainly located in metropolitan areas, new commuting paths were emerged that stimulated more travel to work.

In spite of the influence of national policies, there is also evidence that the network of highways was a strong conductor of the travel to work advance in this period. Moura et al. (2013) stated that, in the 2000s, city connections grew from the typical core-periphery pattern to

[3] In our data analysis, we work with both paved and unpaved highways. However, Table 1 only shows paved roads because of limited historical data avaiability. In 2000, paved highways were 79% of the total extension (CNT, 2013).

more complex arrangements in the last decades. This is true for the states that form the Brazilian South Region (Porto Alegre, Paraná, and Santa Catarina) that are interwoven by two important highways (the BR 116 and BR 101). This phenomenon is also observable in the Northeastern coast, where the metropolitan region of Recife and the urban agglomerations of Maceió, João Pessoa, and Natal are all linked by the national road network and have expressive numbers of daily migration. The authors noted that, in some cases, travel to work flows materialized following highway paths.

4 Empirical Strategy

4.1 Specification

In this subsection, we propose an empirical model that depicts how highways affect travel to work.

Let i be the index of cities and j the index of states. The cross-section model is:

$$y_i = \alpha + \beta \cdot \text{Highway access}_i + \Gamma \cdot \text{Controls}_i + \lambda_{s(i)} + \varepsilon_i \tag{1}$$

in which y_i is log difference of the total of people who traveled outbound to work in the 2000-2010 period. As our unit of study is the municipality, *outbound commuting* describes workers who travel away from their city of residence daily to reach their workplace. To build our explanatory variable, we borrow from Faber's (2014) approach. Highway access_i is a dummy variable that takes the value of one if any part of the municipality was within 10 km distance of a federal highway in 2000 (and zero otherwise). $Controls_i$ is a vector of eight variables, which are explained with detail in Section 4.2.

Every variable was measured at the municipality level, which is the lowest administrative level in Brazil. While this choice provided us with detailed data, it also imposed a problem: from 2000 to 2010, the number of municipalities went from 5,507 to 5,565. As many municipalities had their borders modified, using the original municipality configuration as the unit of study could lead to bias. Instead, we use MCAs (Minimum Comparable Areas), an aggregation of municipalities developed by IPEA (Reis, Pimentel, Alvarenga; 2007). This aggregation strategy allows us to compare the same spatial units throughout time. Similar to Faber (2014), we exclude the MCAs close to the capital cities from the sample. In our preferred specification, we use the range of 50 km from the nearest capital. The final dataset is comprised of 5,162 MCAs.[4] The model is estimated with state fixed effects $\lambda_{s(i)}$. The country has 26 states and one federal district. As we are working only with federal highways, the state fixed effects can help to partial out the effect caused by state highways; we also cluster errors at the microrregion level.

[4]In this study, we use municipality and MCA as interchangeable terms.

4.2 Endogeneity

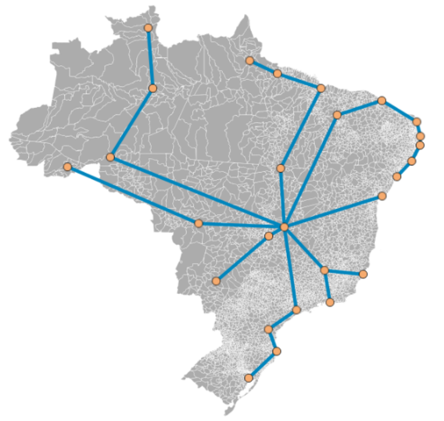
The transportation literature has shown that naive OLS estimations can suffer from endogeneity problems (Baum-Snow and Ferreira, 2015). While new infrastructure can promote job accessibility, it is also true that when decision makers expect a city to grow in employment, they may promote transport investments preemptively. This reverse causality problem could introduce bias to our estimates. In addition, our estimations are prone to suffer from omitted variable bias as there can be unobservable characteristics affecting both provision of infrastructure and access to employment centers. To deal with these issues, several identification strategies have been proposed in the literature. Baum-Snow (2007) used 1947 plans of the Interstate Highway System as an instrument for the network that was built later, being the first work to use construction plans to instrument for realized infrastructure. Duranton and Turner (2012) use the same plans, along with railway networks from the 19th century and expedition routes in past centuries as instruments for current highways' location in the USA. Garcia-López et al. (2017) use Roman roads and 1870 railways as instruments for the Regional Express Rail (RER) infrastructure in Paris metropolitan area. Besides planned routes and ancient roads, other works have used the inconsequential units approach (Redding and Turner, 2014). In this form of identification, straight lines connecting important cities serve as an instrument for highways or railways that were built between them. Smaller cities that conveniently lie in these paths are said to have received a road "accidentally", as if in a random assignment. Banerjee, Duflo, and Qian (2012) used this method as an instrument for China's railway system. More recently, Minimum Spanning Tree (MST) algorithms have been used for generating these artificial networks. These algorithms connect a set of nodes with straight lines minimizing the total length of the segments, thus emulating the job of road planners: connect many cities with a single network minimizing the cost (Faber, 2014). Faber (2014) used this method while studying the impact of China's highway system, and Morten and Oliveira (2018) produced a Spanning Tree Network to predict the Brazilian highway network.

