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The City at your Wheels: Citizens Appraisal of Urban Highways in Santiago

Katiza Mitrovic Sesnic.

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Mitrovic Sesnic, Katiza

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Comisión

Felipe González
Hugo Silva

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Katiza Mitrovic Sesnic*

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Pontificia Universidad Católica de Chile
Thesis commission:
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Hugo Silva

Abstract

Transportation infrastructure influences individuals' housing, employment, and educational decisions, among others, and in this manner, it modifies a city's configuration. The present study aims to understand the citizens' appraisal of those changes generated by new transportation infrastructure. In particular, we aim to quantify the value that new urban highways create for families that live in their surrounding areas. We use a hedonic price model, focusing on changes in housing prices as indicators of net value gains that people derive from properties (and their locations). Using panel data on property transactions from 2007 to 2018, we estimate the relationship of proximity to a highway and housing prices, for one of the most prominent newly constructed urban highways in Santiago: *Acceso Sur*. Following the urban economics literature, we use a difference-in-difference approach that compares the price evolution of dwells located near this motorway and those further away. This quasi-experimental technique permits a causal interpretation of the estimates. In contrast to previous estimates of urban highway's impact on property prices, this work finds a negative effect (5-10% decrease in prices), implying a net value loss for residents living around this kind of infrastructure. The detrimental effect covers a wide area (6-8 km), its intensity diminishes with distance, and it persists over the 8-year post-treatment study period. Mechanisms are explored to reconcile these findings with transportation economics and urban economics models. A decrease in local connectivity, combined with households not experiencing a *de facto* improvement on their city-wide accessibility, explain the negative value given to this new transport infrastructure.

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Hay dos panes. Usted se come dos. Yo ninguno. Consumo promedio: un pan por persona.

-Nicanor Parra

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1 Introduction

Investments in transportation infrastructure worldwide have been on the rise for the last decades (Oxford Economics, 2015). However, growth patterns differ between countries at different development stages. In particular, for developing and transition economies, the share of the Gross Domestic Product (GDP) devoted to transport infrastructure investment has markedly raised, in contrast to a decreasing share in developed countries (OECD, 2013). This trend reflects their efforts to close the infrastructure gap, cover transportation needs, and in this manner, exploit development opportunities. The urban economic theory considers transportation infrastructure within and between cities to be a critical determinant of the growth and distribution of people and resources inside an economy (Munnell, 1992; Straub, 2008; Redding and Turner, 2015; Donaldson, 2018). However, the channels through which these two types of infrastructure (inter-city and intra-city highways) affect growth and development are very different. Roads connecting cities play a major role in determining commerce, and therefore the focus is on the transportation of goods. On the other hand, even though urban highways do play a role in the distribution of goods around the city, their distinctive feature comes from their ability to transport people. Urban motorways are meant to connect city zones, increasing people's accessibility to markets, jobs, residential zones, educational, health, and recreational facilities, among others. This type of infrastructure modifies the distribution of opportunities through the city, by increasing accessibility in zones near highway routes. If people value having better access to the urban opportunities mentioned above and, therefore, are willing to pay more in order to live in these zones with better accessibility, then the evolution of prices in the real estate market is partially determined by changes in transportation infrastructure. Consequently, isolating the effect of the construction of an urban highway on housing prices is a comprehensive way of capturing the value created for citizens due to the increase in accessibility brought by urban transport, net from other dis-amenities that this infrastructure may bring.

In Chile, investments in highways amounted to USD 10.000 million, during the 1993-2006 period.[1] Urban motorways in particular -this is, leaving aside inter-city highways-, represent an essential component of transportation and infrastructure investments. During the same period, more than a third of the total value of the national concession portfolio was invested in them (USD 3.752 million) (Engel et al., 2009). Moreover, for the city of Santiago -the country's capital and where 40% of the country's population lives-, substantial investments on urban highways are projected for future years, with an important component of public resources devoted to them. For example, the *Vespucio Oriente* highway, which has a projected total investment of USD $900 million, and includes a government subsidy for the concessionary company of USD $400 million (Dirección General de Conseciones, 2018; Ministerio del Interior y Seguridad Pública, 2014). The increasing growth of the national vehicle fleet, which has accelerated in the recent years (16% increase between 2017 and 2018), together with a steady growth in the use of highways (average annual growth of 9,5% in the 2010-2017 period), has motivated policymakers to see urban motorways as an attractive alternative for supporting the growth of cities.[2] However, little has been studied on how they actually impact the city and how much value citizens derive from them.

This work aims to quantify the value that new tolled urban highways create for households located in the surrounding areas, using changes in housing prices after its opening as an indicator of citizens' net value gains or losses. Using data for the city of Santiago, Chile, from 2007 to 2018, and exploiting the construction of a new urban highway: *Acceso Sur*, I estimate the relationship between proximity to this transportation infrastructure and dwellings' prices.

[1] According to estimations of concession investments in highways by Engel et al., 2009. UF is valued at CLP $20.000 and the dollar at CLP $500.

[2] See Appendix D.

In developed countries, there are not many opportunities to study the construction of a completely new intra-city highway, as most of their cities already have a dense transportation network. On the other hand, evidence on emerging and developing countries is scarce because even if sizable investments in transport infrastructure are more common than in developed countries, data availability limitations impede a causal analysis of their effects. The recent construction of *Acceso Sur* represents a valuable opportunity to study this relationship in an emerging country context and an understudied region as Latin America is.

Acceso Sur is the newest intra-city highway in Santiago, and it has been fully operational since 2011. It connects with *Ruta 5*, a 237 km inter-city highway that connects Chile's capital with other important cities in the south. However, this study does not focus on inter-city accessibility improvements brought by this highway, but primarily on intra-city accessibility gains. To isolate these intra-city changes, we exploit the fact that the urban portion of the motorway (which connects south-east peripheral zones with the city's central ring road) was opened to the public almost three years after the inter-city portion's opening (which connects south-east peripheral zones with *Ruta 5* and other cities at the south of Santiago). In this manner, the separated opening of *Acceso Sur's* urban portion can be interpreted as a predominantly urban highway investment, and therefore determine a threshold year between the pre-transport-innovation period (2007-2010) and the post-treatment period (2011-2018). Furthermore, as the primary goal of this project was to complete *Ruta 5* -a highway intended to connect the country-, then the specific location of *Acceso Sur* is arguably exogenous (it is not related with unobserved characteristics of the area where the highway was built). This exogenous source of variation in the access to transportation networks allows a causal interpretation of the estimated results.

The panel nature of our data enables us to implement a hedonic price model using difference-in-difference and event study estimation techniques. Through these empirical approaches, the price evolution of treated houses - those located inside a buffer zone around Acceso Sur- is compared to that of control houses -situated inside the city but outside this zones-. By including fixed effects at the observational unit level: *manzanas*[3] our specification statistically controls for invariant structural and neighborhood characteristics of these areas, such as proximity to topographical elements -like rivers or hills-, and the presence of manmade infrastructure and services -like bridges or industries. Also, time effects are included to control for general trends affecting the city, as movements in the economic cycle, fluctuations in construction materials prices, countrywide changes on construction regulations, and tax reforms. Furthermore, differential trends between treated and control groups are partially controlled for by including baseline characteristics interacted with year dummies. Due to the wide variety of characteristics that can be controlled for -and the efficiency problems derived from interacting them with year dummies-, machine learning techniques are employed in the covariates selection process.

The literature usually reports positive impacts from investments in transport infrastructure on growth, development, and even distributional outcomes (Banerjee et al., 2012; Donaldson, 2018; Mu and Van de Walle, 2011; Alam et al., 2019; Bird and Straub, 2014; Dercon et al., 2009). However, these conclusions are disproportionately based on inter-city infrastructure, and less attention has been given to within city infrastructure (arguably because of data limitations or identification difficulties). According to theory and intuition, inter-city infrastructure affects cities' development through channels very different from intra-city infrastructure. Therefore, despite having a vast body of literature analyzing inter-city roadways, these results can not be directly extrapolated to predict the appraisal of an urban highway. On the other hand, studies that measure the impact of proximity to *urban* infrastructure innovations also find evidence of beneficial effects

[3] *Manzanas* are administrative geographical units, comparable to blocks. For this work, I use the *manzanas* coding employed by Chile's Tax Agency: Servicio de Impuestos Internos (SII).

(see for example Gibbons and Machin (2005); RODRÍGUEZ** and Targa (2004); Gibbons et al. (2019)). Martínez and Viegas (2009) does a comprehensive review of the estimates found for public transport in North-American and European cities, and from the 53 cases/locations reviewed, in only one, a negative effect is found (and only initially), the rest exhibit mainly positive effects and of a relevant magnitude. Notwithstanding, the focus of this literature is on public transport infrastructure (such as subway or light rail extensions), while evidence on urban highways is scarce, and again limited mostly to developed economies. This paper aims at filling the void in the literature regarding the impacts of intra-city highways, as perceived by citizens and embodied in housing prices.

Previous works analyzing proximity to urban highways' effects on property prices systematically found a positive relation. Langley Jr (1976); Langley (1981); Boarnet and Chalermpong (2001); Vadali and Sohn (2001); Vadali (2008); Funderburg et al. (2010); Concas (2013) find premiums on the price of properties located at roughly 3 km (or less) from new or renewed motorways, and these estimates vary between a 3% change and a 31% change. These works only detect a negative relation in the immediate vicinity of the highway (dwells "attached" to the new infrastructure, or located at 0.35 km from it), and these estimates fluctuate around -30% and -14%. [4] The impact of different stages of the highway implementation is explored (planning, construction, and opening). Authors conclude that premiums truly raise when the construction phase is perceived to be reaching its end (for example, after litigation's resolution), and that price impacts are minimum during the construction phase in comparison to post-opening stages. Moreover, Boarnet and Chalermpong (2001) look at new toll roads, but Vadali and Sohn (2001), Vadali (2008), and Concas (2013) use improvements or expansions of older roads. In this sense, our work makes a further contribution by analyzing new infrastructure projects.

A related branch of the literature directly measures accessibility changes brought by highways and estimate their effect over property prices. Again, most of the works find a positive impact, at least for properties located outside the motorway's immediate vicinity (Levkovich et al., 2016; Iacono and Levinson, 2011; Tillema et al., 2012). An exception is Martínez and Viegas (2009), in which urban highways in the city of Lisbon are associated with a negative percentage change on dwells' prices that ranges from 7.32% to 11.05%. Nonetheless, these results are based on cross-sectional data, and, due to the highly endogenous process of locating sizeable transport investments, it is not possible to interpret these coefficients as causal.

Contrary to earlier literature, estimates obtained in this work evidence a substantial decrease in property prices in areas proximate to *Acceso Sur* after its opening. Relative to other properties in Santiago that are located farther away from the highway, the treated dwells experienced a negative percentage change in prices that fluctuates between -10% and -5% depending on the treatment and control definitions used, and on the inclusion of covariates. No previous work has found such a systematic negative causal relationship between a new motorway and citizens appraisals of the houses near it. Moreover, thanks to the city-wide coverage of our transaction data set, a data-driven approach is used to calculate the extension of the treatment effect, in contrast to most of the literature. Our estimates evidence a detrimental impact that extends over an 8 km radius around *Acceso Sur* (6 km for some specifications), which is a much wider treatment area than the ones used in previous literature. This suggests that other works may be underestimating the extent of the impact, and therefore selecting less adequate counterfactuals -with the implied risk of obtaining biased estimators-. In line with previous works, the impact of proximity to the highway dilutes as the property's distance to it increases (despite the opposite sign of the effects). In this manner, the strongest effect is found in the first kilometer from the highway, where esti-

[4]Some works just drop the observations located in a 0.35 km radius around the highway based on the differential treatment effects expected from previous literature, or based on descriptive evidence collected in field surveys.

mates get close to a 15% decrease. Finally, regarding the temporal dimension of our results, from the Event Study approach it can be concluded that the net adverse effects found are persistent through all the study period, this is, at least over a medium-term horizon.

The idea that at some distance from the highway, the positive appraisals of accessibility gains would overcome its negative externalities is not congruent with our results. In the *Acceso Sur* case, the impact does not change of sign, suggesting that improvements in accessibility never compensate for the harmful elements that this infrastructure brings into the neighborhood. Therefore, a more comprehensive analysis of mechanisms is taken. Four channels in which the highway may have produced these net adverse effects are studied. In the first place, a decrease in local accessibility is explored. *Manzanas* that preserve their within-neighborhood levels of connectivity once the highway opens, do experience lower treatment effects on absolute terms. However, the total effect is still negative and significant, at least at a 4 km radius from the highway. Secondly, a detriment on city level accessibility is explored. Evidence shows that an important share of the people living near *Acceso Sur* does not have enough resources to exploit the within-city gain in accessibility brought by the highway. Moreover, in *manzanas* with a higher fraction of its households owning those resources, or which experienced a more profound gain in intra-city connectivity, the combined treatment effects are closer to zero, but again negative for the closest treatment categories (less than 5 km from the highway). A third mechanism: negative environmental externalities, partly explain the stronger negative effect in the first 1-2 km, based on suggestive evidence collected from various sources. Finally, data is not congruent with supply and demand forces as being the factors driving the price fluctuations observed near *Acceso Sur* after its opening. Consequently, data supports a relationship between transport infrastructure and citizen's appraisals mediated through neighborhood and city level accessibility, combined with environmental impacts.

We begin this work with a brief theoretical explanation of the hedonic pricing model (Section 2). A description of Santiago's context follows in Section 3. Then, Section 4 describes the data used, and descriptive statistics are displayed. Section 5 presents the methodological approach taken to empirically give an answer to the question being investigated. Section 6 that follows shows the results obtained, their interpretation, and an exploration of possible the mechanisms involved. A discussion of the estimates' validity can be found in Section 7, together with additional exercises to check their robustness. Finally, Section 8 concludes.

2 Theoretical Framework

This section begins with a succinct explanation of the hedonic pricing model. It is followed by a conceptual description of a model that explains the relationship between a household's residence and transportation decisions.

2.1 Hedonic Pricing Model

The rationale of using housing prices for calculating the value added by urban amenities -in most of the urban economics literature as well as in this work- has its roots in Lancaster's (1966) consumer theory, together with Rosen's (1974) hedonic price model. Lancaster's theory claims that consumers do not value products *per se*, but derive utility from the product's characteristics, and therefore see products as bundles of attributes. Hedonic pricing models employ a revealed preference approach to capture the marginal value that each attribute generates for a consumer. In these models, the price paid for a good reflects the aggregation of appraisements of the product's individual attributes, plus the value that comes from the interaction of different attribute's combinations. Applied to the housing market, it enables to price structural, neighborhood, and accessibility characteristics of a property, by using a multivariate regression on its price (Sheppard, 1999).

2.2 Residence-Transport Model

Models to depict families housing decisions have refined over the decades, but their core principle remains essentially the same: households choose their residence location based on an evaluation of the different attributes that can be derived from a property, subjected to a budget constraint.[5] In this thesis, Chang and Mackett's (2006) model extension is used to explain the forces behind property price fluctuations as triggered by the opening of *Acceso Sur*.[6]

In this model, locations are treated as heterogeneous commodities, which can be fully described with a vector of homogeneous characteristics: $\mathbf{z} = (..., z_j, ...)$ for j= 1, 2, ... J. Each of the vector's elements represents the quantity of attribute j that is present in that particular location. Attributes pricing can be expressed with a hedonic price function: $\phi(\mathbf{z}) = \phi(..., z_j, ...; \alpha)$, where α is a vector of parameters.

Households compete with each other for selecting locations through bidding. Each of the n players (households) seeks to maximize the total utility they derived from the location's attributes, considering the aggregated needs of all its intra-household members.[7] For simplification purposes, players can be divided into M classes of households with homogeneous behaviors within each group. The interaction between transport and land-use is modeled using a bi-level formulation, in which some households' problem is to select a new location, while a second-order problem is the minimization of transportation cost for all the players. In this manner, land use determines travel demand, and therefore transportation patterns, while transport influences land-use through changes in accessibility that disturb the location of activities. Consequently, transport impedance and locations' attraction are determined endogenously.

A formal mathematical presentation of the games pay-offs, and the resultant equations relating the two decision variables (transportation cost and locational attraction) can be found in Chang and Mackett (2006). Conceptually, households that change location maximize a utility function that considers three elements: a vector of consumption goods, a location's appraisal, and the family's total transportation costs. The family's budget constraint comprises the monetary costs of these three elements, where the location's costs are determined by the hedonic price function previously described. Based on this restricted optimization problem, households select the location they will compete for, in order to reside on it. Following Alonso et al. (1964) bidding scheme, the higher bidder gets the disputed location.

The opening of a new highway affects two components of the household's utility function: transportation costs and a location's appraisal. For the household class that owns motorized vehicles, transportation costs probably decrease thanks to this new infrastructure; however, for pedestrian or public transport users, a fall in these costs is not evident. Moreover, if transportation is divided into local and city-wide mobility, it can be argued that when *Acceso Sur* services started, the transportation cost for intra-neighborhood trips increased, as is later discussed in Section 6. For a sufficiently low share of the households owning a car, the predicted outcome on locational

[5] Alonso et al. (1964) is one of the firsts and most influential works in this area.

[6] The modeling decision follows Vicuña (2019).

[7] In this manner, internal trade-offs between the desired locations for different household members are captured. For example, if the best working and educational opportunities are located at opposing locations.

attraction -and hence housing demand- near the motorway, is expected to be negative. Because of the inelastic nature of properties in the short run, the housing market will capitalize on the amenities or dis-amenities brought by new infrastructure implemented in their proximate areas. As a consequence, the prices of dwells located near *Acceso Sur* will be expected to rise or fall depending on the proportion of each household class, and on the changes they experience on their transportation costs. An empirical check of this effect on prices is proposed in Section 5 and implemented on Section 6.

3 Context

"Chile is a middle-income country with an open economy heavily reliant on trade and a complex geography coupled with uneven population and resource distribution" (OECD, 2017). Almost 90% of Chile's populations reside in urbanized areas, and more than 40% of the country's population is located in the metropolitan area of Santiago. This zone and its 6.5 million inhabitants extend through an area of 640 km^2 (Tiznado-Aitken et al., 2018). In terms of the number of jobs and GDP, the region comprises 40% and 45% of each, respectively (OECD, 2017). Urban population growth has been on the rise due to internal migration trends from rural zones, attracted by the concentration of economic activities in the urbs (Ahmad and Zanola, 2015). By the same logic, external migration is also being attracted to Chile's metropolitan areas and particularly its capital.

Santiago exhibits critical socio-spatial segregation; where a person lives, and the quality of the public services accessible from that location is highly determined by their socioeconomic status (Sabatini et al., 2009). An urban planning process undertaken between 1980-2002 relocated vulnerable people into peripheral areas (Tapia Zarricueta, 2011). Moreover, Santiago is composed of 37 municipalities (*comunas*) that manage both: their own budgets (which are highly dependant on their inhabitants' income level) and the land-use regulations present in their territories. The lack of a metropolitan authority makes coordination between land-use and transport policies difficult (Tiznado-Aitken et al., 2016). This combination of factors have led to a high residential segregation within the city (OECD, 2017; Salazar Burrows and Cox Oettinger, 2014), as can seen in Appendix G, Figure 23. The north-eastern part of the city concentrates most of the households that belong to the highest socioeconomic group ("AB"), while at the west and south most households belong to the lowest socioeconomic levels ("D" and "E"). Public investments tend to exacerbated this segregation as projects concentrate in the areas were high-income people live (OECD, 2017). Finally, in recent decades, the north-eastern area has -increasingly and disproportionately- attracted productive activities and services into its boundaries. As a consequence, distance to these labor and service opportunities has increased for lower-income families, as can be seen in Figure 24 (Tiznado-Aitken et al., 2018; OECD, 2017). These spatial distribution patterns are comparable with many other Latin America cities (Rodríguez Vignoli, 2008).

Since February 2007, a new city-wide public transport system was implemented, the Transantiago. It is based on trunk and feeder structure, which integrates buses and the subway, both of which are operated by private companies (Muñoz and Gschwender, 2008). The new system formalized the bus fleet, and its operation improved the safety and environmental standards, and it integrated the payment between buses and the subway. Nonetheless, it increased the average journey's duration and the number of transfers required. Despite a gradual improvement in the quality of service, citizens' overall perception of the system is negative (Muñoz et al., 2014). Moreover, complementary infrastructure -like bus rapid transit corridors- were not built as early as 2007, and the quality of infrastructure to access the public transport system is unequal between low and high-income areas, favoring the fist ones (Tiznado-Aitken et al., 2016). The subway network has experienced several expansions, and since integration with Transantiago, its utilization rate has raised considerably, reaching higher levels than comparable OECD countries (OECD, 2017).