Following previous literature, our identification strategy will rely on a inconsequential units approach borrowed from Morten and Oliveira (2018). The authors built a minimum spanning tree network tailored to mimic the Brazilian government highway plans in 1950s. With the construction of the capital Brasília in a central region of the country, the government simultaneously started building a national highway system connecting the capital to all state capitals. Along with longitudinal, transversal and diagonal roads, they built eight radial highways starting in Brasilia and expanding to the rest of the country. Based on this historical data, the authors divided Brazil into eight segments and built a minimum spanning tree network that connected Brasília to all state capitals within each segment. Our MST network is shown in Figure 1.

Our first stage regression is:

$$\text{Highway access}_i = \sigma + \mu \cdot \text{Access MSTN}_i + \Gamma \cdot \text{Controls}_i + \lambda_{s(i)} + \eta_i \quad (2)$$

Figure 1: The Minimum Spanning Tree Network



Specifically, our instrument Access MSTN_i is a dummy variable that takes the value of one if any part of the municipality was within 10 km distance of the artificial network.

The relevancy condition states that the instrument should be a good predictor of the explanatory variable. As discussed above, historical evidence suggests that the national highways system, from the 1950s, was mainly developed to connect capital cities of Brazil to Brasília as straightforwardly as possible (Morten and Oliveira, 2018). Thus, a minimal spanning tree that connects capital cities to Brasília with straight lines and using the smallest possible total extension should be a good proxy for the engineers' and social planners' strategy at the time. We are confident that our instrument satisfies the relevancy condition, as shown by the first stage F well above the threshold value of 10 (see Table 3). We also believe that our instrument satisfies the exogeneity condition. Due to the inconsequential nature of the generated lines, it is reasonable to affirm that the instrument cannot affect the travel to work levels via any other way except by predicting highway access.

However, as much as the inconsequential units approach is already consolidated in the literature, we take an additional step: we include control variables to ensure the exogeneity of our instrument. The log distance from the nearest capital accounts for the fact that cities near the capital are more likely to receive roads. The log distance from Brasília, the country's capital city, is included because the network was intentionally generated to connect all capital cities to Brasília. The log distance to the coast controls "for access to traditional methods of transportation that existed before the lines of interest were constructed" (Banerjee et al, 2012). Finally, we include three variables that measure proximity to important cities in the economic history of Brazil: key cities to the sugar, gold and coffee business cycles. Cities related to these periods needed a lot of transportation so they are historically better connected. These variables are indices: they take the value 1 if the municipality was directly affected by the respective economic cycle, and a value between 0 and 1 for nearby cities within 200 km based on distance according to a functional form.[5] We also include log of GDP per capita in 2000 and log of population in

[5]For more details, see Naritomi, Soares, and Assunção (2012).

2000 to account for previous levels of development.

4.3 Data

Our dataset was obtained from 3 different sources. The Brazilian Demographic Census is performed by the Brazilian Institute of Geography and Statistics (IBGE) every ten years. We use Census data from 2000 and 2010 to obtain our dependent variable at the municipality level for each decade. The Ministry of Transport, Ports and Civil Aviation provides digital maps and pictures of the highways of Brazil for each decade from 1960 to 2010, and the Brazilian Institute of Geography and Statistics (IBGE) provides digital maps for the Brazilian municipalities. From these data, we were able to compute the explanatory variable using GIS techniques. We also used GIS and Python libraries to produce the instrument, which is based on Morten and Oliveira's (2018) work. We also use a set of geographical and historical controls. The distance to the nearest capital and to the coast was computed by the authors. As historical controls, we used three indexes that measure the proximity of each municipality to the central locations of three critical moments of Brazilian economic history: the sugar cycle, the gold rush, and the coffee boom. These indices were produced by Naritomi, Soares, and Assunção (2012).