In parallel, the road network at the national level (and also for its capital) has been expanding since the last three decades: "Following a period of under-investment in road infrastructure, the government embarked on an ambitious franchising programme in the 1990s via build-operate-and-transfer (BOT) contracts. The main goal of the programme was to attract significant private investment to reduce the perceived deficit in road infrastructure" (Engel et al., 2000).[8] In this manner, Chile spent more than two times the share of the GDP of comparable OECD countries on road infrastructure between 2008 and 2013 (1.35% of the GDP). This coordination and financial efforts have positioned the country's road sector in the 35th place of the World Economic Forum's Global Competitiveness Index (GCI) (OECD, 2017).[9]

Several highway expansions occurred in Santiago in the last decade, as seen in table 1. However, the selection of projects in which to focus this work relies on relevance and causality criteria. New highways are expected to have a much higher impact than projects that only include upgrades; hence, the study target is on new motorways. Then, for Costanera Norte, the timing of its construction and the start of its operations were close to the announcement, construction, and start of operations of three key buildings.[10] These three projects had a profound impact on the city's configuration by boosting a new city business district known as "Sanhattan" (Moyano, 2010). Proximity to this pole of tertiary employments, may increase the value of properties nearby or well connected to it, and therefore may be a confounding factor when studying the impact of Costanera Norte highway over housing prices. The emergence of "Sanhattan" makes it difficult to isolate the transportation investment effect from those effects occasioned by a change in the location of the business center. Moreover, both investments relate to each other, making it harder to interpret the estimates of infrastructure investments as causal. Therefore, this project is discarded for the present work's focus. Nororiente highway and San Cristóbal's tunnel are non-representative and smaller-scale projects. The first extends for 21.5 km but passes mainly through un-urbanized highlands, and its construction was impulsed and partly financed by real estate companies to connect a new sub-urban pole (Nororiente, 2018). The second corresponds to a 4.1 km tunnel, and accordingly, most of its route abuts the interiors of San Critóbal's hill, rather than urban neighborhoods. On the other hand, *Acceso Sur* with its 46.6 km of lanes that cross through several municipalities inside Santiago serves as an ideal transport investment to study.

Acceso Sur highway's concessionaire and terms were publicly announced in 1998. The project was part of a bigger inter-urban concession responsible for building and operating 266 km of Chile's most extensive highway, Ruta 5. However, the motorway includes 11.2 km of lanes that run through urban zones, and it crosses several municipalities from the Gran Santiago area (La Granja, La Pintana, La Florida, Puente Alto, San Bernardo, Buin, and Paine) (Dirección General de Conseciones, 2010).[11] Total investments materialized in the Ruta 5 project reach USD 1,348.7 millions, however, only USD 295.2 millions correspond to *Acceso Sur* (**?**Ruta del Maipo, 2018a).[12] As can be deducted from Table 1, this represents one of the smallest total investments for the group of concessioned urban highways, and by far the one with the lowest investment

[8] "In the two decades since the launch of the concessions programme in 1992, Chile has procured 82 projects worth a total of USD 19 billion, and built or rehabilitated 2,500 kilometers of highways using this mechanism" (MOP, 2016).

[9] The GCI is constructed based on surveys answered by business leaders. Therefore, its results represent these sectors perceptions on the infrastructure, in contrast to the appraisal of the society as a whole, or objective measurements of the roads physical characteristics.

[10] Costanera Center, Titanium, and Torres de Agua

[11] From Appendix D it can be noted that the areas located near the *Acceso Sur* represent one of the most vulnerable sectors of the capital.

[12] The USD 295.2 million includes the sum originally stipulated in the contract, plus the disbursement needed to construct two additional collectors not included in the original design of the highway (Ruta del Maipo, 2018a).

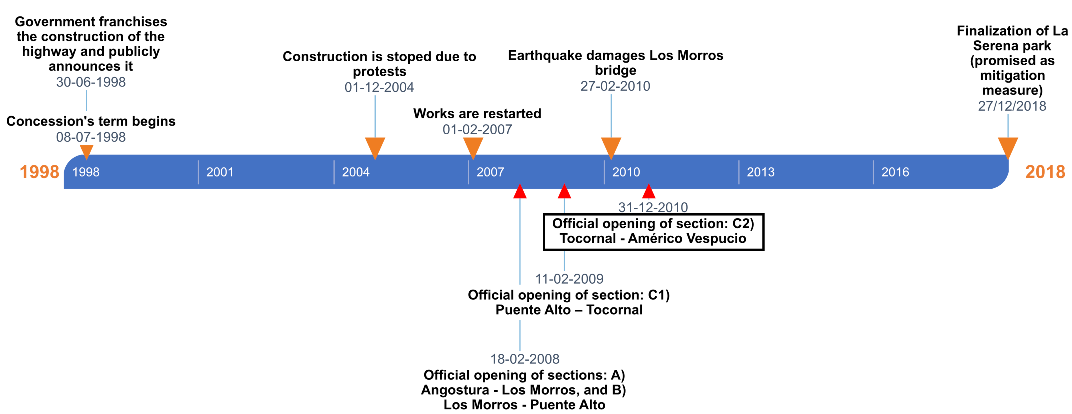
Table 1: Characterization of Santiago's Concessioned Highways

	Type of Highway	Inaguration Date	Extension (km)	Total Investment (MM USD)	Investment per km (MM USD)
Autop. Vespucio Norte	Upgrade	04/Jan/06	29	891.9	30.8
Vespucio Sur Express	Upgrade	27/Apr/06	24	866.6	36.1
Autop. Central	Upgrade	08/May/06	60	1,244.2	20.7
Costanera Norte	New	04/Oct/07	43	1,200.5	27.9
Autop. Nororiente	New	06/Feb/08	21.5	353.9	16.5
Túnel San Cristóbal	New	03/Jul/08	4.1	167.9	41.0
Autop. Acceso Sur	New	01/Apr/10	46.6	295.2	6.3

Notes: Highways materialized investments are expressed in UF by the MOP, and transformed into USD using the 2017 average value of the UF (CLP 26,571.93) and the 2017 average exchange rate (CLP 649.33). *Acceso Sur* total investment include the original contract sum, plus the disbursement needed to construct two additional collectors that were not included in the original design of the highway. Source: Own elaboration with data from Ruta del Maipo (2018a); **?**.

per constructed kilometer. This lower construction costs are despite the expenditure increases experienced due to an 8-year delay in the works. The highway was scheduled to open in 2002, but due to citizen protests, coordination problems between the government entities, and technical specifications that failed to comply with environmental regulations, the project only started its operations on December 31, 2010 (Sagaris and Landon, 2017). Figure 1 resumes in a timeline all the relevant events related with *Acceso Sur*.

Figure 1: Timeline of events for *Acceso Sur* highway



Source: Own elaboration

An important aspect of this project is the fact that the highway was legally defined as inter-urban, despite having one-fourth of its route inside Santiago's urban limit. This contractual detail allowed the concessionaire to minimize the number of crossing points along the route, and the necessary infrastructure for the abutting neighborhoods to remain connected (traffic lights, crosswalks, and runways, among others).[13] Another particularity of this concession was the lack of

[13]In its 46.6 km of extension, *Acceso Sur* only disposes of seven entry points, and 32 crossing points, which are not evenly distributed through the route. As a consequence, for extensive areas, the motorway is in practice a wall that cuts its abutting neighborhoods into two.

public participation in the project's design. In contrast to past experiences like Costanera Norte, the demands from the civic society affected by the new infrastructure were not incorporated in the bidding conditions, as *Acceso Sur* bidding had already been closed when it was announced to the public. As a result, citizen demands were only partially incorporated in the form of mitigation measures and compensations. For example, *Acceso Sur* runs predominantly at surface level, and despite neighbors intense protests, negotiations only led to burying 2.9 km of the route.[14] Furthermore, the compensation package offered -which included traffic signals, the reconstruction of green areas destroyed during the highway's construction phase, and the expansion of the coverage of public transport- took another 8-year period to be materialized, after the highways opening. This is, until our last year of study (2018), not all mitigating measures had been implemented.

Transportation's modal split patterns in the Santiago are dominated by public transportation trips (42% on 2012), but this mode is followed closely by private vehicles (35% for the same year), and a non-negligible portion of the trips correspond to active modes like walking or cycling (18% for 2012), as can be seen from Table 2. From 2001 to 2012, public transportation has experienced a drop in the proportion of trips when divided by mode, while private vehicles show a similar percentage change but with a positive sign. Most developing countries exhibit some degree of substitution from public to private transport as their economies grow. This change in behavior is partly explained by road provision plans, like the "predict and provide" approach[15] and accelerating rates of motorization (Ribeiro et al., 2007; Goodwin, 1999).

In line with the socio-demographic and infrastructure investment patterns that Chile has been experiencing, car use and ownership rates have been steadily growing for the last decades. Between 2004 and 2014, a doubling in the number of passenger cars per capita occurred, and this trend has inevitably raised urban congestion (OECD, 2017). Nevertheless, "59% of households do not have access to a car and are still captive public transport users" (Tiznado-Aitken et al., 2016). Thus, segregation is also expressed in the different motorization rates across the city, as can be seen on Appendix D, figure 22.[16]

Table 2: Commutes in Santiago 2001 and 2012

Mode	2001 (thousand)	2001 (%)	2012 (thousand)	2012 (%)
Private	1.240	30%	1.991	35%
Public	2.067	50%	2.364	42%
Bicycle	136	3%	287	5%
Walking	543	13%	824	15%
Other	163	4%	187	3%
Total	4.148		5.653	

Notes: The same 38 municipalities are considered for both years. Source: Herrera (2019) using data from Encuesta Origen Destino 2001 and 2012.

When analyzing Santiago's housing market for the last decade, three factors are relevant for the present work. In the first place, the national strategy to cover the dwelling needs of its

[14]On the contrary, Costanera Norte's initial plan was modified following citizen unrest so that three out of four sections of the highway were constructed underground (Sagaris and Landon, 2017).

[15]"...the principal transport concern of governments, at least until the mid-1990s, was to roll out a roads programme, largely disconnected from considerations associated with other transport modes and from other forms of spatial development. This approach became known as 'predict and provide' where the demand for travel by various modes was extrapolated, and then attempts were made to match the supply of infrastructure to that potential demand. [...] The policy emphasis was therefore on mobility rather than accessibility, with the benefits biased strongly toward those able to travel by private car."

[16]Tiznado-Aitken et al. (2016) found that households earning over USD 2.000 monthly had more than three times the number of cars per person than households earning lower than USD 1.000.

population is based on tenure. As a consequence, the government's support implied that 67% of the houses built between 1976 and 2007 were given some type of subsidy. This policy focus explains the notably higher rates of dwell ownership, relative to OECD countries (76% versus 68%, respectively) (Asahi, 2015; Simian, 2010). A relevant caveat is that properties subsidized by government funds can only be sold after a five-year period. Another particularity of the Chilean housing market is its low levels of mobility, again compared to the OECD countries. In particular, lower-income families, like most of the ones that live near *Acceso Sur* highway, change residence even less frequently (Asahi, 2015; OECD, 2010). Finally, during the study period, there was a change in the tax regulations that significantly impacted the real estate market. At the end of 2014, it was announced that from 2016 onward, properties would be charged with the value-added tax. The future price increase that this tax would generate motivated a substantial rise in the number of properties transacted during 2015 (26.8% respect to the previous year according to Aspillaga Sierralta et al. (2016)).

4 Data

This work uses a panel database of Santiago's property transactions that covers the period 2007-2018.[17] It includes detailed information for 714,599 transactions, corresponding to 628.440 properties, distributed across 40 municipalities from the Gran Santiago area.[18] Data includes each transaction's selling price in UF[19], its date, the plot's size, and constructed area, the property's year of construction, the type of property (house or apartment), the condition of the property (new or used), a quality indicator according to SII's classification (with a scale that goes from 1 to 5), the land use category of the plot and the geographical coordinates of each transaction.

Transactions of residential properties are 658,894, which represents 92.2% of the data. Other land use categories that follow are "warehouse and storage", "parking lots", "commerce" and "offices", with 3.1%, 2.7%, 0.8% and 0.6% of the transactions respectively. The limited number of observations in these other categories would imply too little observations for each geographic unit-year in the panel. The unbalanced panel and the limited statistical power for these categories of land use would not enable a correct estimation of the potentially differential effects that highways can exert in each one of them. Therefore the analysis is bounded to residential properties only.

The sub-sample of residential transactions involves 575,773 different real estates, from which 12.8% experienced more than one transaction during the 12-year study horizon (this corresponds to 23.8% of the total number of sales). This panel of properties with repeated purchases over time could be used to estimate the relationship of interest; however, this approach has pitfalls. It implies losing an enormous amount of data, and restricting the sub-sample to such a limited number of observations can lead to failure in detecting an effect due to lack of power. On the other hand, having cut the number of observations in this manner can induce selection bias. This risk is especially true if the properties that experienced more frequent transactions are systematically different from the rest of the properties. It is plausible to think that this is the case and that the price evolution dynamics can be different for these two classes of properties. In such a scenario,

[17]This data set was constructed by Toc-Toc, a Chilean private company dedicated to collecting, analyzing, and distributing real state data. The property's database was provided for its use in this thesis as part of an agreement between Toc-Toc and Pontificia Universidad Católica de Chile, with the aim of fostering evidence on real estates price determinants.

[18]The transactions data set covers 34 out of the 35 municipalities inside Santiago City (only Padre Hurtado is missing), plus 4 "satellite" municipalities at the periphery (Colina, Peñaflor, Pirque y Buin) and Til-Til municipality. The municipality of Santiago is further divided into Santiago, West Santiago, and South Santiago.

[19]Chile uses the UF as a unit of currency indexed to inflation, it is monthly calculated and adjusted on a daily basis. In general property, transactions are denominated in UF.

the estimated effects would be less informative for the public policy debate, as it is more desirable to know the broader impact of highways, not only its impact on a particular set of properties. For these reasons, data is aggregated at the level of *manzanas* according to the National Tax Agency's (SII) classification (block-like spatial units used to calculate real estate taxation).

In order to aggregate the data at the *manzana* level, first, each transaction is georeferenced in ArcMap using the coordinates information contained in Toc-Toc's dataset. A layer with the SII's administrative division of the city into 51,400 *manzanas* is used to classify each transaction into one of these geospatial units. The transactions database contains at least one residential property's sale for 44,419 of these *manzanas*. Price per squared meter is averaged between all the transactions that occur inside the same *manzana* and year.[20] With ArcMap software, the centroids of each *manzana* are used to calculate the Euclidean distance from that unit of observation to *Acceso Sur* and to its nearest entry point (to construct the independent variables of our different specifications). The following control variables are also constructed in the above-mentioned manner: distance to the highway network and entry points to it (at baseline, 2007, and after the opening of the new highway, 2010); distance to the subway network (as measured in 2007); and distance to the central business district (CBD).[21] The location of the centroids is also used to construct an indicator variable that identifies the *manzana* located inside the urban limit -according to Santiago's Metropolitan Regulatory Plan-, and alternatively a dummy for being located inside the city's ring road.

Property characteristics contained in the transactions database are also aggregated at the *manzana* level for the baseline year: 2007. Not all the *manzanas* in the dataset experienced transactions during this baseline year. Therefore, for the specifications that control for baseline covariates the sample is restricted to the 13,525 *manzanas* that did have transactions in 2007 (and also in some year after 2010), which amounts to a 30.5% of the sample.[22] Though a large number of observations is lost, the sample remains significant, and the result's main patterns do not vary substantially (albeit estimates precision is considerably damaged). Controlling for covariates, -despite its associated reduction in sample size-, is still worthwhile as it handles potential endogeneity problems, while still having enough precision to make confident conclusions. Because of this imminent trade-off, both specifications are always presented, as complementary evidence.

Additional neighborhood characteristics to control for when estimating the equation of interest are obtained from the 2002 Census. This data uses the INE's classification for *manzanas*, which divides the city into 43,513 units. The census data is incorporated, by merging the "INE's *manzanas* to the corresponding "SII's *manzanas*, but only 37,707 of these have a corresponding INE pair, so the sample is further restricted when including census covariates. Among these controls are population, demographic and socioeconomic variables.

[20]Alternatively, shorter periods could be employed to aggregate spatial data. Results were replicated using semesters, instead of years, and results were remarkably similar. Therefore, to have simpler interpretation, aggregation is kept at a yearly frequency.

[21]Three alternative definitions of CBD are used: La Moneda, Baquedano, and Tobalaba. Each one is georeferenced based on the location of the subway station in that zone. When choosing one particular definition, La Moneda is chosen as it also represents the center of the city or its "km 0".

[22]Alternatively the years 2008, 2009, and 2010 could also have been considered as part of the baseline period to have a larger sample size when controlling for covariates at baseline. However, as sections of the studied highway opened on those years, including them as controls would be capturing part of the potential treatment effect of these first portions of *Acceso Sur*, and this threatens to bias the estimates. With this in mind, only 2007 is employed as the baseline year.

4.1 Panel Balance

The final dataset constructed from Toc-Toc's transaction database, the distance calculations from ArcMap, and the Census results, conforms an unbalanced panel with 25,432 distinct "SII *manzanas* and 142.493 observations at the *manzana*-year level. Not every *manzanas* experienced transactions in each of the studied years; part of them do not have data for any pre-treatment year, and some others do not have any data for the post-treatment years. The lack of pre and post-treatment observations may be the source of an estimation problem. If most of the *manzanas* located near the studied highway, do not have data for at least one pre and one post-treatment year, there would not be enough power to detect a possibly small effect. From the sample, 25,432 *manzanas* have data for both -before and after- periods, as defined by the threshold year 2011. From these group, 2,308 *manzanas* (1,168 *manzanas*) are located within the first 2 km (1 km) from *Acceso Sur* . This makes it possible to estimate the effect of proximity to a highway, as there is a reasonable number of before and after observations, even for the most restrictive treatment definitions.

4.2 Descriptive Statistics

To characterize Santiago's *manzanas*, dividing them between those that could be considered as proximate to *Accceso Sur* highway and those that are further away, five categories of treatment areas are defined, and they are compared to a control group that comprises all the areas not covered by the treated zones. In particular, treatment categories are defined with successive 2 km fringes from the highway, starting at 0-2 km and progressing until 8-10 km. In this way, all the *manzanas* with centroids located within a distance of 0-2 km from *Acceso Sur* are included in the first treatment category, while those positioned at 8 to 10 km from the highway belong to the last treatment category. The control group is defined as all those *manzanas* located outside a 10 km buffer zone around *Acceso Sur*.

Table 3 shows the average level of a series of property, neighborhood, and *manzana's* characteristics in each of the treatment categories and the control group for comparison. It can be seen that as the treatment definition covers a more distant area from *Acceso Sur*, the price per squared meter of the properties in the baseline year goes up. Still, for each of the treated categories, it remains substantially below the control level. To better deal with the presence of outliers, the logarithmic form of the dependent variable is preferred; in this case, the price transition from *manzanas* located in the first 2 km from the highway to the price of those further away than 10 km is smoother. For the first treatment category, initial distance to the highway network more than doubled that of the control group, but for the last two treatment categories, this is between 6-8 km from *Acceso Sur*, initial distance to the highway network is much more comparable to that of the control group. Likewise, it can be seen that the opening of *Acceso Sur* considerably reduced the distance to Santiago's highway network for the *manzanas* located within the first 6 km from it. On the contrary, distance to the subway network is lower for each of the treatment categories compared to the control group, especially for the first 4 km buffer around the new highway. Moreover, treatment categories are located further away from the city center (La Moneda CBD). Concerning the baseline year, considerably fewer transactions occurred in the first 6 km of the treated group. These properties, score subtly higher in the quality index, have substantially fewer squared meters constructed, were constructed a couple of years earlier, and they have a significantly higher portion of used properties and houses sold (rather than new properties and apartments). Finally, the socioeconomic differences as measured from the 2002 Census are relevant, however from the second treatment category onwards, the treatment and control groups do not differ by more than 5% in terms of total population, and in no more than five percentage points in the fraction of female population, the fraction of owned dwells and the motorization rate.