In Table 2 we show some descriptive statistics for the variables used in the regression analysis. We notice that men's travel to work growth is higher then women, on average. This effect can be seen in the categories: "with children", "without children", and "single"; being "married" the only exception. Among women's categories of outbound commute, women without children shows the largest growth of the decade, while single women had the smallest growth. The same can be said about men. Also, the data suggest that married workers increased their level of travel to work more than single workers, and people without children engaged more in long-distance commuting than workers with children.

Table 2: Descriptive Statistics

	count	mean	std	min	median	max
Outbound growth	5480	0.985	0.773	-3.376	0.874	5.718
Outbound men growth	5480	1.078	0.844	-2.624	0.933	6.078
Outbound men with children growth	5480	1.075	0.967	-3.424	0.874	5.839
Outbound men w/o children growth	5480	1.632	1.142	-2.707	1.448	5.635
Outbound single men growth	5480	0.993	1.015	-3.217	0.840	5.876
Outbound married men growth	5480	1.205	0.933	-3.424	1.013	5.650
Outbound women growth	5480	0.813	0.980	-3.890	0.718	5.239
Outbound women with children growth	5480	1.060	1.242	-4.174	0.908	5.384
Outbound women w/o children growth	5480	1.370	1.291	-3.552	1.346	5.125
Outbound single women growth	5480	0.581	1.097	-4.005	0.510	5.078
Outbound married women growth	5480	1.264	1.178	-3.185	1.105	5.558
Log population 2000	5480	9.334	1.069	6.678	9.247	13.886
Log GDP per capita 2000	5480	10.439	1.343	7.338	10.210	16.424
Log nearest capital dist	5480	12.121	0.723	8.768	12.246	13.742
Log coast dist	5480	12.375	1.119	7.369	12.553	14.853
Log Brasília dist	5480	13.781	0.513	10.549	13.848	14.916
Sugar proximity index	5479	0.074	0.200	0.000	0.000	1.000
Coffee proximity index	5479	0.092	0.255	0.000	0.000	1.000
Gold proximity index	5479	0.123	0.281	0.000	0.000	1.000

5 Results

5.1 Main results

The first column of Table 3 shows that the first stage regression. According to the statistics in column 3, the instrument is significant, with a first stage F above 10, even when several control variables are taken into account. To further test the strength of our instrument, we run the Kleibergen-Paap rk Wald statistic that measures weak instruments and we reject the null-hypothesis that the model is underidentified. We also report the p-value from the chi-squared Anderson-Rubin test, a test that evaluates the relevancy of an instrument in just-identified models (Moreira, 2009). We are able to reject the null-hypothesis of the A-R test at the 5% level in all of our models where the explanatory variable is significant. Given that we have a strong first stage, we can move on to explore the impact of highways on our variables of interest.

Our main results are reported in the fourth column of Table 3. Our first conclusion is that highways had a statistically significant and causal effect on the workers commuting patterns. According to our estimates, when the average Brazilian municipality had access to a highway in 2000, many residents were encouraged to look for job opportunities in neighboring employment centers – a growth of 49.6% over ten years. As Table 2 reports an average travel to work growth of 98,5% along the 2000 decade, our results suggest that highways were responsible for aproximately half of this growth. Our findings suggest that being connected to a highway favored the evading movement of workers towards those new employment centers. Better transportation infrastructure offer workers faster access to a larger radius, so when a city is connected to a highway, more workers can use that infrastructure to look for job opportunities in a larger labor market outside their city of residence (Bjarnason, 2014). As we exclude municipalities close to capital cities, we are able to capture the evasion-inducing effect of highways on the average Brazilian municipality.

This interesting result is aligned with past descriptive data from the literature. According to the typology proposed by Moura et al. (2013), more than 56% of Brazilian cities are of the evader type, while 31% are of the bidirectional type, and 12% are receptors. The authors explain that, between 2000 and 2010, job opportunities became more spread out in the country's territory. As some cities developed thriving employment centers, these places became attractive to workers from surrounding municipalities that had limited job offers. These workers started looking for jobs in these flourishing locations. As each new employment hub attracted workers from several nearby municipalities, many more cities became ”evader” type.

Table 3: Main model results

	First Stage	Second Stage		
	(1)	(2)	(3)	(4)
	OLS	OLS	IV	IV
MSTN access	0.165***			
	(0.0250)			
Highway access		0.00565	0.574*	0.496**
		(0.0288)	(0.301)	(0.240)
Controls	Yes	Yes	No	Yes
State FE	Yes	Yes	No	Yes
Observations	5162	5162	5163	5162
R^2 / pseudo R^2	0.142	0.128	-0.145	0.0621
First stage F			51.87	43.41
Kleibergen-Paap p-value			1.29e-08	1.11e-08
Anderson-Rubin p-value			0.0420	0.0399

Clustered standard errors in parentheses.
* p<0.10, ** p<0.05, *** p<0.01.

5.2 Heterogenous results

5.2.1 Gender

Empirical studies have long asserted that the pattern of commuting of men and women differ, and women generally have more restrictions to accept longer-hours work than men (Mcquaid et al., 2001; Shearmur, 2006; Sandow, 2008; Cassel et al. 2013; Bergantino and Madio, 2016). Past studies had already pointed out that women commute less than men in Latin America (Silveira-Neto et al., 2015; Olivieri and Fageda, 2021). This has been associated with different explanations. First, because of the aforementioned Household Responsibility Hypothesis (see Section 2), travel to work may impose a higher cost to women than for men. As women generally have more responsabilities at home, a better access to a highway will not benefit her if she is not able to take advantage of this improved access. The opportunity cost – leaving the house work behind and working far away from her children – may be too high for the average brazilian women. Second, there is evidence that women are more likely to work close to home. This is largely because female-dominated occupations are more evenly distributed in space when compared to male-dominated jobs (Sandow and Westin, 2010). Third, the percentage of women who work in part-time jobs is larger than for men (Censo, 2010). If they work less they also receive less on average, which implies that for many women the potential earnings do not compensate the costs of travelling to work. Fourth, according to Silveira-Neto and Moura (2018), in Brazil, long commute time is causally associated with chance of being a victim of violence in urban centers, especially for women. It is possible that this effect is even more pronounced in the context of travelling between cities, as in the highway the driver is more alone and more vulnerable than inside an urban area.

We explore this effect by running regression analysis for men and women separately. The new set of estimates is presented in the following Table 4. In our estimates, we found a causal impact of highway access on travel to work for men, but not for women. This result is consistent with the idea that reducing commuting costs may not be enough for promoting travel to work, as the worker can have other reasons to not leave their city of residence. In the case of women, this can be explained by the Household Responsibility Hypothesis, by the fact that female-dominated jobs are more evenly distributed in space, by the fact that women tend to work in part-time jobs, and because of risks associated with travelling alone. It is interesting to notice that there was no significant result for women regardless of marital status or the presence of children. This result suggests that the Household Responsibility Hypothesis is not the only factor behind the lack of women's travel to work. Regarding men, the results are similar among columns. For men without children (column 3), the results suggest that highways were responsible for aproximately half of the average travel to work growth in the 2000 decade (compare to Table 2). The only result without significance was for single men (column 4). This subgroup of the male workers are likely younger, less skilled, and less experienced, thus they should find fewer opportunities outside of their hometown than their counterparts.

Although past studies have also found that women commute less than men (Sandow, 2008; Silveira-Neto et al., 2015; Bergantino and Madio, 2016; Olivieri and Fageda, 2021), our analysis showed a stronger result: for Brazil, between 2000 and 2010, better access to highway had no impact on female workers.

Table 4: Results for Men and Women

Men	(1) All	(2) With child	(3) W/o child	(4) Single	(5) Married
Highway access	0.595**	0.688**	0.893**	0.331	0.754**
	(0.269)	(0.320)	(0.399)	(0.306)	(0.324)
Controls	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes
Observations	5162	5162	5162	5162	5162
First stage F	43.41	43.41	43.41	43.41	43.41
Kleibergen-Paap p-value	1.11e-08	1.11e-08	1.11e-08	1.11e-08	1.11e-08
Anderson-Rubin p-value	0.0245	0.0229	0.0151	0.287	0.0129
Women	(1) All	(2) With child	(3) W/o child	(4) Single	(5) Married
Highway access	0.249	-0.116	0.353	0.224	0.124
	(0.291)	(0.388)	(0.382)	(0.320)	(0.373)
Controls	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes
Observations	5162	5162	5162	5162	5162
First stage F	43.41	43.41	43.41	43.41	43.41
Kleibergen-Paap p-value	1.11e-08	1.11e-08	1.11e-08	1.11e-08	1.11e-08
Anderson-Rubin p-value	0.398	0.767	0.362	0.489	0.740