Table 3: Characterization of Santiago's *manzanas* with different treatment categories

	Treatment Categories					Control
	0-2 km	2-4 km	4-6 km	6-8 km	8-10 km	> 10km
	(1)	(2)	(3)	(4)	(5)	(6)
Property's price per m^2 in 2007	39.18†	17.68	18.16	18.19	22.03	29.66
ln (property's price per m^2 in 2007)	2.66	2.79	2.83	2.80	2.98	3.08
Distance to *Acceso Sur* since 2011	0.98	3.12	4.95	6.96	9.02	15.73
Distance to Acceso Sur's entry points since 2011	1.56	3.35	5.28	7.15	9.04	15.74
Distance to highway network in 2007	4.43	3.53	3.15	1.84	1.68	2.01
Change in distance to highway network (2007-2011)	-3.58	-1.21	-0.42	-0.12	-0.01	-0.02
Distance to subway network in 2007	1.70	1.05	2.77	2.66	1.89	3.96
Distance to CBD (La Moneda)	15.60	13.68	13.32	9.76	7.00	9.43
Baseline Covariates in 2007 levels						
Number of transactions	2.69	2.87	3.38	5.09	8.42	7.03
Property's quality	3.93	3.66	3.61	3.56	3.45	3.55
Property's constructed m^2	62.10	73.34	71.26	89.52	93.02	97.03
Total constructed m^2 from properties sold	172.81	202.20	235.52	442.20	625.86	569.47
Property's age	18.59	23.29	19.34	27.97	27.95	24.12
Fraction of sold properties that were new	0.06	0.05	0.09	0.13	0.14	0.14
Fraction of sold properties that were houses	0.97	0.89	0.90	0.78	0.56	0.67
Census Covariates in 2002 levels						
Socioeconomic classification by decile	6.86	7.43	7.65	7.01	7.87	7.82
Population	172.12	192.73	186.60	203.22	211.23	185.33
Fraction of female population	0.51	0.52	0.52	0.52	0.53	0.53
Dwells owned by its users	0.76	0.73	0.73	0.72	0.64	0.69
Households owning a motorized vehicle	0.58	0.64	0.66	0.61	0.63	0.66
Household leaders with a college degree	0.06	0.15	0.19	0.16	0.33	0.27
Number of transactions in 2007-2018	10.11	16.53	20.72	23.76	47.66	32.28
Number of yearly transactions	1.82	2.22	2.70	2.95	5.01	3.63
Number of observations in 2007	724	998	1,451	640	981	7,880
Number of observations	11,887	11,533	14,914	9,033	8,677	78,607

Notes: Columns 1-5 provide the average per *manzana* for each variable, for *manzanas* with centroids located within a distance of 0-2, 2-4, 4-6, 6-8 and 8-10 from *Acceso Sur*, respectively, while column 6 groups *manzanas* located further away than 10 km. Prices are in UF and come from the Toc-Toc database. Distances are in kilometers. Population variables are measured in total number of people and come from Censo 2002. Property's quality is measured using a 1-5 scale, according to SII classification. Areas are measured in m^2 and comes from de SII database. Property's age is in years and come from the Toc-Toc database. † This value is abnormally high due to an extreme outlier, in which the average price per m^2 exceeded the 15,000 UF, without this *manzana* the average price per m^2 would be 15.43 UF.

However, important differences remain in the socioeconomic classification, where *manzanas* near the highway belong to lower deciles on average, and most strikingly the percentage of household leaders with a college degree is 4.5 times higher in the control group than the first treatment category, until the 8th kilometer this fraction remains below the 0.2. The same patterns can be found when defining the treatment and control based on the distance to the highways entry points.

5 Identification Strategy

Estimating the causal effects of changes in accessibility brought by transportation infrastructure investments is hard, probably because the locations that experience these changes differ from those that did not. Other factors that determine housing prices, with or without the transportation investment present, can be influencing both groups differently and would continue to do so after the introduction of the transport investment. Therefore, analyzing a change in prices before and after the infrastructure construction does not imply a causal link, as neither does a cross-sectional comparison. This reasoning motivates the difference-in-difference approach, which compares two groups (those that received an accessibility improvement - the "treated"-, and those who did not -the "controls"-), and also compares two periods (before and after the accessibility improvement). In this manner, the evolution of property prices for the "treated" units can be netted from the evolution that would otherwise have happened to that group, had the project not been realized (which is approximated by the price evolution of the control group). Consequently, this research design controls for time invariant-level differences among treated and untreated zones; hence, there is a higher probability that confounding factors affecting house prices are accounted for, and the obtained estimates can be interpreted as causal. Notwithstanding, if counterfactual *trends* differ between the two groups, then causality can not be claimed, while if the effects fade in time, the estimate would be underestimated Miller (2017).

We exploit the opening a new and extensive urban highway constructed in the city of Santiago, together with highly detailed data on properties transactions for the period before and after its opening, to implement a difference-in-difference design. This approach captures the effect of proximity to a highway, netted from the price changes that this area would have otherwise experienced, assuming that price evolution in this area would have followed trends parallel to those experienced in the rest of the city.

The difference-in-difference approach serves to overcome some of the problems that arise when using cross-sectional data and estimating by Ordinary Least Square (OLS) in the context of transport investments. A significant component of where, when, and how highways are constructed in Chile is determined jointly with other omitted variables that impact housing prices. The government franchises the construction of this type of infrastructure to private companies but impose technical and operational specifications in the public tender bases. Part of these legal obligations and some of the concessionaires' business decisions may be determined by unobserved factors that are also directly influencing proprietary prices. For example, property owners' socioeconomic status and political connections in a particular neighborhood can influence the construction of a highway closer or further away from their dwells and simultaneously determine other types of public spending in the area (parks, health care centers, or public transportation). Property prices respond to both, and in this way, other public spending confounds the highway's effect. Furthermore, the process by which individuals distribute their residency sites throughout the city certainly comprises selection and sorting and therefore is endogenous. Consequently, unobservable characteristics and selection in the housing market generate bias on OLS coefficient estimates, and causality cannot be inferred from them. Nonetheless, with difference-in-difference estimates that use location fixed effects, and considering that socioeconomic, political and other unobservable factors of specific neighborhoods remain relatively stable during medium-length study horizons (12 years in this case), then interpreting the coefficients as causal is more plausible than when obtained from cross-sectional or before-after comparisons.[23]

Nevertheless, the non-random assignment of a highway's location and opening time may cause endogeneity problems even in a difference-in-difference setting. To address this issue, the study context has been selected based on the "inconsequential place approach" (Banerjee et al., 2012; Redding and Turner, 2015). The rationale is to exploit that infrastructure investments intended to connect specific locations, "unintentionally" pass near other zones. Areas in between

[23]In the sample used, *manzanas* experienced only 11.87 property transactions on average for the whole 12 years study period. This fact combined with the significant portion of dwells inhabited by their owners (70,35% in every *manzana* according to the 2002 census), makes it reasonable to assume that on average neighborhood's communities did not experience a substantial change in their composition during the studied horizon.

the locations to be connected receive an increase in accessibility, without the government explicitly intending to do so, but as a result of being located on the way of a cost-minimizing route between the two key zones. This is the case for *Acceso Sur*, which mainly serves as a continuation of Chile's most extensive highway: Ruta 5, enabling a connection between Chile's capital and other cities (Ruta del Maipo, 2018a). Its route's location is less related to unobservables from the area where it passes by (south-eastern Santiago), than other urban highways recently constructed in the city. Hence, it is more plausible to interpret the difference-in-difference estimates as causal.

Even for an inconsequentially treated location, some specific elements of the transportation infrastructure can be endogenously determined, and therefore special caution should be placed when their impact is studied. *Costanera Norte's* modifications after social protests give a clear example of how unobserved characteristics of the areas proximate to the highway can influence this infrastructure's characteristics (in particular, which portions are constructed underground). Likewise, entry points to a motorway are probably not randomly assigned within the route. For both infrastructural elements, the government, the concessionaire, and the citizens clearly have incentives to place them in specific locations (depending on density levels, traffic patterns, or the characteristics of the neighborhoods nearby). As a consequence, distance to the highway's route is preferred as the variable that defines treatment, instead of its entry points. Nonetheless, these motorway's elements are used to conduct heterogeneous effects, having the precaution of interpreting them in a non-causal way.

A limitation common to other studies exploring the impacts of urban transport infrastructure is the incapacity to separate growth from reallocation forces (Redding and Turner, 2015). It can not be concluded from our results if the observed changes in prices that occurred after *Acceso Sur's* opening were originated by the growth (decrease) on the appraisal of properties near the new infrastructure, or if these price changes relate to a reallocation of people within the city. Again, the low mobility rate of households in Chile suggests that reallocation, -at least in the short run-, is not that strong. Ergo, the observed results can be derived from a negative appraisal of houses near the highway (the treated group), or due to positive appraisals of *manzanas* located farther away (the control group).

5.1 Specification

The geographic unit of treatment, *manzanas* according to the SII coding, follows the standard in this literature, which often uses the smallest administrative segmentation available that allows having transactions in the before and the after periods for enough units (Ahlfeldt et al., 2015; Bardaka et al., 2019; Gibbons et al., 2019). The observational unit employed is then: *manzana*-year.

The base structure for all specifications in this work is as follows. The dependent variable is the natural logarithm of the average price per squared meter of properties that experienced transactions inside *manzana* i, during year t. $Post2010_t$ is an indicator variable that takes the value of one for observations that correspond to years after the opening of the *Acceso Sur* highway. While $Near_i$ is another indicator variable that denotes observations located inside a buffer zone around the new highway (different threshold distances are used to test for varying levels of proximity). Also, fixed effects are incorporated at the *manzana* level, to account for observable and unobservable characteristics that persist over time, while year dummies included capture general trends affecting all *manzanas*.[24] The last expression represents the time-varying unit-specific unobservables that are

[24]The *manzana*-level fixed effects absorb the $Near_i$ term as they can perfectly explain which *manzanas* are "near", as this "near" status is invariant over time. Likewise, year fixed effects absorb the variable $Post2010_t$. In a

not accounted for in the model. β_3 is the coefficient of interest in equation (1), as it approximates the average percentage change in property prices that arise in *manzana*-year's affected by the opening of the new highway, net from the general time trend between the before and after periods (captured by β_1), net from the treated locations particularities with respect to the control ones (captured by β_2), and keeping constant the *manzana's* invariant characteristics. [25]

The first specification used to implement the difference-in-difference approach follows a simple hedonic regression that relates property prices with proximity to the highway network as follows:

$$ln(p_{it}) = \beta_1 Post2010_t + \beta_2 Near_i + \beta_3 Post2010_t * Near_i + \gamma_i + \eta_t + \varepsilon_{it} \quad (1)$$

Specification (1) relies on an identification assumption of parallel trends. This assumption is plausible in our study context, as discussed earlier in this section, but particularly so for shorter periods (1-3 years, for example). Nevertheless, for an 8-year span (2011-2018), the forces that influence the price evolution of properties differently for the treated and the control groups may plausibly imply differential trends in the medium run. Hence, an expansion of the model is incorporated, which attends this potential threat to the validity of the estimates (particularly for those estimates of years further away from the treatment date). This new specification controls for the baseline level of certain characteristics (socioeconomic status, percentage of households owning a car, educational attainment of the household leaders, percentage of households inhabited by its owners, among others) interacted with year dummies, which accounts for differences in the price evolution between treated and control groups that arise from these baseline covariates initial differences. Moreover, the interaction with year dummies enables *manzanas* with similar baseline levels to vary distinctly for each of the subsequent years after the highway opening. Therefore, this specification imposes a less strict identification assumption: parallel trends conditional on the level of those baseline characteristics. The equation is as follows:

$$\begin{aligned} ln(p_{it}) = \beta_1 Post2010_k + \beta_2 Near_i + \beta_3 Post2010_k * Near_i \\ + \beta_{4k} \mathbf{X}_{it=2007} * \sum_{k=2011}^{2018} Year_k + \gamma_i + \eta_t + \varepsilon_{i,t} \quad (2) \end{aligned}$$

Where $\mathbf{X}_{it=2007}$ represents a vector of *manzana's* characteristics measured at the baseline year: 2007. The selection of which covariates to include in this specification is made using Lasso machine learning techniques. The motivation behind this approach is avoiding the manual process of selection, which involves a series of econometrical disadvantages, especially in the case of having a wide pool of variables from were to select the controls. For instance, failing to pick enough controls or including the wrong ones causes omitted variable bias. On the other hand, even though including more controls than the necessary ones does not bias the estimates, it does hurt the efficiency of these estimates, and if too large a number is employed, this would end up overfitting the model (Ahrens et al., 2018). This last issue becomes more relevant when including factor

simpler formulation of equation (1) only the interaction term $Near_i * Post2010_t$ could be included, but we prefer the longer specification to be more explicit on the difference-in-difference approach employed.

[25] The precise interpretation of each coefficient n is: $ln(p_{t+1}) - ln(p_t) = \beta_n$, which can be expressed as $p_{t+1}/p_t = e^{\beta_n}$. Therefore, the percentage change on property prices between period t and $t+1$ can be approximated by β_n: $(p_{t+1} - p_t)/p_t = e^{\beta_n} - 1$. β_n is a good estimation of $e^{\beta_n} - 1$ for small values of β_n, which is the case for most of our estimates. Consequently, and for brevity, in the rest of this work coefficients are interpreted as percentage changes, even though they are only approximations.

variables and interaction terms, as is the case for our potential set of covariates. Thus, inference Lasso is applied in Stata to select from a pool of possible controls the ones that would be used in the final estimations. Lasso's process of optimization relies on a sparsity assumption, this is, that the number of covariates in the true model is small relative to the number of observations, and the magnitude of their coefficients is enough to be detected by the algorithms (Stata, 2019). The size of the sample being used makes this assumption credible. The pool of potential controls ("high-dimensional controls") includes: distance to different central business districts, initial distance to highway network (and their entry points), initial distance to subway network, total population, fraction of female population, socioeconomic characterization, properties ownership status, households motorization rate, percentage of household heads with a college degree, urbanization rate, property's quality index, total and average constructed squared meters, number of transaction, percentage of new properties, percentage of house type properties (in contrast to apartments), properties age (and the squared age), and frequency of transactions. All the variables represent the *manzana's* average for the year 2007 and are expressed in levels and logarithmic form.

A log-linear specification is tested (by including high-dimensional controls only in level form) based on the series of advantages that Malpezzi (2002) mentions, but a log-log specification is also tested (by including all potential controls in their logarithmic form) to check the sensibility of the estimates found.

Furthermore, the availability of panel data that spans for more than a few periods allows for a more precise decomposition of the dynamics that proximity to highways generates over time. To see the evolution of this effect we expand the model to incorporate differential responses for every year after the highway started its operations, according to this equation:

$$ln(p_{it}) = \sum_{k=2011}^{2018} \beta_{1k} Year_k + \beta_2 Near_i + \sum_{k=2011}^{2018} \beta_{3k} Year_k * Near_i + \beta_{4k} \mathbf{X}_{it=2007} * \sum_{k=2011}^{2018} Year_k + \gamma_i + \eta_t + \varepsilon_{it} \quad (3)$$

Now the estimations of β_{3t} coefficients can be interpreted in the same manner as those from equation (2) except that the percentage change in property prices of the treated *manzanas* relative to control *manzanas* with similar baseline characteristics, corresponds to the period from 2010 to year t. In this way, it can be seen if the effect increases, remains stable or diminishes as the years pass.

A final extension of our specification allows for non-linear treatment effects, as it is expected from the theoretical and empirical literature that the balance among amenities and disamenities brought by a highway vary with distance to its route (entry points). For this reason, categorical values are incorporated into the definition of treated. We allow the number of categories (R) to vary in order to test for differential effects on different extensions of territory, using the following specification:

$$ln(p_{it}) = \sum_{k=2011}^{2018} \beta_{1k} Year_k + \sum_{r=1}^{R} \beta_{2r} Near_{r,i} + \sum_{r=1}^{R} \sum_{k=2011}^{2018} \beta_{3kr} Year_k Near_{r,i} + \beta_{4k} \mathbf{X}_{it=2007} * \sum_{k=2011}^{2018} Year_k + \gamma_i + \eta_t + \varepsilon_{it} \quad (4)$$

The coefficients of interest in this equation: β_{3ts} are interpreted as the average percentage change in property prices between years 2010 and t, that arise between *manzanas* located inside the threshold distance ring determined by category s (for example, a 1 km to 2 km radius from the highway) compared to prices from *manzanas* located further away than the last category S (for example, further away than 10 km from *Acceso Sur*), but which are similar in baseline characteristics ($\mathbf{X}_{it=2007}$).

The last equation is simplified in some occasions as a difference-in-difference specification to present results in a more comprehensive way. In this approach the year dummies that interacted with the different categories of $Near_{r,i}$ are replaced for the $Post2010_t$ indicator variable:

$$ln(p_{it}) = \beta_1 Post2010_t + \sum_{r=1}^{R} \beta_{2r} Near_{r,i} + \sum_{r=1}^{R} \beta_{3r} Post2010_t * Near_{r,i} + \beta_{4k}\mathbf{X}_{it=2007} * \sum_{k=2011}^{2018} Year_k + \gamma_i + \varepsilon_{it} \quad (5)$$

A particular form of our last specifications includes on the right side of the equation a lag of the dependent variable to control for the average initial value of the properties in each *manzana*. By including an interaction term between 2007's property prices and year dummies, the interpretation of the coefficients of interest is changed. The 2007 prices already incorporate the anticipatory change in prices that houses possibly experienced after works were restarted in February of that year (after being suspended for more than two years). The route through which the highway would run was known to the public by this date, and there was ongoing construction of it, so this price integrates both the expectations of the future opening of the transport infrastructure and the possible dis-amenities derived from its construction. Therefore, the estimated $\beta_{3ts}s$ capture only the differential change in prices from what was already incorporated in 2007, this is, the change in prices derived from the opening and operating of *Acceso Sur* highway.

In order to evaluate the additional impact of being located near the portion of the subway that ran underground (with local streets functioning over it), in contrast to the rest of the motorway that passed at surface level, and also to evaluate the extra effect of a property located near a highway entry point, the following equation is used:

$$ln(p_{it}) = \beta_1 Post2010_t + \sum_{r=1}^{R} \beta_{2r} Near_{r,i} + \sum_{r=1}^{R} \beta_{3r} Near2_{r,i} + \sum_{r=1}^{R} \beta_{4r} Post2010_t * Near_{r,i} + \sum_{r=1}^{R} \beta_{4r} Post2010_t * Near2_{r,i} + \beta_{5k}\mathbf{X}_{it=2007} * \sum_{k=2011}^{2018} Year_k + \gamma_i + \varepsilon_{it} \quad (6)$$

Were $Near2_{r,i}$ is defined in the same manner than $Near_{r,i}$, with the only difference being the infrastructure's element from which distance is measured. In some specifications *manzanas* distance is measured from highway's underground section and in others from the highway's entry points.

To explore if the opening of *Acceso Sur* had a differentiated effects across the exposed *manzanas*, we test for four heterogeneities: belonging to the area inside the central ring road of the city, household's motorization rate, distance to CBD, and socioeconomic condition of the households that compose it. Testing the heterogeneous treatment effects is executed using regression (7), which includes an indicator variable Z_i that interacts with the treatment definition. Where Z_i takes the value of one if *manzana* i complies with specific levels for the covariates mentioned.

$$\begin{aligned} ln(p_{it}) = \beta_1 Post2010_t + \beta_1 Post2010_t * Z_i + \sum_{r=1}^{R} \beta_{2r} Near_{r,i} + \sum_{r=1}^{R} \beta_{2r} Near_{r,i} * Z_i \\ + \sum_{r=1}^{R} \beta_{3r} Post2010_t * Near_{r,i} + \sum_{r=1}^{R} \beta_{3r} Post2010_t * Near_{r,i} * Z_i \\ + \beta_{4k} \mathbf{X}_{it=2007} * \sum_{k=2011}^{2018} Year_k + \gamma_i + \varepsilon_{it} \end{aligned} \quad (7)$$

5.2 Treatment and Control Definitions

In this subsection, the previously mentioned variables that define the treatment: $Near_i$ and $Post2010_t$, are further defined. Several alternative definitions are considered, and this is combined with a non-parametric approach to explore the possible threshold distances and threshold dates to capture more comprehensively the highway's impacts on different city zones. It is important to mention that the scope of this work is to identify changes within city areas by comparing property prices evolution between them. Consequently, even if the opening of *Acceso Sur* may have impacts extending through all the city of Santiago, this work's estimations do not pretend to capture city-wide effects, for which there is no control group in the data set employed.

The distance that delimits the treated area and the thresholds inside it that divide this area into different categories of treated can be set according to the literature. For example, Langley Jr (1976) determines through surveys and field measurements regarding noise and air pollution that adverse effects are found for the households located in the first 0,35 km from a highway in Virginia, United States. Other studies have followed this classification and have separately estimated the effects for properties located outside the 0,35 km buffer but inside a 3,2 km radius from the highway, further dividing this treated zone into smaller categories according to their distance from the highway (Boarnet and Chalermpong (2001); Vadali and Sohn (2001); Vadali (2008)). To select the threshold distances, they follow previous literature or use criteria based on maximizing the R^2 of the estimates. Although this approach allows for a comparison with previous works, it imposes a rigid structure over the relationship that is being studied. For this reason, the present study employs a non-parametric approach to explore how the effect evolves as a wider treated zone is considered, and uses different controls to grasp a better sense of the possible biases conveyed by each. Finally, we complement these estimates with those obtained using literature's standard thresholds to contrast the results with earlier studies.

Also relevant when defining the explanatory variable, $Near_i$ in this case, is to think about the fundamental source of the studied effect. From which element of the highway should distance be measured from to define the treated units depends on which are the primary sources of changes in citizen's valuation derived from this transport infrastructure. The potential accessibility improvements brought by this new highway are more closely related to the highway's entry and exit points than to the route itself. This distinction is relevant in the *Acceso Sur's* context, as its entry (exit) points are located distant from one another, relative to other Santiago's urban highways (see Appendix F). This implies that for two *manzanas* located at the same distance from the highway's route, one could be experiencing a more profound increase in accessibility, by being located closer to its entry point as people could access and use it in less time and with less effort. On the other hand, proximity to a highways *route* importantly affects the intensity of the potential dis-amenities derived from the highway, while keeping constant the distance to its entry points. Therefore, we use both, distance to highway's route and distance to highways entry points as alternative forms to define the treated zones. Although, distance to the highway is chosen as the principal variable to avoid the endogeneity problems of entry points, as discussed in the previous section.

The erratic nature of the decisions taken during the planning and execution of highways in Chile, especially urban highways, make the public announcements of routes and their terms a noisy signal for proprietary buyers and real estate companies. In this context, it is not clear that a particular announcement may affect housing prices with more intensity than concrete actions, like the culmination of a highway and the start of its operations. Therefore the threshold year can be considered either the year that the first portion of *Acceso Sur* was opened (2007), the year the second portion was opened (2009), or the year the last section opened (2010). Earlier works that have studied the timing of premiums in property prices related to the construction and opening of urban highways found the most prominent effects in final construction periods or after the openings ((Boarnet and Chalermpong, 2001; Vadali and Sohn, 2001; Vadali, 2008; Concas, 2013)). These works conclude that appreciation of houses only occurs after families can be certain about the materialization of the new infrastructure. Gibbons and Machin (2005) argue that property buyers do not necessarily incorporate in their willingness to pay the projected improvements in accessibility that this new infrastructure would potentially bring in the future because of two reasons. Firstly, due to the uncertainty surrounding the date in which the highway would become available for use, and secondly because of the dis-amenities of living near a construction site with lower accessibility until the highway is operational. These two issues combined with the fact that most properties are bought for living purposes (and people are thought to heavily discount future benefits if they imply contemporaneous detriments to their everyday life) suggest that these adverse effects dominate over the speculative forces driven by real estate buyers.[26]. These massive infrastructure investments are often subject to litigation and risk suffering technical complications that may considerably delay the works. The cited literature documents this kind of dynamics for the United States, but for the case of Chile, these concerns are probably exacerbated. Concessions in this country are frequently re-negotiated, and their finishing dates delayed (Engel et al., 2009). Moreover, the *Acceso Sur* highway, in particular, has been one of the most polemic projects since the concession system began in 1993; it took twelve years for it to be utterly operational since it was adjudicated, with the works fully paralyzed at the middle of this period due to neighbors protests against it and critical planning errors (Sagaris and Landon, 2017).[27] As a consequence, if accessibility premiums are to be found for the properties located near *Acceso Sur*, they will presumably appear stronger after its conclusive opening, this is 2011 onwards.

Furthermore, the first section from *Acceso Sur* to open: "*tramo* a y b", better fit the definition of inter-city highway, as most of its 28 km route runs outside the urban limit of Santiago, and is not connected to other urban highways in Santiago, nor to any of the city's business center, instead it connects houses in the limit of urban Santiago with cities at its south, as the highway leads to Chile's mayor inter-city highway: *Ruta 5*.[28] Likewise, the second portion to open; "tramo c1", is also located just in the urban limit of the city, besides it only extends for 3.5 km, and it does not connect to the city center or other highways. Finally, "*tramo* c2" is a 7.7 km route that connects the portions of *Acceso Sur* that had already been inaugurated with "*Vespucio* Sur" highway (part of the ring road that circumvents Santiago's city center). This makes the opening of the last section of *Acceso Sur* the deepest change in *urban* accessibility generated by this highway.

[26]see (Gibbons and Machin, 2005) for a critique of the traditional asset pricing model when applied to real estate

[27]See Appendix 3 for a review of the highways construction problems and litigation that delayed its construction and opening.

[28]Refer to Appendix 4 for a map of *Acceso Sur* sections

Likewise, public's attention peak (as measured by Google Trends) was reached the year of this final opening.[29] The second highest point was reached at the time the first portion opened, and even though this is the longest section of the highway, the number of searches during this period was only around two-thirds of those made when "*tramo* c1" opened. These conceptual arguments lead us to focus on the opening date of this last portion of the highway (December 31st, 2010) as the most critical threshold year, and in this manner, the years 2007-2010 are defined as the pre-treatment period and 2011-2018 as the post-treatment period. Nonetheless, a series of sensibility tests are conducted to empirically support the preponderance of the effects from this year onward.

6 Results

This section starts by checking the identification assumption of parallel trends. Afterward, treatment effects are analyzed considering three aspects: the extent of the impact through the city, the variation in the treatment's intensity as *manzanas* locate further away from the highway, and the fluctuations in the treatment effect as years pass by after the opening of the motorway. In order to explore each of these dimensions, two classes of estimation methodologies are used: Event Study and Difference-in-Difference. The first one helps to check the temporal persistence of the effects, and as they do prevail over time for *Acceso Sur's* case, it is useful to employ then the second methodology to attain more precisely the extension of the impact, and the evolution of the effect as distance increases inside this zone. Furthermore, to explore how far the highway's impacts span, the treated area is first set as a *unique* zone, defined by a threshold distance, and several thresholds distances are tested. Finally, to check for non-linear effects of proximity to the motorway, different treatment categories are defined, instead of a unique one. This is, for example, subdividing the 10 km radius around the newly opened transport infrastructure into ten groups according to *manzanas* distance to it, starting by 0-1 km, then 1-2 km, and continue until 9-10 km.

6.1 Checking Parallel Trends

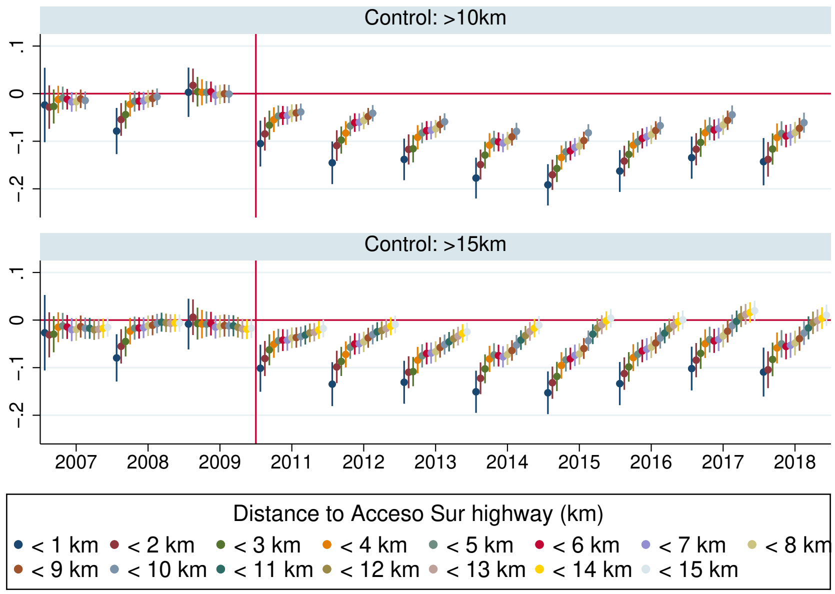
Before estimating the relationship of interest: highway proximity over property prices, the identification assumption of our empirical strategy is checked. Even though parallel trends assumption can not be directly proven, pre-trends do serve as suggestive evidence for plausibly believing that these trends would have continued in a parallel evolution in the hypothetical scenario in which no highway was constructed and opened. Because treatment and control groups are defined non-parametrically, pre-trends are also compared in this flexible manner. For this purpose, the hedonic regression is estimated several times using the combinations of twenty-five different *unique* treatment definitions, and four alternative control groups. These alternative definitions are described in detail in the next section, but essentially what changes is the amplitude of the treatment zone going from 0-1 km to 0-25 km from the highway. Regressions are run first without covariates, and then these are incorporated to test the sensitivity of the estimates.[30] Covariates employed are distance to subway network, distance to Santiago's center (La Moneda), initial distance to the

[29]See Appendix 5 for a graphic representation of the number of searches made in Google's search engine by the words *Acceso Sur* in Chile from 2004 (earliest year available) to 2019.

[30]Covariates are in their 2007 level and interacted with year dummies following equation (3). Three alternative specifications using covariates are used: all covariates in levels, all covariates in logs, and finally, covariates in logs except the ones that are proportions. The selection of covariates was based on theoretical grounds and previous literature, as using Lasso inference techniques for estimating the 420 regressions required would have been computationally too demanding and time-consuming.

highway network, total population, the fraction of female population, socioeconomic index, motorization rate, percentage of dwells owned by its inhabitants and percentage of household leaders with a college degree (all covariates are in terms of the *manzana's* average).

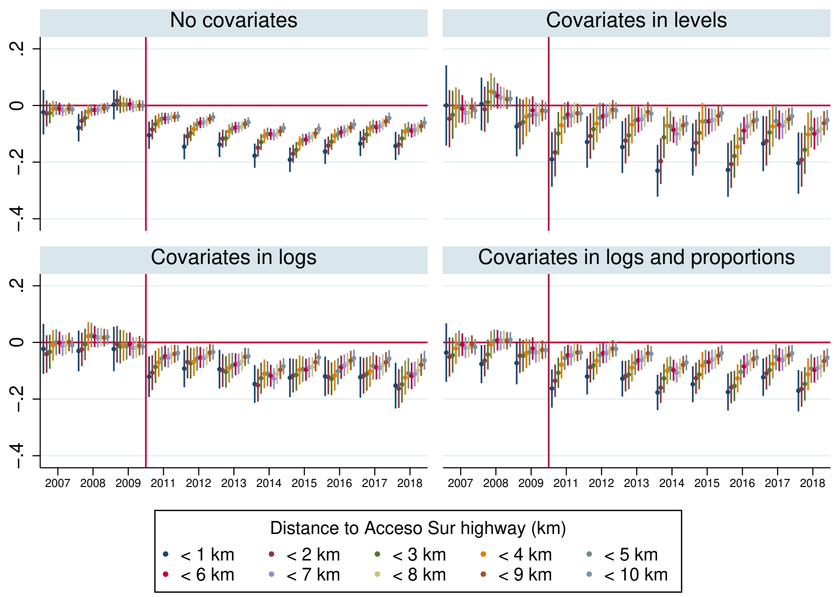
Figure 2: Event Study for Different Treatment Definitions and Two Alternative Control Groups: "10 km Onward" and "15 km Onward"



Notes: Each dot represents the estimated treatment effect for a different $Near_i$ definition, obtained from running equation (3). This specification contains only one unique treatment, which is determined by the threshold distance to *Acceso Sur* inside which all *manzanas* are categorized as treated. The control groups are all manznanas located farther away than 10 km from the highway (in the top sub-graph), and farther away tha 15 km (at the bottom sub-graph). No covariates included. Each line behind a dot represents the point estimate's 95% confidence interval.

Figure 2, shows the estimated coefficients for the various definitions of treated, and the control group determined by *manzanas* located outside a 10 km buffer from the highway (15 km buffer). Each point was estimated using a separate regression. The group of dots above each year represent the estimated percentage change in prices from 2010 until that particular year, when comparing treated and control groups, and each colored dot represents a different *unique* treatment group. From left to right, the first dot denotes a 0-1 km zone as treated, the next one a 0-2 km zone as treated, until the 10th one representing a 0-10 km area around the highway as treated (15 km area as treated). A vertical line indicates the baseline year, which corresponds to the year before *Acceso Sur* was opened (2010). It can be seen that before the treatment, the treated and control *manzanas* did not have significant differences in their property prices, as most of the estimates are near zero, and their confidence intervals almost always pass through it. The only coefficients significantly different from zero are found in the year 2008 and for treatment threshold distances of 3 km or less. This makes sense as these *manzanas* located in the immediate vicinity of *Acceso Sur* are more exposed to price fluctuations following the opening of the first portion of the highway, that took place precisely that year (2008). But, otherwise, it can be concluded that before 2011, property prices fluctuated following parallel trends between the treated and the control groups (for the different definitions of treated). The graphs replicating these exercises with 20 km and 25 km control groups can be found in Appendix A. As the control's threshold distance increases, this leaves a smaller portion of the city to be used as the control group, and also a less representative one. As a consequence, the confidence intervals of the estimates jump, especially when using the 25 km threshold. Notwithstanding, the point estimates remain reasonably stable, replicating the already seen pattern of pre-treatment estimates near to zero. Finally, Figure 3 which incorporate covariates into the specification also exhibit parallel trends between treated and control *manzanas* previous to the highway opening, and this result is robust to the different forms in which covariates are included (level form, logarithmic form, and a combination of both). In essence, the control groups studied do serve as a valid counterfactual for the various definitions of treated zones, and this can be ascertained more clearly for the "10 km onward" control group, as confidence intervals tend to be smaller in this case.[31]

Figure 3: Event Study for Different Definitions of Treatment and "10 km Onward" Control



Notes: Each dot represents the estimated treatment effect for a different $Near_i$ definition, obtained from running equation (3). This specification contains only one unique treatment, which is determined by the threshold distance to *Acceso Sur* inside which all *manzanas* are categorized as treated. The control groups are all manznanas located farther away than 10 km from the highway. A specification with no covariates is included, the other three include covariates in different forms, according to the labeling of every sub-graph. Each line behind a dot represents the point estimate's 95% confidence interval.

After checking parallel trends for these *unique* treatment groups, we analyze this assumption for multiple-treatment groups. In order to make sure that the different treatment categories (which compose a *unique* treatment) can be compared to the "10 km onward" control threshold, equation (4) is ran. In Table 8 from Appendix A, five 2 km categories are compared to the mentioned control group. Again data supports the identification assumption for each of the treated groups.

[31] A more rigorous check of the parallel trends assumption can be seen in Appendix A, which shows a Table 7 with the estimated coefficients of the displayed graphs.

6.2 Treatment Effects

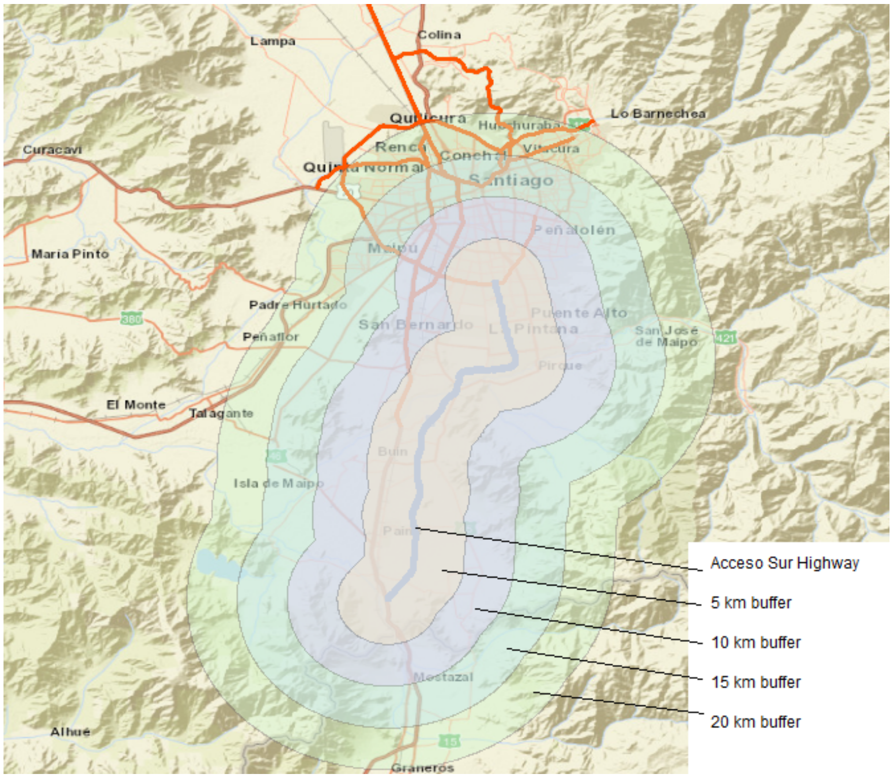
After checking the identification assumption, the focus turns to measuring the treatment's evolution within time and space, and its extent through the city. In the first place, from figure 3, it is clear that the estimated impact -of being proximate to the highway, once the infrastructure started its operations- remains fairly stable through the years, all through the study horizon, for each of the treatment definitions. The percentage change in property prices with respect to the year 2010, is approximately the same for each of the years between 2011 and 2018. In this manner, the Event Study can be replaced with a difference-in-difference approach without diluting a possibly relevant temporal pattern. The difference-in-difference approach, by grouping observations into only two temporal dimensions (before and after the treatment), allows more precise estimation of the spatial impact of the highway -in terms of its extension, and also when analyzing possible fluctuations through the affected area-.

The first step to understand the spatial nature of Acceso Sur's impact is selecting a treated and a control zone. The following non-parametric approach is taken to identify a range of plausible threshold distances in which the highway's effects are concentrate. First, the control group is defined as all the *manzanas* in the sample located outside a 10 km buffer around *Acceso Sur*, and using specification (1), the hedonic regression was run for ten *alternative* definitions of $Near_i$. The difference among these definitions was the threshold distance of the buffer around *Acceso Sur* used to define the treated zones; they went from 1 km to 10 km (always starting at 0 km from the highway). The same procedure was repeated using a control group defined as: "those *manzanas* further away than 15 km", then with 20 km, and finally with 25 km. For each of these control groups, regression (1) was run for 15, 20, and 25 alternative definitions of $Near_i$, respectively. Each of these definitions started with a 0-1 km buffer around the highway and subsequently increased the threshold distances by 1 km until the treatment group included all *manzanas* inside a 15 km, 20 km, and 25 km radius around *Acceso Sur*, respectively. Four of these unique treatment groups are depicted in Figure 4, which helps to see the extent of these buffers through the city.

By gradually widening the treated area and assuming highway's effects fade to some degree with distance, it can be expected that the estimated coefficients will, at some point, reach zero. Assuming a linear effect, by expanding the threshold distance, more *manzanas* that are unaffected by the highway would end up inside the "treated" category, diluting the effect experienced by the closer *manzanas* that were affected. Non-linear effects inside the treated zone are further explored in the next paragraphs, but for now, this exercise will enable an exploration of the treatment effect's sensitivity to the definition of treated.

Figure 5 shows a clear pattern; proximity to *Acceso Sur* highway is associated with a negative evolution of prices relative to the control areas between the pre and post-treatment periods. This negative percentage change is significant for the four control definitions, at least for the treatments with a threshold of 5 km or less (when using control over 20 km) and 13 km or less (when using 15 km and 25 km). When the "10 km onward" control is employed, all the treatment definitions generate negative and significant estimates; this means that on average, all *manzanas* located inside this 10 km buffer zone receive a negative impact after the opening of the highway. The smaller the threshold distance, the stronger the adverse effect, and as the threshold distance expands, the effect's magnitude diminishes. This pattern suggests three things: first, *Acceso Sur's* opening brought negative effects that intensify in areas closer to the highway; second, this effects reach a much wider area compared to the previous literature (which only found negative effects for the first 0,35 km); finally, this negative effect that dissipates with distance to the highway does so in a linear way. This last finding is relevant because it can be concluded from it that, if

Figure 4: Buffer zones around Acceso Sur

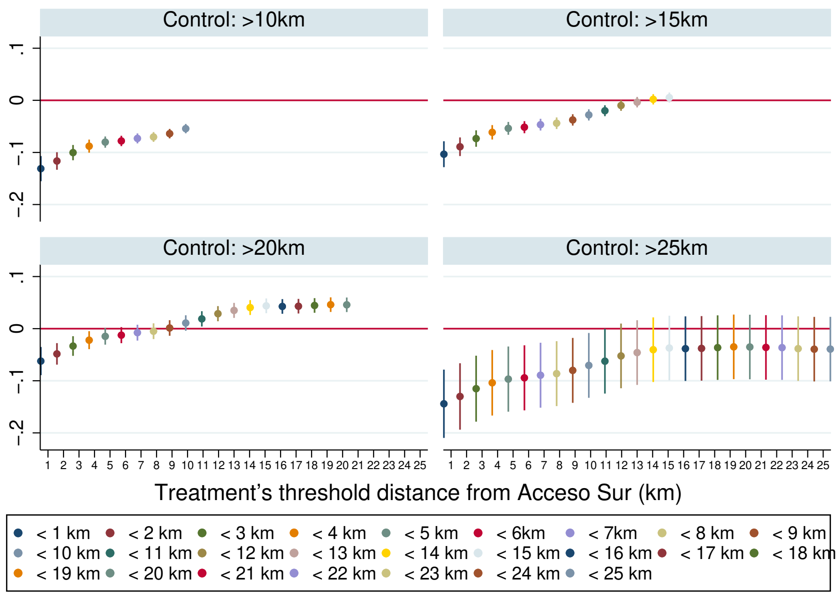


Source: Own elaboration

negative effects extend for long distances and their magnitude monotonously decreases (as seen in Figure 5 for the 10 km and 15 km control groups), then, when using a medium distance control definition (as 10 km), the estimated coefficients would probably be lower bounds. This is because the group used as a counterfactual has also experienced some adverse effects derived from the highway, and hence the treatment effects found would be capturing only the *extra* decrease in prices for being particularly close to the highway. The same general trends can be observed when estimating equation (2) that incorporates covariates for the “10 km onwards” control group, but no clear effects are found for control definitions starting farther away (this graph can be found in Appendix B). All these elements justify the use of the “10 km onwards” control, -or even ones that start before, at 8 km or 5 km, for example-, as in the worst-case scenario they would lead to underestimating the highways true impact.