Clustered standard errors in parentheses.
* p<0.10, ** p<0.05, *** p<0.01

5.2.2 Education

In Table 5, we estimate our regression model by education levels. We expected to see some variation in the coefficients, as the level of education may dictate the worker's ability to arbitrate between modes of transport. Non-skilled workers, for instance, usually occupy more precarious jobs and are more dependent on public transport. The transport alternatives that most benefit from highways are less accessible to the non-skilled, as these solutions may weigh more on their budget. High-skilled workers, on the other hand, are less bonded by migration costs and should be more willing to move closer to their workplace. As they earn higher salaries, they should de able to afford higher costs of living than their counterparts.

In Table 5, ”Non-skilled” refers to those who did not finish the Primary education level. The ”Primary” columns comprise those who completed at least the first nine years of the mandatory educational path (also known as Elementary School). ”Secondary” columns refer to those who finished at least High School, and ”Tertiary” includes those who have an university degree or beyond. The results confirmed our expectations. The estimates show no significance for the ”Non-skilled” category (column 1), significance for workers with primary and secondary education (columns 2 and 3), and no significance for workers with tertiary education. When compared to our main results, the effect of highway access for the primary and secondary education groups are larger than for the general population (compare to Table 3). These findings emphasize that people with middle-level education seem to be more willing to travel greater distances and for a longer duration than either non-skilled or very skilled workers. Possible reasons could explain these effects. Non-skilled workers are generally poorer than their counterparts, and, according to Duarte (2020), low-income workers gravitate towards informal work near home due to the high costs of commuting. Those low-skilled workers find little incentive travelling long distances, as they cannot benefit from a larger labor market that offer better opportunities for skilled workers. Having access to a highway, thus, should not drastically change those workers travelling patterns. We can also find reasons to explain the absence of significance for workers with an university degree. Travel to work is usually a means to avoid migration costs; it allows the worker to benefit from a larger labor market without paying more in rent and costs of living. High-skilled workers, however, earn higher salaries, and should be less restrained by costs of living. They have higher opportunity costs, thus they are more willing to move closer to work even if this means higher costs. There, these skilled workers should be near better professional opportunities and can benefit from the amenities of a larger city.

Although a positive relationship between education and commuting was already detected by Cassel et al. (2013) in Sweden and by Silva and de Freitas (2020) in Brazil, our study is the first to explore how each educational level respond causally to the provision of highways.

Table 5: Results for education level

	(1) Non-qualified	(2) Primary	(3) Secondary	(4) Tertiary
Highway access	0.460	0.843**	0.710**	0.537
	(0.289)	(0.387)	(0.334)	(0.384)
Controls	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Observations	5162	5162	5162	5162
First stage F	43.41	43.41	43.41	43.41
Kleibergen-Paap p-value	1.11e-08	1.11e-08	1.11e-08	1.11e-08
Anderson-Rubin p-value	0.115	0.0267	0.0217	0.147

Clustered standard errors in parentheses.
* p<0.10, ** p<0.05, *** p<0.01

5.3 Robustness analysis

Our instrumental variable choice assume that the national roads network aimed to connect capital cities, so other cities that are located in their path are there accidentaly. However, to strengthen our exclusion restriction, we followed Faber (2014) and excluded from the sample all cities within 50 km from the state capital cities for our main estimations. As this threshold may appear ad-hoc, in this section we use different sample of cities according to other criteria; the capital cities, however, are always excluded from the sample.

Our data show that most of the highway network expansion occurred in the past (see Table 1) as capital cities were prioritized. The roads that were built in the last decade were mainly further from capital cities, which may suggest that the relationship between roads and travel to work growth is stronger far from the capitals. We thus investigate if the inclusion of more cities near the capitals weaken the relationship between roads and travel to work growth. We first vary the threshold from 50 km to 30 km, as it is possible that a threshold of 50km was too conservative. Thus, in the columns 1 and 2 of panel ”All” of Table 6, we run regressions letting more cities in the sample. Compared to the main results (see Section 5.1), the coefficients are statistically the same and maintain significance at least at the 10% level. If the estimations were significantly different, this could indicate that, despite our identification strategy, the highways of our sample were still being influenced by the economy of the municipalities. Put differently, our explanatory variable would be endogenous. These results, however, validate our estimation strategy, and also demonstrate that our estimations are robust to the variation of subsamples.