Having explored the possible treatment and control groups -by testing their validity, and by using the data to narrow down the range of feasible definitions for them-, it is conceivable now to grasp a more precise understanding of the effect’s evolution with distance from the highway. For this purpose, the originally *unique* treated zone is divided into ten categories following equation (5), with each of them comprising a 1 km width ring around the highway, and Difference-in-Difference estimators are computed. In this manner, a different treatment effect is allowed for *manzanas* located in the 0-1 km from *Acceso Sur*, than for the ones located at a distance of 1-2 km, or 2-3 km, and so on until the last category of treated, located at 9-10 km from the highway. The control *manzanas* are defined as all those contained in the sample except for those inside a 10 km buffer around *Acceso Sur* .

Figure 5: Difference-in-Difference Treatment Effects for Different Treatment and Control Definitions (No Covariates)

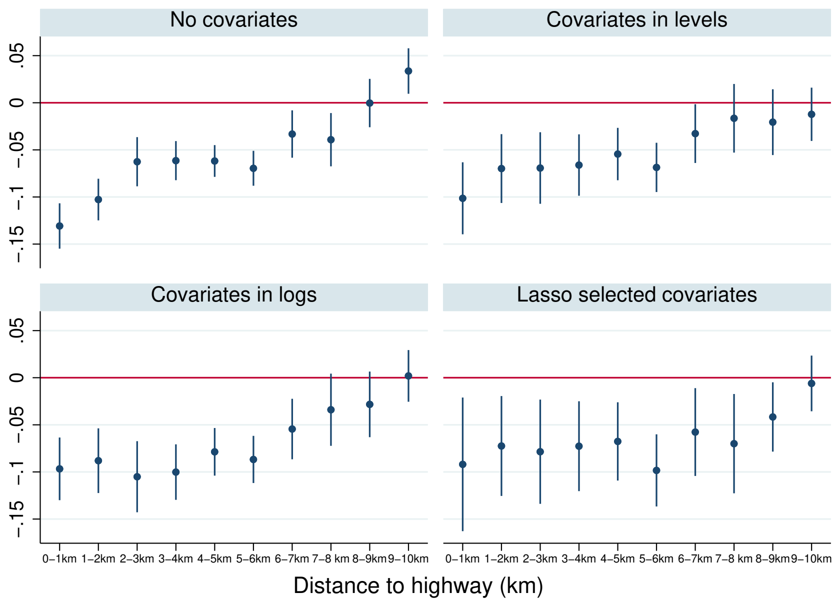


Notes: Each dot represents the estimated treatment effect for a different $Near_i$ definition, using equation (2). This specification contains only one unique treatment, which is determined by the threshold distance to *Acceso Sur* inside which all *manzanas* are categorized as treated. The control groups are all manznanas located farther away than 10 km from the highway in the first graph (up and to the left), the other graphs use 15 km, 20 km and 25 km as threshold distances for the control group. No covariates are included. Each line behind a dot represents the point estimate's 95% confidence interval.

Table 4 groups all the estimates obtained from regressing equation (5), while Figure 6 illustrate the pattern form between different treatment categories. The four specifications used, -without covariates, with covariates in levels, with covariates in logs, and using the set of controls selected by Lasso techniques- follow a remarkably similar pattern. There is a decrease in property's prices relative to the control group after the opening of *Acceso Sur* that starts with a 10% negative percentage change for those located in the first 0-1 km from the highway, and that gradually decreases to around a 5% negative change for the 1-6 km area. Finally, the effect completely dissipates at roughly 8 km or more from the highway. The inclusion of covariates in various forms mainly expands the confidence intervals, and subtly flatten the positive slope formed by the successive point estimates. For example, when using the Lasso selected controls, the estimated treatment effect is more homogeneous between the first eight categories of treated, and these estimates fluctuate between the -5 to -10% change. Comparing this pattern with the one observed in the specification with no covariates suggests that the bigger difference between the treatment categories' effects is partly explained by property's prices evolving at different rates for *manzanas* that start with different baseline characteristics. These differential trends are captured by the covariates interacted with the year dummies.

Finally, the three dimensions of analysis for the treatment effect (time evolution, spatial variation, and spatial extension) are jointly studied by estimating equation (4). This is, with year dummies interacted with each of the R $Near_{r,i}$ categories. Through this evaluation, any particular pattern, that was disguised behind the temporal or spatial aggregations employed until

Figure 6: Difference-in-Difference Treatment Effects: Ten Treatment Categories and "10 km Onward" as Control Group



Notes: Each dot represents the estimated treatment effect for a different treatment category, using equation (5). This specification contains ten treatment categories, each defined by an specific distance range from *Acceso Sur* (inside which all *manzanas* are categorized as treated). The control groups are all manznanas located farther away than 10 km from the highway. The first subgraph contains no covariates, and the other three contain them in the different forms specified in their labels. Each line behind a dot represents the point estimate's 95% confidence interval.

now, would be evidenced and may shed light into the mechanisms causing the effects. For the eight post-treatment years, and the ten categories of treatment originally used, this would imply estimating 80 coefficients. However, the following adaptation -based on the data- is used to simplify the interpretation of results. It can be seen from Figure 6 -especially from the no covariates specification-, that the first two categories' estimates have a similar magnitude, the next four categories have again very close estimates, then from 6 km to 8 km the estimates are around -5%, and for the last two categories it can be concluded that they are non-negative. Having this in mind, it is reasonable to group categories for every 2 km. Hence, the number of treatment categories is set to five ($R = 5$), and they are defined using 2 km thresholds (going from 0-2 km, 2-4 km, until 8-10 km), the control group is maintained at "10 km onward".

Table 9 in Appendix B contains the estimates for each category and year. Most notable are the estimates for the *manzanas* located in the first 2 km from the *Acceso Sur*; this area experienced a negative percentage change in the average sale price of their properties between 2010 and each of the years in the study period. When using the no-covariates specification the percentage change went from -8.5% in the first year after the opening, reached its peak of -17.0% on 2015, and the negative, statistically significant and economically relevant effect remained strong until the last study period year (this is, -13.8% in 2018). When including covariates in the specification (columns 2-3), the estimates' magnitudes get more homogeneous between years but remain around a 10% decrease. In particular, the specification with covariates in levels gives the smallest estimated effects (around 10%), while the one using Lasso to select the controls gives

Table 4: Difference-in-Difference Treatment Effects: Ten Treatment Categories and "10 km Onward" as Control Group

	(1)	(2)	(3)	(4)
0-1 km from highway	-0.131***	-0.101***	-0.097***	-0.092**
	(0.012)	(0.019)	(0.017)	(0.036)
1-2 km from highway	-0.103***	-0.070***	-0.088***	-0.072***
	(0.011)	(0.019)	(0.018)	(0.027)
2-3 km from highway	-0.063***	-0.069***	-0.105***	-0.079***
	(0.013)	(0.019)	(0.019)	(0.028)
3-4 km from highway	-0.061***	-0.066***	-0.100***	-0.073***
	(0.011)	(0.017)	(0.015)	(0.024)
4-5 km from highway	-0.062***	-0.054***	-0.079***	-0.068***
	(0.009)	(0.014)	(0.013)	(0.021)
5-6 km from highway	-0.070***	-0.069***	-0.087***	-0.098***
	(0.009)	(0.013)	(0.013)	(0.020)
6-7 km from highway	-0.033***	-0.033**	-0.054***	-0.058**
	(0.013)	(0.016)	(0.016)	(0.024)
7-8 km from highway	-0.039***	-0.016	-0.034*	-0.070***
	(0.014)	(0.019)	(0.020)	(0.027)
8-9 km from highway	-0.000	-0.021	-0.028	-0.042**
	(0.013)	(0.018)	(0.018)	(0.019)
9-10 km from highway	0.034***	-0.012	0.002	-0.006
	(0.012)	(0.014)	(0.014)	(0.015)
Covariates	No	Level	Log	Lasso
N of observations	175,474	127,458	111,368	56,808
N of manzanas	41,216	30,590	24,544	8,646
N of high-dimension controls				545

Notes: This table provides the ATT for *manzanas* located proximate to *Acceso Sur* highway after its opening (on 2010), according to equation (5). Ten treatment categories are considered based on distance to the highway, at 1 km intervals until the 10th km. Control *manzanas* are those located farther away than 10 km. *Manzana* and year fixed effects are included in all specifications. Unit of observation is manzana-year. Pre-treatment years included in the regression are 2007, 2008, 2009 and 2010 (its estimated coefficients are found in Table 8), while post-treatment years cover from 2011 to 2018. Covariates included in column 4 where selected based on Lasso machine learning techniques. Clustered standard errors in parenthesis (clustering at the *manzana* level).* p<0.10, ** p<0.05, *** p<0.01.

estimates that are always higher than 10% in absolute value and even get close to a 20% decrease for the later years.

For the 2-4 km treatment category, effects do not seem to appear immediately after the opening, and when they do appear they are considerably smaller in magnitude, going from -5.8% on 2012, to a peak of -9.8% between the period 2010 to 2015, and getting near the 4% decrease for the final years. Interestingly, when covariates are included in the regression point estimates remain at levels similar to those found in the 0-2 km category, this is, closer to the 10% decrease. For the treatment category defined in the next 2 km (at a 4-6 km distance), estimated effects start at lower magnitudes (-3 to -8% depending on the specification, for at least the first two years); again the peak is reached around 2015, but this time it just reaches the 10% decrease; finally, the percentage change in prices compared to 2010 remains around -8% until 2018. Less fluctuation between specifications is seen from 2017 onward.

For the category defined as 6-8 km from *Acceso Sur* point estimates remain negative, but most of the time, they are not significantly different from zero. Significant estimates are found for the years 2013 to 2016 and fluctuate from -5% to -10%, and then back again to -5%. Finally, for the last category of treatment: 8-10 km from the highway, no significant change in price can be concluded when comparing them to similar *manzanas* at the other side of the threshold distance (10 km), except for some particular exceptions like 2015 and 2017, but only in some specifications.

From this granular analysis, it can be seen that no particular treatment category presents relevant deviations from the time aggregated findings obtained from Difference-in-Difference estimations. Nor did they differ substantially from the *unique* treatment simplifications used in the first Event Studies presented. Consequently, the four main findings of this section can be confirmed: the opening of the highway brought a negative net effect into the households proximate to it, and this effect is captured by a decrease in property prices of broadly a 10% change; the effect is persistent over a short and medium-term horizon; it reaches a 6-8 km radius around the infrastructure; and it decreases with distance, with the strongest impact found for the first 2 km from it.

6.3 Mechanisms

To the best of our knowledge, no previous work has found such a systematic -and causally interpretable- decrease in property prices after the opening of a highway in the areas proximate to the new transport infrastructure. A negative effect had only been observed for dwells in an immediate vicinity of 0.5 km or less, but not for wider areas around the motorway. To better understand these counter-intuitive results, four mechanisms are explored in this section. Econometric techniques are used to test these potential mechanisms When possible, and complementary, descriptive evidence is collected.

6.3.1 Local accessibility

In the first place, neighborhoods exposed to a newly constructed highway may experience a deterioration in their accessibility levels, as the highway necessarily cuts the local area into two separate zones. This is especially true for highways constructed at surface level, with few vehicles or pedestrian crossing points, few entries and exit points, and where these elements are located far away from each other. This is precisely the case of *Acceso Sur*, with only seven entry points distributed along its 46.6 km, and 32 crossing points. Besides, these infrastructure items are not evenly distributed trough the route leaving extensive areas with no formal connection between the abutting zones at each side of the highway, as can be observed from Figures 19 and 20 in Appendix F. Residents of proximate areas incur in higher efforts and higher costs every time they need to cross to the other side of the motorway. If traveling by car, the citizen will now need to find the closest crossing lane that may be several kilometers away, or enter the highway for a short distance, having to incur in paid tolls for it. For short distances, this can comprise a significant portion of the total mobility costs. In particular, the introduction of a highway strongly damages the neighborhood connectivity for trips made by active transportation means (walking or cycling). The time and effort considerably increase when citizens have to dodge a highway when walking or cycling to a nearby area. Furthermore, there is evidence that pedestrian runways or sidewalks in the car crossing points were not well designed or implemented, and are perceived as more insecure (Sagaris and Landon, 2017; Carrasco, 2015). An explanation for this is the official classification of the highway as an *inter*-city motorway, which allowed the concessionaire to provide low-quality infrastructure to support pedestrians transport and local streets.[32] Elder and disabled citizens may be forced to employ motorized transportation means as the only way to get across the highway due to these increased physical efforts and security concerns .[33] This turns even more problematic if travel patterns near the new infrastructure are strongly inclined towards intra-neighborhood trips. Evidence collected by Iglesias et al. (2019) shows that active transport modes represent a higher portion of the trips for lower-income households; for the first quintile walking and cycling comprise more than half of their trips, while for the richest quintile they represent roughly one-fourth of their trips (as can be seen in Table 5). On the other hand, these authors also find that households with the lowest incomes (Q1) make trips 35.4% shorter in distance than the ones with higher income (Q5); hence, mobility at a local scale is particularly relevant for this group. Considering that *Acceso Sur* crosses an area populated with families predominantly from the lowest income groups, then it can be expected that the opening of this highway affected a substantial portion of the trips realized by them, and this adverse effects on local accessibility would be captured in lower property prices.

Table 5: Mobility Indicators and Modal Share by Income Quintile

	Mobility indicators			Modal share by quintile				
Mode	Travel time (min)	Distance (km)	Speed (km/h)	Q1	Q2	Q3	Q4	Q5
Car	30.1	8.3	16.2	9.3%	13.8%	19.7%	31.1%	48.7%
Public transport	58.9	10.4	10.3	22.8%	23.2%	24.8%	24.9%	16.5%
Share taxi	31 4.7	9	4.7%	3.3%	3.9%	2.3%	0.8%	
Bicycle	17.1	2.3	8.2	4%	4.1%	3.8%	4.7%	3.4%
Walking	7.4	0.5	3.7	47.4%	43.8%	36.6%	27.9%	22.3%

Source: Iglesias et al. (2019) based on data in SECTRA (2015).

To measure the feasibility of this reduction in local accessibility as an essential factor behind *Acceso Sur's* negative appraisal, the evolution of short trips could be compared between the treated and control areas. However, the fraction of intra-neighborhood trips can arguably be inelastic for residents living in the treated areas. First, because the per capita trips for lower-income quintiles are all-ready at low levels (1.2 times lower than the wealthier quintile (Iglesias et al., 2019)), so it would be hard for these families to reduce trips in an extensive margin. Second, most of these households do not have access to private motorized vehicles, and are therefore captive of the public transport (that is considerably slower) or active modes (that limit the potential distance of the trips), making longer trips remain unattractive relative to local ones. As a result, it can be expected that intra-neighborhood trips remain a substantial portion of the total trips. Nevertheless, this persistence in the high fraction of short trips -even after the highway opening-, would disguise any increase in the transportation efforts for these short trips.

Another element that would imply a bigger relevance put on intra-neighborhood trips is the scarcity of basic services. If *comunas* or neighborhoods near *Acceso Sur* have few schools, health centers, marketplaces, working places, and bus stops, then there are higher chances that the closest available option is now located on the other side of the highway. Evidence on Santiago's

[32]For example, social movements demanded basic traffic elements like pedestrian crossings and traffic lights. Appendix K contains pictures of these infrastructure.

[33]The major of Renca -a *comuna* exposed to four urban highways- illustrates the negative effects of this transport infrastructure by describing how one of these highways -which runs right through a marginalized neighborhood- is causing elders living just 500 meters away from the local health center to rely on unauthorized cabs to access the health services they need, which charge them abnormal tariffs; and how other of the highways deprived the neighborhood from access to the Mapocho River, and with this it took away the green areas and aesthetics components brought by this natural resource (Radio ADN, 2019)

distribution of facilities and services indicates that this is the case for low-income areas, like the ones surrounding *Acceso Sur* (Iglesias et al., 2019). Distribution of social, educational, and health services in the areas proximate to the highway can be seen in Appendix I. For example, Figure 31 depicts the distribution of schools near the highway. It can be noticed that if a family wants to put their children in a municipal school, there is a big chance that the nearest municipal school is located on the other side of the motorway. The deficient crossing infrastructure that these families would be forced to confront on a daily basis may be further limiting the school choices in the sector, and therefore, less utility can be derived from living there. This same pattern applies to the other services studied as can be seen from the figures in the appendix.

To empirically test if this decrease in local accessibility is a motivating factor behind the citizen's negative appraisement of *Acceso Sur*, we exploit the fact that 2.9 km of the highway is a tunnel, with local streets, sidewalks and bike lanes found above it. Even though during the construction phase the area around this section may have experienced a deeper deterioration[34], after the opening of the highway local accessibility should have been preserved in a better way than in the rest of the highway. An underground motorway leaves the streets at the surface with levels of local connectivity closer to those found at the pre-opening period. Therefore, a more moderate negative effect is expected for this particular section. The formal testing of this hypothesis is conducted by running equation (6) with the variable $Near2_{r,i}$ defining ten treatment categories based on distance from the *manzanas* to the highway's tunnel section. This is, $Near2_{r,i} = 1$ if *manzana* i is located at a distance of $r - 1 < distance < r$, with $r = \{1, 2, 3, ..., 10\}$.

When including the additional treatment of proximate distance to Acceso Sur's tunnel, the original treatment of proximate distance to any section of the highway after the opening remains negative, and around 15% for the first 6 km in the specification with no covariates (as can be seen in Table 15 in Appendix C). Figure 7 depicts how the effect for *manzanas* located near the tunnel is positive for this same distance (0-6 km), and then fades away. However, this positive impact does not completely compensate for the general effect of being near the motorway, as checked by making a linear combination between both effects. Table 17 in the same appendix, groups this linear combinations and shows that the combined effect ranges from a -5% and -8%.[35] This evidence supports the hypothesis that local accessibility is an important factor when citizens praise dwells, notwithstanding, it is not the only one. The negative change in prices that occurred even in the areas proximate to the tunnel section of the highway suggests that other negative externalities are derived from a motorway operating nearby, and are not solved with the construction of an underground highway.

Another empirical test for the local connectivity hypothesis can be attained by comparing the treatment effects for *manzanas* located inside of *Vespucio*'s ring road (where *Acceso Sur* starts) and at the rest of the zones near the highway. Properties located inside the ring road and near the motorway experience an increase in intra- and inter-city accessibility after its opening, without a relevant deterioration in their local accessibility. As can be seen in Figure 19 in Appendix F, in this area *Acceso Sur* does not cut the neighborhood into separate parts. Consequently, if local accessibility was the only negative factor related to a new highway operating in proximate areas, then no decrease in property prices should be observed after 2010 in this zone (relative to the rest of the city). We ran equation (7) with the indicator variable Z_i activating for *manzanas* inside

[34]The excavation needed to construct the underground section implied the cutting of this streets, the suspension of water services, deviations of public transport routes, and possibly stronger noise and atmospheric pollution Sagaris and Landon (2017).

[35]The specifications with covariates behaves differently; no significant effect is found for the treatment of proximate distance to the highway, neither for the treatment of proximate distance to the tunnel section, after the opening. However, the linear combination of both effects generates the usual negative percentage changes. The reduction of the sample imposed when using covariates, makes estimates less precise and can be causing these results.

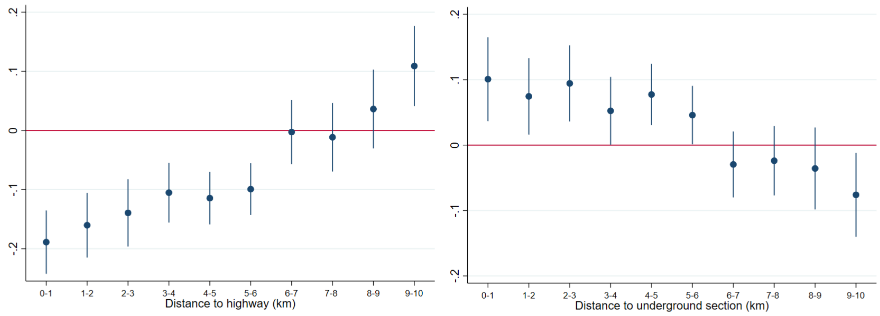


Figure 7: Difference-in-Difference Treatment Effects for Distance to Acceso Sur Highway and Distance to its Underground Section

Notes: Each dot represents the estimated effect for a different treatment category following equation (6). On the graphic at the left $Near_{r,i}$ treatment categories' effects are displayed (which use distance to *Acceso Sur* in their definition). The graphic at the right displays $Near2_{r,i}$ estimates that use distance to the underground portion of the highway to define the treatment categories. Both graphic's contains ten treatment categories, each defined by an specific distance range from *Acceso Sur* (underground portion), inside which all *manzanas* are categorized as treated. The control groups are all manznanas located farther away than 10 km from the highway (underground portion). No covariates are included. Each line behind a dot represents the point estimate's 95% confidence interval.

Vespucio, and the results are presented in Appendix C Table 10. The original treatment effect, for $Post2010_t * Near_{r,i}$, remains negative, statistically significant, and with a magnitude of around 10% for the first 8 to 9 km from the highway. The treatment effect is attenuated for *manzanas* inside *Vespucio*, as captured by the positive coefficients that accompany the triple interaction term: $Post2010_t * Near_{r,i} * Z_i$. Figure 8 maps these last coefficients, they are systematically bigger than zero for the different specifications, but statistically significant principally from the 4th km until the 8th km from the highway. Table 16 in Appendix C computes the linear combinations between the treatment and heterogeneous effect, for each treatment category. For the first 4 km from the highway, the sums of the point estimates are negative and amount to approximately a 10% change; nonetheless, they are not statistically significant. On the other hand, for *manzanas* located farther away, the combined effects give a clear null effect. This evidence is compatible with the local accessibility hypothesis, as properties with a distance of more than 4 km from the highway, projected from its starting point at *Vespucio*, clearly experience a negligible detriment in their local connectivity compared to those at that same distance but from any point in the interior portion of the highway. For this reason, a null effect is found at this distance, only in *manzanas* inside the ring road. While, for *manzanas* that are more proximate -at a distance of 4 km or less-, probably other negative externalities remain, despite the relatively better local connectivity derived from being inside *Vespucio* (but, as there is not enough statistical power, we are not able to distinguish this effect from zero).

6.3.2 Intra-city accessibility

A complementary hypothesis that could explain that no positive effects are found for this particular highway -in contrast to the previous literature- is the null or negative effect on city-level accessibility, experienced by the communities proximate to it. This possible explanation relates to the way in which citizens living near the highway use -or do not use- the new transport infrastructure, and how the transportation modes they predominantly use for longer distance mobility were affected by the opening of *Acceso Sur*. In concrete, to test this mechanism, heterogeneous effects are computed regarding household's motorization rates, socioeconomic level, distance to

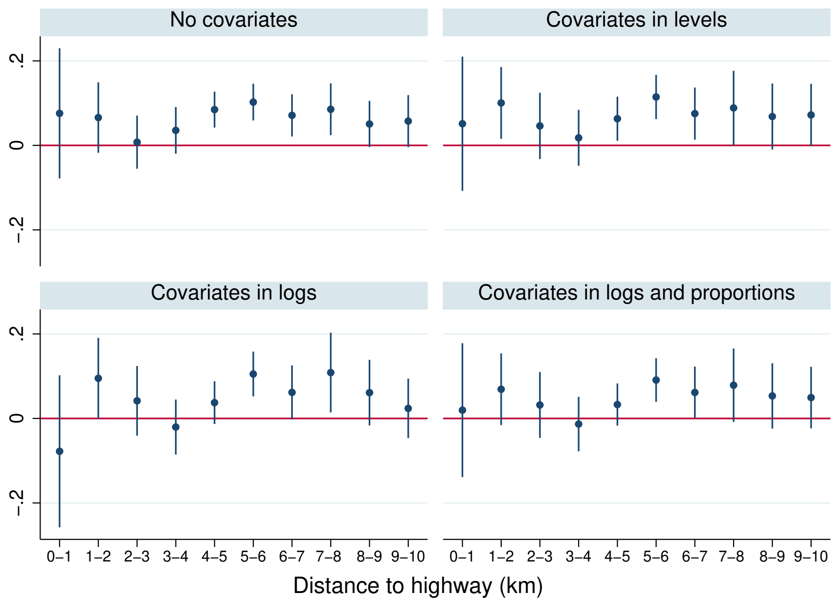


Figure 8: Dif-in-Dif Heterogeneous Treatment Effects for *Manzanas* Located Inside *Vespucio*'s Ring Road

Notes: Each dot represents the estimated heterogeneous effect for a different treatment category following equation (7). The indicator variable Z_i is defined as *manzanas* located inside *Vespucio*'s ring road. Ten treatment categories are considered based on distance to the highway, at 1 km intervals until the 10th km. The displayed effects are the coefficients accompanying the interaction term between each treatment category and the "Inside *Vespucio*" dummy. Control *manzanas* are those located further away than 10 km. Each line behind a dot represents the point estimate's 95% confidence interval calculated using clustered standar errors (at the *manzana* level).

the highway's entry points, and distance to Santiago's CBD. In addition, descriptive evidence is collected for changes in public transport and active transportation modes for the treated zone.

The lower rate of motorization in the proximate areas is the first factor to be considered. As seen in the descriptive statistics in Table 3, and in Figure 22 from Appendix G, in the first kilometers around *Acceso Sur* fewer households posses a motorized vehicle compared to the rest of the city population. As long as highways are made for particular motorized vehicles, these households have no opportunity to exploit the accessibility improvements brought by this transport infrastructure. Even if they have to commute into the city center, or to industries located at the south of the city, and the highway does connect their living areas with these places, if the costs of owning and using a car are prohibitive enough to make this transportation mode an unfeasible option, then these households will not be able to use the highway. Then, its opening would not be perceived as an accessibility improvement. This exclusivity in the use of highways, reserved to those owning a private motorized vehicle, is exacerbated by that fact that *Acceso Sur* is a paid toll road, that operates with relatively expensive fares.[36]

Still, the fraction of the population in the proximate areas that do own a car and enough resources to use the highway could enjoy less congestion and faster travel times to other city zones

[36]As part of a concession, the highway operators have the right to adjust their tariffs every year to account for inflation and are allowed an additional increase of 3.5% to 5% (Ruta del Maipo, 2018b). A strong movement against the high values charged emerged in 2013, and until 2019 it remains active demanding the lowering of this fares.

and also other cities by using this infrastructure. As a consequence, real estate prices should be capturing this better accessibility for *manzanas* with higher initial levels of motorization rate, and higher socioeconomic conditions. Evidence suggests that this kind of heterogeneous effect do exist.

Equation (7) is ran defining Z_i as an indicator variable that takes the value of one for *manzanas* that have a percentage of households owning a private motorized vehicle higher than the sample's 75^{th} percentile (that is 77.5%). Results are presented in Table 11, Appendix C, and the additional impact of belonging to this type of *manzanas* is depicted in Figure 9. Stronger treatment effects are estimated for the first 3 km from the motorway, and they are closer to a 20% decrease than to the usual 10% found in previous specifications. This implies that proximity to the highway is particularly detrimental for *manzanas* with a lower motorization rate than the 75^{th} percentile. On the other hand, belonging to areas with motorization rates above the 75^{th} percentile tends to generate a positive effect over dwells prices for different distances from the highway (see Figure 9). Nonetheless, even for these *manzanas* in which most households own a car, the total effect of Acceso Sur's opening is negative for the first 6 km, as calculated in Table 16, Appendix C. The only properties that were better off after this new infrastructure are those located at a 9-10 km distance from it, however, these results are not robust to the inclusion of covariates.

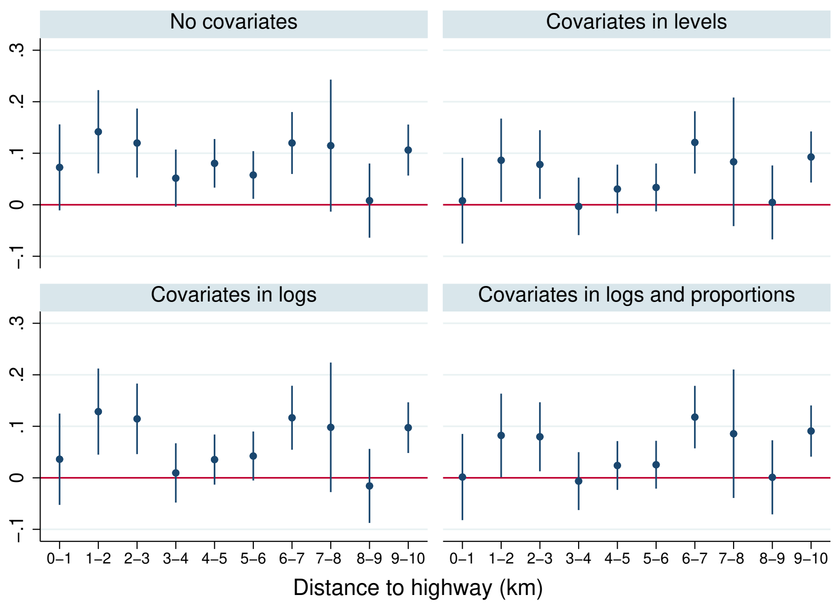


Figure 9: Dif-in-Dif with Heterogeneous Treatment Effects: *Manzanas* with Motorization Rate Above the 75^{th} percentile

Notes: Each dot represents the estimated heterogeneous effect for a different treatment category following equation (7). The indicator variable Z_i is defined as *manzanas* were the percentage of households owning a motorized vehicle is higher than the sample's 75th percentile. Ten treatment categories are considered based on distance to the highway, at 1 km intervals until the 10th km. The displayed effects are the coefficients accompanying the interaction term between each treatment category and the "High motorization" dummy. Control *manzanas* are those located further away than 10 km. Each line behind a dot represents the point estimate's 95% confidence interval calculated using clustered standar errors (at the *manzana* level).

Likewise, *manzanas* average socioeconomic condition can be used to proxy the share of households that can afford to drive a car regularly and use a payed-toll highway. For these households, the opening of *Acceso Sur* has the potential to boost connectivity with other city zones. To test for this heterogeneity, Z_i is defined as all *manzanas* in which the average household CSE decil is above the sample's 75^{th} percentile (8.95 out of 10). Again different treatment effects are found for the richer areas, compared to the rest of the population. As evidenced in Figure 10, and Table 12 in Appendix C, belonging to *manzanas* with high average CSE makes *Acceso Sur* negative effects smaller, however they remain negative until the 6^{th} km from the highway (see Appendix C).

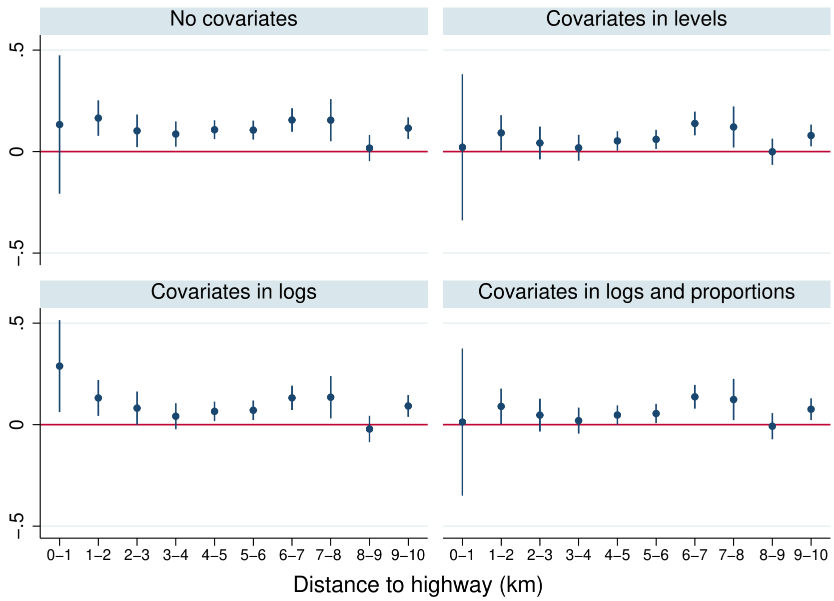


Figure 10: Dif-in-Dif with Heterogeneous Treatment Effects: *Manzanas* with average socioeconomic condition above the 75^{th} percentile

Notes: Each dot represents the estimated heterogeneous effect for a different treatment category following equation (7). The indicator variable Z_i is defined as *manzanas* were the average socioeconomic condition of the households that compose it -measured by CSE decils-, is higher than the sample's 75th percentile. Ten treatment categories are considered based on distance to the highway, at 1 km intervals until the 10th km. The displayed effects are the coefficients accompanying the interaction term between each treatment category and the "High CSE" dummy. Control *manzanas* are those located further away than 10 km. Each line behind a dot represents the point estimate's 95% confidence interval calculated using clustered standar errors (at the *manzana* level).

By combining these two findings it can be concluded that some households are benefiting from the highway, and data suggests that this are the families that posses private vehicles and enough resources to exploit the new transport infrastructure, in order to increase their levels of accessibility within the city.

Another way to empirically check if households positively appraise intra-city accessibility improvements generated by a highway, is by studying cross-sectional variation in accessibility, for households proximate to it. When a new motorway starts its operations, there can be a substantial variation on the city-wide accessibility improvements brought by this infrastructure for households located at the same distance from the route. Two sources of accessibility variation can be exploited: differences in proximity to the motorway's entry points, and the differences in the distances to the city's CBD.

Greater accessibility improvements are expected for households that are proximate to one of the highway's entry points, as they do not need to travel a considerable distance to use the new transport infrastructure. This is especially true for *Acceso Sur* with its relatively scarce entry and exit points. As a consequence, when estimating the additional effect of proximity to entry points, a positive effect should be observed, at least for the first kilometers.[37] Equation (6) is used to test this hypothesis, with $Near2_{r,i}$ defined as an additional treatment composed of ten treatment categories. Each determined by the distance to *Acceso Sur's* entry points, at 0-1 km, 1-2 km, and so on until 9-10 km. Results and linear combinations of the estimated coefficients can be seen in Tables 14 and 17, respectively, in Appendix C. Figure 11 confirms the hypothesized pattern, while proximity to the highway, in general, is a source of negative impact on house prices -that dissipates with distance-, proximity to its entry points positively impacts the real state market -also with fading effects as distance grows-. Even if these treatment effects are not statistically significant on their own, when combined, a negative and significant effect is obtained. However, of a smaller magnitude than previously seen, in a range of -5% to -10%.[38]

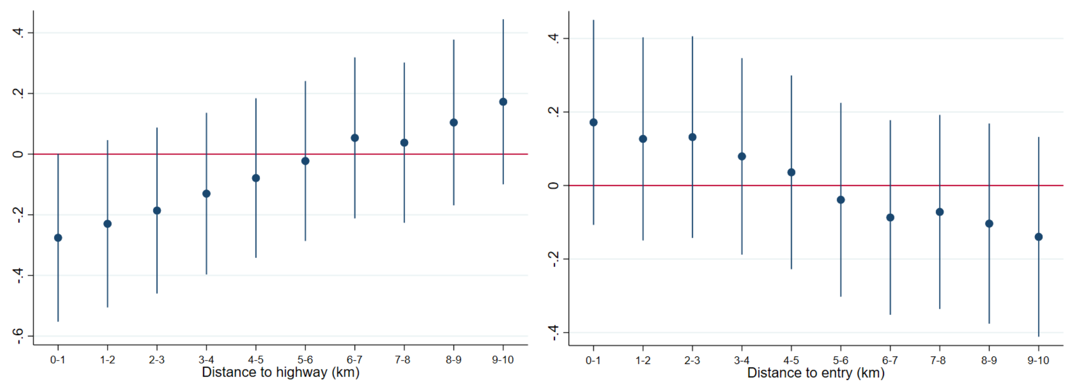


Figure 11: Difference-in-Difference Treatment Effects for Distance to *Acceso Sur* Highway and Distance to its Entry Points

Notes: Each dot represents the estimated effect for a different treatment category following equation (6). On the graphic at the left $Near_{r,i}$ treatment categories' effects are displayed (which use distance to *Acceso Sur* in their definition). The graphic at the right displays $Near2_{r,i}$ estimates that use the minimun distance to one of the motorway's entry points to define the treatment categories. Both graphic's contains ten treatment categories, each defined by an specific distance range from *Acceso Sur* (underground portion), inside which all *manzanas* are categorized as treated. The control groups are all manznanas located farther away than 10 km from the highway (underground portion). No covariates are included. Each line behind a dot represents the point estimate's 95% confidence interval.

On the other hand, as *Acceso Sur* runs from the city's ring road to its periphery, properties proximate to it vary significantly on their distance to the CBD. For more isolated zones, the opening of this highway -that connects them with Santiago's central areas- has a deeper impact in terms of city-level accessibility. Therefore, the treatment effect for these zones is expected to be positive, or at least less negative than it is for areas that are already well (or better) connected with the CBD. Equation (7) is used to explore this point, with the dummy variable Z_i taking the value of one for *manzanas* that locate farther away than 10.80 km from Baquedano's CBD, which is the median distance from it in the sample. The expected heterogeneous effect is found, as seen in Figure 12 and Table 13 in Appendix C. Linear combinations of the estimated coefficients can be seen in 16, in the same Appendix. *Manzanas* farther away from the CBD than the median, do not

[37]As distance from the highway increases; the distance from the entry points should become less relevant. Mainly because the highway does not bring a substantial gain in accessibility for properties located farther away from it.

[38]In a linear combination that adds the coefficients of treatment categories defined by the same distance to both transportation elements (route and entry points), for example, 3-4 km from both.

experience a significant decrease in their property prices, -in contrast to *manzanas* located closer than the median-. This occurs mainly for treatment categories between 2 km and 6 km from the motorway. *Manzanas* located at 2 km or less from the highway, and far from the CBD, still suffer from negative appraisals after the highway opening; nonetheless, the effect is less pronounced than for those *manzanas* closer to the CBD. This implies that the accessibility benefits are not that relevant for properties located too close, or too far away from the new transport infrastructure, but can be substantial and compensate other negative externalities for intermediate distances from it.

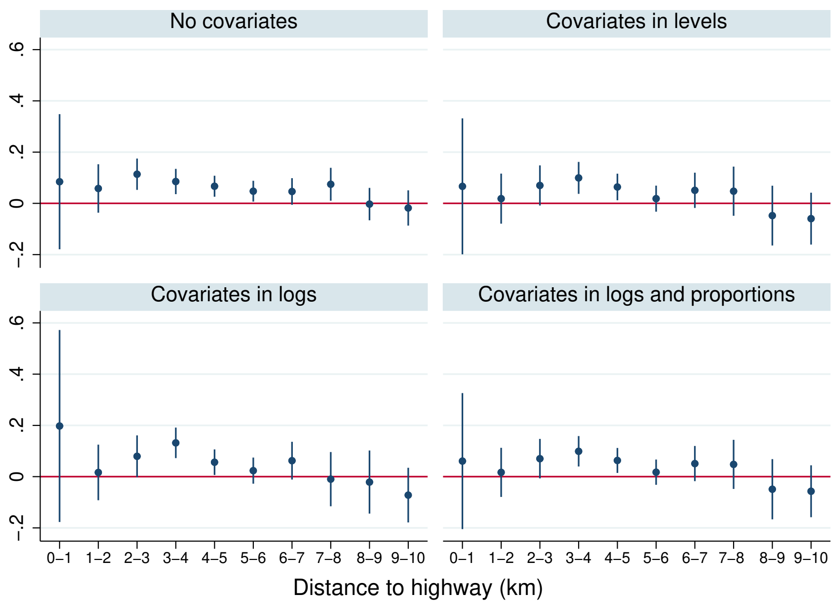


Figure 12: Dif-in-Dif with Heterogeneous Treatment Effects: *Manzanas* located farther away from the CBD than the median

Notes: Each dot represents the estimated heterogeneous effect for a different treatment category following equation (7). The indicator variable Z_i is defined as *manzanas* located farther away from the CBD than the median of the sample. Ten treatment categories are considered based on the distance to the highway, at 1 km intervals until the 10th km. The displayed effects are the coefficients accompanying the interaction term between each treatment category and the "Farther from CBD" dummy. Baquedano Subway station is considered the CBD, and the median distance to it is of 10.80 km. Estimates using Tobalaba as CBD are remarkably similar, while no significant heterogeneous effects were found for when using La Moneda as CBD. Control *manzanas* are those located further away than 10 km. Each line behind a dot represents the point estimate's 95% confidence interval calculated using clustered standard errors (at the *manzana* level).