In columns 3 and 4 of panel ”All” of Table 6, we only remove cities that are part of metropolitan regions. This is an important robustness test, as being part of a metropolitan region implies participation in policies that benefit the whole area (metropolitan transport solutions being a meaningful example). The estimated coefficients are similar to the main estimation (Table 3) in significance, signals, and size. This is evidence that our results are not simply a consequence of policies that unite municipalities of a same metropolitan region.

As maritime transport has a close relationship to land transport for cargo, the presence of ports can drastically change the transportation dynamics and infrastructure of a city. Cities with ports tend to have a historical link with others based on the transport infrastructure necessary for the flow of production. Also, populous cities with highways are generally denser cities, as infrastructure is only justified if it will be used by many people. So we also exclude from the sample cities with more than 300 thousand residents and that had access to a highway to control for unobservable factors associated with agglomeration gains and transportation infrastructure at the state level.

For the next results, we return to our original 50 km threshold and impose additional restrictions. In columns 1 and 2 of panel "All" Table 6 we ran our analysis excluding every municipality that had a port. The coefficients remain significant at the 10% level, but become smaller. In columns 3 and 4 of panel "All" Table 6, we exclude cities with populous cities that had highway access. The estimated effects are of the same magnitude and sign of our main results, and also maintain a significance of 5%. These results show that our results are robust to important sample variations.

We also run our analysis for men and women separetely in the panels "Men" and "Women" of Table 6. In accordance to our results in Subsection 5.2.1, all results are significant for men but not for women.

Table 6: Varying the subset of cities

	(1)	(2)	(3)	(4)
All				
	30km from capitals	Metropolitan regions	Removing cities with ports	Removing populous cities
Highway access	0.442*	0.447**	0.501**	0.495**
	(0.226)	(0.219)	(0.239)	(0.240)
Controls	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Observations	5357	4240	5127	5144
First stage F	45.04	49.63	43.35	43.81
Kleibergen-Paap p-value	5.86e-09	6.13e-09	1.16e-08	9.96e-09
Anderson-Rubin p-value	0.0509	0.0458	0.0366	0.0399
Men				
	(1)	(2)	(3)	(4)
	30km from capitals	Metropolitan regions	Removing cities with ports	Removing populous cities
Highway access	0.528**	0.471*	0.604**	0.592**
	(0.252)	(0.245)	(0.268)	(0.269)
Controls	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Observations	5357	4240	5127	5144
First stage F	45.04	49.63	43.35	43.81
Kleibergen-Paap p-value	5.86e-09	6.13e-09	1.16e-08	9.96e-09
Anderson-Rubin p-value	0.0342	0.0589	0.0218	0.0251
Women				
	(1)	(2)	(3)	(4)
	30km from capitals	Metropolitan regions	Removing cities with ports	Removing populous cities
Highway access	0.221	0.300	0.246	0.252
	(0.281)	(0.286)	(0.290)	(0.290)
Controls	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes
Observations	5357	4240	5127	5144
First stage F	45.04	49.63	43.35	43.81
Kleibergen-Paap p-value	5.86e-09	6.13e-09	1.16e-08	9.96e-09
Anderson-Rubin p-value	0.435	0.300	0.401	0.390

Clustered standard errors in parentheses.
* p<0.10, ** p<0.05, *** p<0.01

6 Conclusions

In this study, we investigated whether the improvement of transportation infrastructure can ease access to a larger labor market, thus promoting growth. To our knowledge, there are no published empirical works that study the connection between highways and travel to work for a developing country. To explore the relationship between highways and travel to work, we analyzed data for 2000 and 2010 for all municipalities of Brazil through instrumental variable regression. We have evidence that highways can promote better access to a larger labor market, as proximity to highways are causally related to workers daily commuting to a different city. This result implies that even a city with a limited labor market can see an improvement in its employment levels if the city is well connected to municipalities that offer more jobs. Hence, the expansion of highways can be seen as a policy for increasing better job allocation in the country.

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