Heterogeneities in treatment effects based on distance to entry points and distance to CBD support the hypothesis that households positively value intra-city accessibility gains, but these positive effects are not strong enough in the case of *Acceso Sur*. The net negative appraisal that is found can be explained because of the limited number of families benefited, relative to the total affected population, and or as a result of other adverse effects dominating over the positive valuation of city-wide accessibility gains in this particular housing market.

To this point, it is clear that few households proximate to the studied highway had the means to exploit the accessibility improvements brought by this infrastructure, and for those that did have the resources, the positive accessibility effects are not that strong to compensate for other negative impacts. Only some properties -those who experimented a deep change in their connectivity levels with the rest of the city- exhibit a non-negative effect. This where the households located in the most peripheral zones near the motorway. However, it can also be the case that a relevant portion of the proximate households experienced a deterioration in their intra-city accessibility levels. The motorway can be congesting the arterial streets nearby, reducing the speed and frequency of public transport, and it can also increase the speed at which private vehicles circulate, making active transportation modes more dangerous and unattractive in the vicinity of the highway. For example, pedestrians may be forced to use longer routes in order to avoid risky crossing points. Moreover, the implementation of Transantiago in 2007 had already adversely affected the public transport coverage of this area (see Appendix H), but the opening of the highway further damaged the service quality for its residents as discussed in Landon (2013).[39] Through exploratory and descriptive techniques Sagaris and Landon (2017); Carrasco (2015); Landon (2013) consistently find increases in transportation times for residents in the areas where the new highway passes, combined with difficulties to access public transport. This evidence supports the idea that the opening of the highway brought an increase in the vehicle flow around it, and worsened the city-level accessibility for its residents, which do not frequently use cars as their transportation mode. This could explain part of the negative appraisal given to *Acceso Sur*.

Furthermore, it is logical to think that if people in a highway's proximate areas predominantly use the public transport, then the opening of the highway would only be perceived as a gain on accessibility and be positively valued by them, as long as it enhances the public transport.[40] In 2008 four public bus services experienced modifications in their routes and started using Acceso Sur's side path, which was announced as a measure that would considerably reduce the users' transportation times. The available data set has only one year to test for the potential positive effect in terms of appraisals, but at least for this one year, the adverse effects found for the highway's operations were somewhat attenuated (see Figure 3). This suggestive evidence reveals the importance of how a transportation infrastructure interacts with other transportation services, as citizens appraisals will finally derive from the combination of both. It also highlights the differential effects to be expected, depending on transportation modes that predominated in the treated area. In the case of *Acceso Sur*, a sizeable investment was made for cars, but public transport was left aside for the majority of the study period.

6.3.3 Negative Enviromental Externalities

The third potential explanation for the adverse appraisal that citizens are giving to *Acceso Sur* opening, are negative environmental externalities. The constant flow of vehicles through this type of infrastructure generates air pollution, sound pollution, and aesthetically damages the surrounding areas. As several authors have documented, there is a positive relationship between highways and these externalities, and consequently, exposure to them negatively affects real estate prices (Nelson, 1982; Wilhelmsson, 2000; Theebe, 2004; Kim et al., 2007; Levkovich et al., 2016). However, these effects are generally limited to a closed area around the highway, for example, no more than 1 km away from it, and accessibility gains are said to exceed the negative environmental externalities past a certain threshold distance. In our study context, the design of the highway and how it is operated may be causing its functioning to generate higher levels of pollution, that expand for a wider area. This, combined with ambiguous accessibility gains, may explain the stronger intensity of the negative effect in the first kilometers from the highway (rather than just the first 350 m, as seen in the literature). In particular, for the *Acceso Sur* project, no environmental impact evaluation was conducted before the concession was signed (Landon, 2013). As a consequence, structural

[39] After conducting 70 interviews on a random sample of people living near *Acceso Sur*, the author finds that citizens perceived an increased difficulty to access the bus stops and a reduced frequency of the buses.

[40] Even if it was part of the mitigation package that the MOP promised to deliver, public transport in the area was only improved on 2018.

elements of the highway were not designed to comply with environmental standards. Only after the upsurge of a social movement that denounced the environmental risks of the project, and which protested against its construction, these aspects were taken into consideration.[41] However, as the concession contract had already been signed, responsibility issues arose between the MOP and the concessionaire, over who should develop and finance the mitigation measures. Furthermore, ar argued by Sagaris and Landon (2017), the process mainly comprised partial mitigation measures, as the structural problems were left mostly untouched to respect the previously signed contract with the concessionaire.

The case of atmospheric pollution clearly illustrates how these regulatory and governance problems intensified the negative environmental externalities derived from *Acceso Sur*. The highway's projected air pollution impacts -used to design the mitigation measures- were estimated using data for the years 2000 and 2005, despite the highway initiating its services in the year 2011. In this way, the Environmental Qualification Resolution (RCA, its acronym in Spanish) of 2005 resolved to have no mitigation measures taken to address atmospheric pollution, as the estimated atmospheric pollution levels were below the legal threshold. The problem is that the number of cars in Santiago experienced one of the steepest increases from 2004 until today, and consequently, the projected pollution levels were severely underestimated when deciding not to develop mitigation measures (Carrasco, 2015). Data from an environmental station near the highway reveals that after the opening of *Acceso Sur*, there was an increase in two types of air pollutants that are associated with motorized vehicle flow: Particulate Matter 2.5 (MP 2.5) and Particulate Matter 10 (MP 10) (SINCA, 2019). Figures 34 and 33, in Appendix J, depict this pattern. Epidemiological evidence supports a causal relationship between these two atmospheric components and premature deaths, and several morbidity problems, as a consequence of both, acute exposure, and prolonged exposure (see Vargas (2011) for a recent literature review). The station used to measure these elements is located at 1.5 km from the highway; hence, the worsened atmospheric conditions (potentially due to the highway) extended for at least a 1.5 km range. Consequently, the stronger negative percentage change in prices for the first 1 or 2 km from *Acceso Sur*, may be in part due to people's negative appraisement of the deteriorated atmospheric conditions and its associated health risks. However, due to a limitation on the number of environmental stations with which to contrast the particular results for the *Acceso Sur* area, it can not be ruled out that this increase in PM 2.5 and PM 10 responds to some other city-wide trend, and not particularly to the opening of *Acceso Sur*.

On the other hand, acoustic contamination was detected from the beginning as a critical future externality once *Acceso Sur* started its operations, according to RCA 2005. Projected acoustic levels exceeded the legal limits for the immediate vicinity of the highway (300 m from it). Sound barriers had to be designed to protect the nearby houses, which in the more extreme case were located 60 cm away from the motorway infrastructure. However, no extensive follow-up of these mitigation measures was taken, and residents of the area claim that these actions did not solve the intense acoustic pollution (Carrasco, 2015). In this way, and as depicted in the acoustic map of Figure 35 in Appendix J, the high levels of noise produced by *Acceso Sur* are probably part of the reasons why properties selling prices are lower at least in the first 2 km from the highway.

Furthermore, other types of negative externalities may be playing a role in the negative appraisement of properties proximate to a highway, as documented by Mayeres et al. (1996). This includes higher accident rates, more congestion in the near routes, and higher rates of crime, among others. All these elements are mentioned by residents of the treated area, interviewed by Carrasco (2015). Respondents generally perceive a deterioration in these aspects. This descriptive evidence

[41] In 1999 and 2002 citizens asked for an Environmental Qualification Resolution, this resolution was done, but was adjusted for the last time on 2005, five years before the motorway started operating (Landon, 2013).

suggests that these other adverse effects are also playing a role in the appraisement process of the housing market.

Each of these types of environmental externalities could be measured, and its evolution compared with that of other similar city zones, before and after the opening of *Acceso Sur*. Nevertheless, there are data limitations to conduct this empirical analysis. As most of these negative externalities positively correlate with the vehicle flow, a simple way to check this mechanism is to contrast the highway's vehicle flow evolution over time, and the proximate properties price fluctuations in the same period. From paid tolls registries, it can be observed that for the year 2015, there was a sharp increase in the average daily number of motorized vehicles circulating through *Acceso Sur* (see Figures 36 and 37, in Appendix J). This can explain that the steepest percentage changes observed in the study horizon occurred precisely for 2015 (as Figure 2 and Table **??** systematically show for different treatment categories).

6.3.4 Supply and Demand Forces

A final mechanism considered are demand and supply dynamics. Real estate price changes may not only reflect citizen appraisal of the amenities derived from a property and its location but can also be affected by supply and demand forces. Classical economic theory would explain a decrease in prices as a result of a decrease in the demand and/or an increase in the supply. This analysis better predicts the behavior of homogeneous goods in perfectly competitive markets. To the extent that residential dwells can be considered homogeneous goods and the real estate market behaves like a perfectly competitive one, then the potential mechanisms of supply and demand forces could be accounted for in the observed pattern of property prices near *Acceso Sur*. Evidence on the distribution of this market forces through the city is contrary to the effective change in prices observed after the motorway's opening. As Figure 25 depicts, the areas proximate to *Acceso Sur* concentrate high levels of housing deficit, which should impose upward forces in the property prices.[42]. On the other hand, real state developments tend to focus on other zones of the city, as can also be seen in Figure 25. Therefore, no excess supply is forcing prices to go down near the highway. Complementary to this evidence is the fact that in the same year in which the highway started its operations, a negative effect had already been materialized. The sticky nature of the housing supply, which is not able to expand considerably in the short run, rejects the hypothesis that an excess of dwells available for sale played a role in the systematic decrease of property prices around *Acceso Sur*. Consequently, the observed appraisement patterns are not congruent with demand data, and can not be explained by supply dynamics either.

7 Discussion

7.1 Additional Robustness Checks

To see how sensible the estimated results are, with respect to the control definition, we regress the equations in different sub-samples, including all *manzanas* outside from *Vespucio*'s ring road, the south and south-east macro zones of Santiago, and the group of *comunas* exposed to *Acceso Sur*. Moreover, a Kernel Propensity Score Matching is performed at the *manzana* level. Delimiting the control group to areas near the treated one, and using matching techniques, permit the selection of

[42]It is true that this zone also concentrates low-income families, that can not afford to buy a house. However, considering the government's housing policy, it can be expected that housing demand in this area -and consequently property prices-, grows at least more than areas with equally vulnerable households, but with a lower housing deficit.

a counterfactual that is more similar to the treated one on observable characteristics, and hence, it is more plausible that they also share comparable unobservables. In this manner, the counterfactual price evolution of the treated would be more comparable to that of the controls.

We expect control *manzanas* located proximate to the treated ones to be also similar in terms of structural, neighborhood, and of course, locational characteristics that affect price dynamics and are not observed. In general, assuming that neighborhood characteristics vary continuously through space, we prefer control zones that are near the treated ones, but which have not experienced a decrease in its distance to the highway network. However, there is a trade-off in limiting the sample's extension from the new infrastructure, as it considerably reduces the number of available observations. Moreover, in our study context, it can be seen that Santiago's full sample exhibits pre-treatment parallel trends that plausibly support the identification assumption. Therefore, using the city's full sample has the advantage of achieving a more balanced panel (with enough observations for the treated and controls areas, for periods before and after), and better statistical power to detect treatment effects, without having to sacrifice the counterfactual's comparability to the treatment group. For these reasons, the complete sample is employed in this work's principal sections. Nonetheless, by restricting the sample around the highway, some endogeneity concerns can be resolved. Possible unobservables that were not captured by the parallel trends check can be accounted for when selecting a near subsample, as the control group will have similar levels of them than the treated. Likewise, matching reweights observations in order to give more relevance to control observations that are more comparable to treated ones.

Table 6 shows that in the "Outside *Vespucio*" and "South Macrozone" sub-samples, the effects found for the highway's opening are notably similar to those with the whole sample, this is a negative percentage change can be observed over prices after 2011 and extends to 2018. Confidence intervals are much more extensive, especially if controls are included, but the point estimates remain negative and around the 5% to 10% range, and reduce to around 5% when using some of the specifications with covariates. For the "affected *comunas* subsample" the estimates follow a messier pattern, with many of the years and treatment categories indicating a null effect, and alternate positive and negative effects for the others.

The matching estimates also confirm our results, when using a unique treatment area composed of *manzanas* at 0-6 km from the highway, a -30.1% percentage change is observed for the post-period. If the sample is reduced to include only the observations in the common support, the estimate's magnitude reduces to a more reasonable -7.2% percentage change, in line with our main results.

A further robustness check is to include a lagged dependent variable into equation (5). By controlling for the baseline year property prices, the treatment effects interpretation changes. Now the estimates capture the percentage change in property prices, conditional on 2007 prices. In this manner, the anticipatory and construction effects of the highway would be included in the lagged dependent variable coefficient, and the treatment categories' effects would only include the marginal percentage change. We expect these estimates to be smaller in magnitude since part of the highway effects have already been incorporated in the 2007 prices. The expected negative impact of the highway's construction (as documented by Boarnet and Chalermpong (2001); Vadali and Sohn (2001); Concas (2013)), would imply that to find negative effects after the opening, property prices should decrease even further than in the construction period (relative to the rest of the city's properties). Estimates confirm this additional negative effect after the opening of *Acceso Sur*.

Table 6: Further Robustness Checks

	Basic Model		Lagged lpm2		Outside *Vespucio*		Affected Macrozones		Affected *Comunas*		Matching	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
0-1km	-0.131***	-0.093***	-0.183***	-0.126***	-0.040***	0.010	-0.146***	-0.131***	-0.051**	0.007		
	(0.012)	(0.017)	(0.021)	(0.020)	(0.013)	(0.016)	(0.033)	(0.040)	(0.026)	(0.051)		
1-2km	-0.103***	-0.067***	-0.143***	-0.161***	-0.079***	-0.036**	-0.118***	-0.094**	-0.022	0.044		
	(0.011)	(0.016)	(0.016)	(0.020)	(0.012)	(0.015)	(0.032)	(0.041)	(0.025)	(0.053)		
2-3km	-0.063***	-0.073***	-0.091***	-0.165***	-0.085***	-0.021	-0.079**	-0.088**	0.019	0.059		
	(0.013)	(0.018)	(0.016)	(0.022)	(0.015)	(0.019)	(0.033)	(0.042)	(0.027)	(0.059)		
3-4km	-0.061***	-0.063***	-0.098***	-0.130***	-0.071***	-0.020	-0.077**	-0.085**	0.011	0.052		
	(0.011)	(0.015)	(0.013)	(0.017)	(0.013)	(0.016)	(0.032)	(0.040)	(0.025)	(0.055)		
4-5km	-0.062***	-0.049***	-0.092***	-0.128***	-0.059***	-0.014	-0.078**	-0.085**	0.003	0.033		
	(0.009)	(0.013)	(0.011)	(0.015)	(0.013)	(0.016)	(0.032)	(0.038)	(0.025)	(0.052)		
5-6km	-0.070***	-0.063***	-0.103***	-0.130***	-0.079***	-0.008	-0.086***	-0.113***	-0.012	-0.018		
	(0.009)	(0.012)	(0.012)	(0.015)	(0.014)	(0.017)	(0.032)	(0.038)	(0.025)	(0.052)		
6-7km	-0.033***	-0.028*	-0.057***	-0.093***	-0.108***	-0.022	-0.044	-0.088**	0.012	0.056		
	(0.013)	(0.016)	(0.018)	(0.022)	(0.017)	(0.022)	(0.033)	(0.040)	(0.034)	(0.043)		
7-8 km	-0.039***	-0.013	-0.091***	-0.093***	-0.099***	-0.024	-0.073**	-0.111**				
	(0.014)	(0.019)	(0.020)	(0.026)	(0.015)	(0.021)	(0.036)	(0.045)				
8-9km	-0.000	-0.014	-0.010	-0.046***	-0.072***	-0.009	-0.029	-0.090*				
	(0.013)	(0.018)	(0.014)	(0.017)	(0.017)	(0.022)	(0.038)	(0.050)				
9-10km	0.034***	-0.004	0.019	-0.017	-0.080***	-0.036*	-0.005	-0.071				
	(0.012)	(0.014)	(0.013)	(0.014)	(0.015)	(0.019)	(0.042)	(0.052)				
0-6 km											-0.301***	-0.072**
											0.026	0.029
Covariates	No	Yes	Yes	Yes	No	Yes	No	Yes	No	Yes	No	No
N observations	175,474	127,458	81,598	60,889	99,447	68,829	68,154	48,732	45,129	30,248	93,599	5,336
N *manzanas*	41,216	30,590	12,668	9,636	23,051	16,290	17,728	13,000	11,474	7,898		

Notes: This table provides the ATT for *manzanas* located proximate to *Acceso Sur* highway after its opening (on 2010), according to equation (5). Difference-in-difference estimates are displayed. For columns 1-10 ten treatment categories are considered based on distance to the highway, at 1 km intervals until the 10th km. Columns 11-12 use a unique treatment definition for all *manzanas* within a 6 km radius from *Acceso Sur*. Control *manzanas* are those located farther away than 10 km, except for columns 9-10, in which the control group is defined from a distance of 7 km onwards (as for this subsample no *manzanas* were located at 10 km or more from Acceso Sur). *Manzana* and year fixed effects are included in all specifications. Unit of observation is manzana-year. Pre-treatment years included in the regression are 2007, 2008, 2009 and 2010, while post-treatment years cover from 2011 to 2018. Covariates logs and proportions are included in the even columns until column 10. Clustered standard errors in parenthesis (clustering at the *manzana* level).* p<0.10, ** p<0.05, *** p<0.01.

8 Conclusion

Sizeable investments are devoted to the construction of urban highways. Either in the form of subsidies given to concessionaires or when directly developed by public entities, the tax-payers funds used to rise and maintain this type of infrastructure are considerable. When policy-makers debate on how to generate growth in the cities in a sustainable manner -this is, "[making] ...cities and human settlements inclusive, safe, resilient and sustainable" according to the United Nations' Sustainable Development Goals- a fundamental input to their decisions is how transportation infrastructure impacts the city. Urban highways, subway lines, and public transportation systems are essential tools with which governments can influence a city's configuration. They directly affect the extent and conditions under which different groups of people and services are connected. Moreover, in the long run, they influence the distribution of individuals and opportunities across the city, either segregating or connecting diverse people, and either concentrating services or making them available for a majority. Therefore, an urgent and unmet need to better understand the implications of urban highways arises, for the major investment they represent and their vast potential to impact the city's dynamics.

A possible path to explore the effects of particular transport infrastructure is to rely on a revealed preference approach and employ a hedonic price model to measure how citizens value its proximity once it starts functioning. The recent construction of a 47 km -completely new- urban highway in the city of Santiago, together with the availability of a detailed data set of property transactions extending for several years before and after its opening, posses an ideal scenario to perform a quasi-experimental study design on this subject. This thesis exploits those opportunities and implements a difference-in-difference estimation, were the price evolution of properties -aggregated at the *manzana*-year level- is compared for areas proximate to the new highway and the rest of the city. Our empirical approach allows a non-linear relationship between proximity to the motorway and property prices, and explores in a non-parametric manner the extent of the impact. Furthermore, temporal dynamics are analyzed to identify the short to medium-term price dynamics detonated by this new transport infrastructure's opening. This empirical strategy, combined with the "inconsequentially treated approach", allows a causal interpretation of our results.

For the years previous to the opening of *Acceso Sur*, even though price levels differed significantly between the treated and control zone properties, their trends were statistically comparable. After the opening, dwells in areas proximate to the new motorway experienced a significant decrease in their average price per square meter, compared to the price evolution seen in the rest of the city. Between 2010 and each of the post-treatment years, the *manzanas* located within a distance of 6 km from the highway experienced a negative percentage change that concentrated around 5-10%. These findings are robust to allowing for differential trends according to baseline covariates, using of different specifications, and including a variety of heterogeneities. The effects are concentrated on the first two kilometers from the motorway, where estimates are larger in magnitude. Estimates remain negative and relevant even until the eight-kilometer from the highway, although the magnitude of the effect gradually diminishes with distance. These results imply that *Acceso Sur's* opening brought a negative net impact for the citizens living in a radius of up to 8 km around it, compared to what the rest of the capital's inhabitants experienced. Evidence captured on real estate prices indicates that residents of Santiago negatively appraise proximity to this highway. This effect is statistically significant and remains relatively stable for the eight years following the highway's opening.

The accessibility-improvement argument employed when promoting city development plans that rely heavily on the construction and use of urban highways should at least be questioned in light of the present results. Several potential mechanisms and combinations of them could explain the observed patterns, but the intuitive positive relation between roads and accessibility is challenged by the data. The new transport infrastructure may be reducing neighborhood-level accessibility, there may not be real gains in city-level accessibility for all the affected populations (some groups may even be experiencing losses), or accessibility improvements are being exceeded by negative environmental externalities. Further empirical analysis of our data and complementary descriptive evidence from other sources are consistent with these three mechanisms, as explanations of the negative net appraisals that citizens have given to *Acceso Sur*.

More research is needed to identify the combination of factors that create the conditions for a transport investment of this magnitude to be negatively appraised in such a vast extension of the city and for that many years after its opening. Moreover, it is also critical to study the distributional effects brought by urban highways. In the studied case, the area suffering because of the motorway's proximity happened to concentrate a high proportion of the city's most vulnerable households, and the decision to place the highway in that area only exacerbated the existing spatial inequalities. The negative relationship found -that persists through several kilometers and years, and has the potential of exacerbating inequalities through the city- highlights the critical need to study the absolute and relative impacts of different transportation infrastructures, and just as importantly, the urge that policymakers and city planners base their investments and decisions on evidence.

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Appendices

A Checking Parallel Trends

Table 7: Checking Pre-Treatment Parallel Trends: Diff-in-Diff with different treatment definitions

	2007 (1)	2008 (2)	2009 (3)
Year x 0-1 km from highway	-0.024	-0.079***	0.003
	(0.040)	(0.025)	(0.026)
Year x 0-2 km from highway	0.028	-0.054***	0.017
	(0.023)	(0.018)	(0.018)
Year x 0-3 km from highway	-0.027	-0.044***	0.004
	(0.018)	(0.015)	(0.016)
Year x 0-4 km from highway	-0.012	-0.022*	0.003
	(0.015)	(0.013)	(0.014)
Year x 0-5 km from highway	-0.009	-0.016	0.003
	(0.012)	(0.011)	(0.012)
Year x 0-6 km from highway	-0.012	-0.016	0.004
	(0.011)	(0.010)	(0.011)
Year x 0-7 km from highway	-0.017	-0.015	0.003
	(0.011)	(0.010)	(0.011)
Year x 0-8 km from highway	-0.017	-0.011	0.002
	(0.010)	(0.009)	(0.010)
Year x 0-9 km from highway	-0.011	-0.010	0.000
	(0.010)	(0.009)	(0.010)
Year x 0-10 km from highway	-0.014	-0.006	0.001
	(0.010)	(0.009)	(0.010)

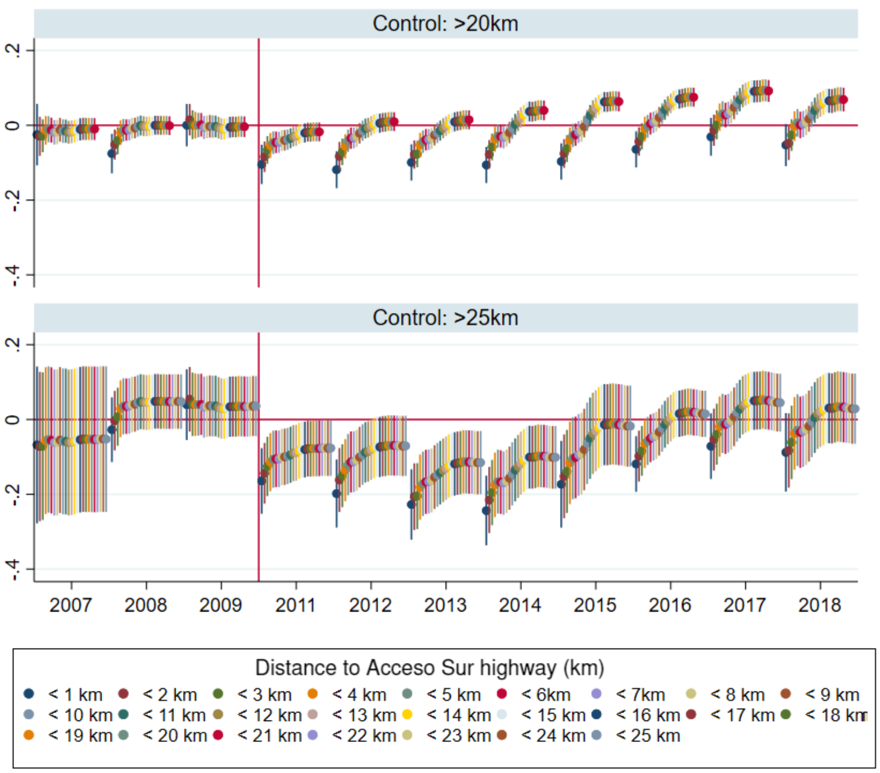
Notes: This table provides the ATT for *manzanas* located proximate to *Acceso Sur* highway before its opening (on 2010), according to equation (3). Ten alternative treatment definitions are considered based on a threshold distance to the highway, starting from 1 km until 10 km. Control *manzanas* are those located further away than 10 km. Each line contains the estimated coefficients obtained from running an Event Study regression with a specific treatment definition. Column 1 represents the year 2007 interacted with each of the treatment definitions, while columns 2 and 3 do the same for years 2008 and 2009, respectively. The year before the opening date is used as base year (2010). *Manzana* and year fixed effects are included, but no covariates are used. Unit of observation is manzana-year. Clustered standard errors in parenthesis (clustering at the *manzana* level).* $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table 8: Checking Pre-Treatment Parallel Trends: Event Study with five treatment categories

	(1)	(2)	(3)	(4)
Within 0-2 km x 2007	-0.028	-0.048	-0.042	-0.100**
	(0.023)	(0.040)	(0.032)	(0.049)
Within 0-2 km x 2008	-0.054***	-0.017	-0.035	-0.078
	(0.018)	(0.033)	(0.029)	(0.057)
Within 0-2 km x 2009	0.017	-0.040	-0.022	-0.100
	(0.018)	(0.037)	(0.031)	(0.070)
Within 2-4 km x 2007	0.006	-0.026	-0.009	-0.024
	(0.018)	(0.032)	(0.030)	(0.046)
Within 2-4 km x 2008	0.008	0.046	0.026	-0.052
	(0.018)	(0.031)	(0.029)	(0.054)
Within 2-4 km x 2009	-0.013	-0.055*	-0.049	-0.114**
	(0.019)	(0.033)	(0.031)	(0.058)
Within 4-6 km x 2007	-0.010	-0.018	-0.007	-0.023
	(0.014)	(0.024)	(0.021)	(0.033)
Within 4-6 km x 2008	-0.007	0.033	0.015	-0.002
	(0.013)	(0.023)	(0.020)	(0.038)
Within 4-6 km x 2009	0.005	-0.015	-0.010	-0.040
	(0.015)	(0.025)	(0.023)	(0.044)
Within 6-8 km x 2007	-0.045**	-0.066**	-0.041	0.005
	(0.021)	(0.027)	(0.028)	(0.035)
Within 6-8 km x 2008	0.011	0.007	0.004	-0.013
	(0.020)	(0.027)	(0.028)	(0.040)
Within 6-8 km x 2009	-0.024	-0.070**	-0.057**	-0.093**
	(0.021)	(0.028)	(0.029)	(0.041)
Within 8-10 km x 2007	0.009	0.013	0.018	0.003
	(0.018)	(0.022)	(0.022)	(0.023)
Within 8-10 km x 2008	0.019	0.024	0.044**	-0.013
	(0.017)	(0.022)	(0.022)	(0.026)
Within 8-10 km x 2009	0.009	0.017	0.020	-0.020
	(0.020)	(0.025)	(0.025)	(0.028)
Include covariates	No	Level	Log	Lasso
N of observations	175,474	127,458	111,368	56,808
N of manzanas	41,216	30,590	24,544	8,646
N of high-dimension controls				533

Notes: This table provides the ATT for *manzanas* located proximate to *Acceso Sur* highway before its opening (on 2010), according to equation (4). Five treatment categories are considered depending on their distance to the highway: 0-2 km, 2-4 km, 4-6 km, 6-8 km and 8-10 km. Control *manzanas* are those located further away than 10 km.The year before the opening date is used as base year (2010). In each column the same Event Study regression is ran, but covariates inclusion and their form varies among them. Covariates in column 4 where selected using Lasso machine learning techniques. *Manzana* and year fixed effects are included in all specifications. Unit of observation is manzana-year. Clustered standard errors in parenthesis (clustering at the *manzana* level).* p<0.10, ** p<0.05, *** p<0.01.

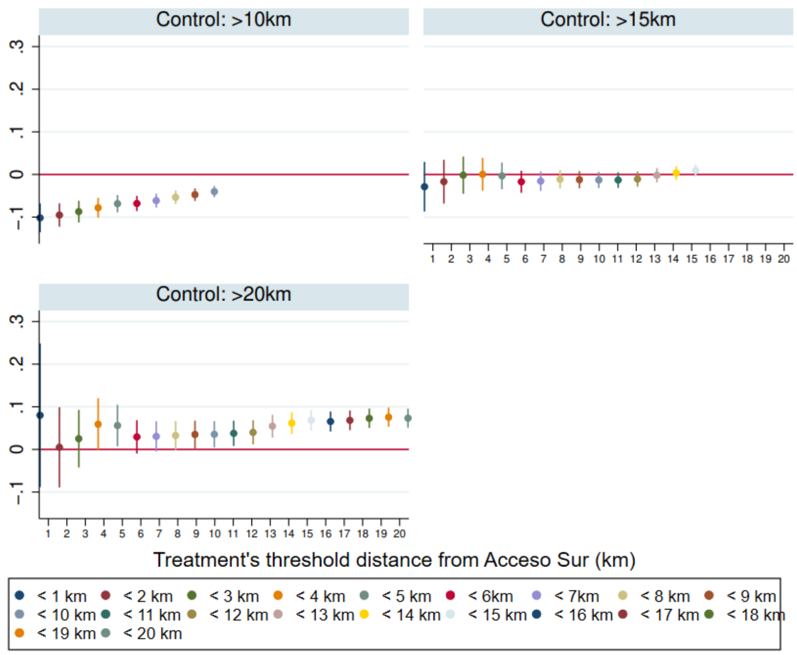
Figure 13: Event Study for Different Treatment Definitions and Two Alternative Control Groups: "10 km Onward" and "15 km Onward"



Notes: Each dot represents the estimated treatment effect for a different $Near_i$ definition, obtained from running equation (3). This specification contains only one unique treatment, which is determined by the threshold distance to *Acceso Sur* inside which all *manzanas* are categorized as treated. The control groups are all manznanas located farther away than 20 km from the highway (in the top sub-graph), and farther away tha 25 km (at the bottom sub-graph). No covariates included. Each line behind a dot represents the point estimate's 95% confidence interval.

B Treatment Effects

Figure 14: Difference-in-Difference Treatment Effects for different treatment and control definitions (with covariates)



Notes: Each dot represents the estimated treatment effect for a different $Near_i$ definition, using equation (2). This specification contains only one unique treatment, which is determined by the threshold distance to *Acceso Sur* inside which all *manzanas* are categorized as treated. The control groups are all manznanas located farther away than 10 km from the highway in the first graph (up and to the left), the other graphs use 15 km and 20 km as threshold distances for the control group. The "25 km onward" control group is not included as confidence intervals get too wide, and no clear interpretation can be taken from it. Covariates included are in levels when they are proportions, and in logarithmic form if they are not proportions. Each line behind a dot represents the point estimate's 95% confidence interval.

Table 9: Event Study with Five Treatment Categories

	(1)	(2)	(3)	(4)
Within 0-2km x 2011	-0.085***	-0.102***	-0.096***	-0.135**
	(0.018)	(0.034)	(0.030)	(0.057)
Within 0-2km x 2012	-0.109***	-0.092***	-0.089***	-0.157***
	(0.016)	(0.032)	(0.028)	(0.058)
Within 0-2km x 2013	-0.117***	-0.075**	-0.090***	-0.143**
	(0.016)	(0.033)	(0.028)	(0.058)
Within 0-2km x 2014	-0.149***	-0.117***	-0.134***	-0.124**
	(0.016)	(0.033)	(0.028)	(0.061)
Within 0-2km x 2015	-0.170***	-0.103***	-0.123***	-0.147**
	(0.016)	(0.033)	(0.029)	(0.066)
Within 0-2km x 2016	-0.142***	-0.147***	-0.113***	-0.148**
	(0.016)	(0.034)	(0.029)	(0.066)
Within 0-2km x 2017	-0.117***	-0.132***	-0.146***	-0.234***
	(0.017)	(0.036)	(0.030)	(0.075)
Within 0-2km x 2018	-0.138***	-0.126***	-0.137***	-0.206***
	(0.019)	(0.039)	(0.033)	(0.070)
Within 2-4km x 2011	-0.026	-0.040	-0.063**	-0.119**
	(0.018)	(0.031)	(0.029)	(0.052)
Within 2-4km x 2012	-0.058***	-0.073**	-0.100***	-0.144***
	(0.018)	(0.031)	(0.029)	(0.053)
Within 2-4km x 2013	-0.068***	-0.068**	-0.111***	-0.105*
	(0.019)	(0.032)	(0.030)	(0.055)
Within 2-4km x 2014	-0.067***	-0.068**	-0.110***	-0.087
	(0.018)	(0.031)	(0.030)	(0.056)
Within 2-4km x 2015	-0.098***	-0.072**	-0.124***	-0.137**
	(0.019)	(0.031)	(0.030)	(0.055)
Within 2-4km x 2016	-0.075***	-0.120***	-0.129***	-0.119**
	(0.019)	(0.033)	(0.031)	(0.060)
Within 2-4km x 2017	-0.047**	-0.092***	-0.128***	-0.066
	(0.020)	(0.035)	(0.032)	(0.062)
Within 2-4km x 2018	-0.042*	-0.059	-0.093***	-0.180***
	(0.022)	(0.038)	(0.036)	(0.065)
Within 4-6km x 2011	-0.034***	-0.026	-0.043**	-0.081**
	(0.013)	(0.023)	(0.020)	(0.038)
Within 4-6km x 2012	-0.031**	-0.028	-0.047**	-0.062*
	(0.013)	(0.022)	(0.020)	(0.037)
Within 4-6km x 2013	-0.059***	-0.038*	-0.075***	-0.089**
	(0.013)	(0.023)	(0.021)	(0.039)
Within 4-6km x 2014	-0.093***	-0.091***	-0.117***	-0.148***
	(0.013)	(0.023)	(0.021)	(0.040)
Within 4-6km x 2015	-0.101***	-0.064***	-0.105***	-0.118***
	(0.014)	(0.023)	(0.021)	(0.039)
Within 4-6km x 2016	-0.075***	-0.076***	-0.079***	-0.083**
	(0.015)	(0.025)	(0.023)	(0.042)
Within 4-6km x 2017	-0.069***	-0.084***	-0.098***	-0.074
	(0.015)	(0.026)	(0.024)	(0.047)
Within 4-6km x 2018	-0.086***	-0.088***	-0.107***	-0.140***

Continued on next page

Table 9 continued

	(1)	(2)	(3)	(4)
	(0.016)	(0.028)	(0.026)	(0.047)
Within 6-8km x 2011	-0.019	-0.026	-0.038	-0.079**
	(0.020)	(0.026)	(0.027)	(0.039)
Within 6-8km x 2012	-0.036*	-0.039	-0.053**	-0.059
	(0.018)	(0.025)	(0.026)	(0.041)
Within 6-8km x 2013	-0.057***	-0.045*	-0.060**	-0.061
	(0.020)	(0.026)	(0.027)	(0.044)
Within 6-8km x 2014	-0.090***	-0.093***	-0.110***	-0.083*
	(0.021)	(0.028)	(0.029)	(0.045)
Within 6-8km x 2015	-0.063***	-0.052*	-0.073***	-0.085*
	(0.020)	(0.027)	(0.028)	(0.044)
Within 6-8km x 2016	-0.049**	-0.062**	-0.064**	-0.071
	(0.021)	(0.027)	(0.029)	(0.044)
Within 6-8km x 2017	-0.016	-0.054*	-0.069**	-0.087*
	(0.021)	(0.028)	(0.030)	(0.052)
Within 6-8km x 2018	-0.048*	-0.078**	-0.075**	-0.125**
	(0.025)	(0.033)	(0.035)	(0.056)
Within 8-10km x 2011	-0.024	-0.028	-0.011	-0.021
	(0.017)	(0.022)	(0.022)	(0.024)
Within 8-10km x 2012	0.031*	0.013	0.020	-0.007
	(0.017)	(0.022)	(0.022)	(0.025)
Within 8-10km x 2013	0.010	-0.005	0.007	-0.006
	(0.018)	(0.023)	(0.023)	(0.025)
Within 8-10km x 2014	0.018	-0.025	-0.018	-0.045
	(0.018)	(0.023)	(0.023)	(0.028)
Within 8-10km x 2015	0.062***	0.029	0.046**	0.015
	(0.018)	(0.023)	(0.024)	(0.027)
Within 8-10km x 2016	0.025	-0.010	0.004	-0.014
	(0.020)	(0.025)	(0.025)	(0.029)
Within 8-10km x 2017	0.062***	0.017	0.030	-0.063**
	(0.020)	(0.026)	(0.027)	(0.031)
Within 8-10km x 2018	0.040*	-0.007	0.009	-0.046
	(0.021)	(0.027)	(0.027)	(0.030)
Include covariates	No	Level	Log	Log and proportions
N of observations	175,474	127,458	111,368	56,808
N of manzanas	41,216	30,590	24,544	8,646
N of high-dimension controls				533

Notes: This table provides the ATT for *manzanas* located proximate to *Acceso Sur* highway, for every year after its opening on 2010, according to equation (4). Five treatment categories are considered based on distance to the highway, all *manzanas* inside that distance range belong to that specific treatment group. Treatment categories are: 0-2 km, 2-4 km, 4-6 km, 6-8 km, and 8-10 km. Control *manzanas* are those located further away than 10 km. *Manzana* and year fixed effects are included in all specifications. Unit of observation is manzana-year. Pre-treatment years included in the regression are 2007, 2008, 2009 and 2010 (its estimated coefficients are found in Table 8), while post-treatment years cover from 2011 to 2018. Clustered standard errors in parenthesis (clustering at the *manzana* level).* p<0.10, ** p<0.05, *** p<0.01.

C Heterogeneous Treatment Effects

Table 10: Dif-in-Dif Heterogeneous Treatment Effects: *Manzanas* Located Inside Vespucio's Ring Road

	(1)	(2)	(3)	(4)
Post 2010 x 0-1 km from highway	-0.148***	-0.138***	-0.114***	-0.109***
	(0.013)	(0.021)	(0.018)	(0.017)
Post 2010 x 1-2 km from highway	-0.123***	-0.115***	-0.118***	-0.091***
	(0.012)	(0.021)	(0.019)	(0.018)
Post 2010 x 2-3 km from highway	-0.072***	-0.107***	-0.129***	-0.093***
	(0.015)	(0.023)	(0.022)	(0.021)
Post 2010 x 3-4 km from highway	-0.079***	-0.097***	-0.109***	-0.072***
	(0.012)	(0.020)	(0.017)	(0.017)
Post 2010 x 4-5 km from highway	-0.089***	-0.093***	-0.099***	-0.067***
	(0.010)	(0.018)	(0.015)	(0.015)
Post 2010 x 5-6 km from highway	-0.105***	-0.122***	-0.128***	-0.098***
	(0.011)	(0.016)	(0.015)	(0.015)
Post 2010 x 6-7 km from highway	-0.068***	-0.078***	-0.088***	-0.062**
	(0.018)	(0.025)	(0.026)	(0.024)
Post 2010 x 7-8 km from highway	-0.089***	-0.078*	-0.108**	-0.066
	(0.026)	(0.041)	(0.044)	(0.040)
Post 2010 x 8-9 km from highway	-0.028	-0.069**	-0.070**	-0.049
	(0.023)	(0.034)	(0.033)	(0.034)
Post 2010 x 9-10 km from highway	-0.001	-0.063*	-0.012	-0.037
	(0.029)	(0.035)	(0.033)	(0.034)
Post 2010 x 0-1 km from highway x Inside Vespucio	0.076	0.051	-0.078	0.020
	(0.079)	(0.081)	(0.092)	(0.081)
Post 2010 x 1-2 km from highway x Inside Vespucio	0.066	0.100**	0.095*	0.069
	(0.043)	(0.043)	(0.049)	(0.043)
Post 2010 x 2-3 km from highway x Inside Vespucio	0.008	0.046	0.042	0.032
	(0.032)	(0.040)	(0.042)	(0.040)
Post 2010 x 3-4 km from highway x Inside Vespucio	0.036	0.018	-0.020	-0.013
	(0.028)	(0.034)	(0.033)	(0.033)
Post 2010 x 4-5 km from highway x Inside Vespucio	0.085***	0.063**	0.037	0.033
	(0.022)	(0.027)	(0.026)	(0.025)
Post 2010 x 5-6 km from highway x Inside Vespucio	0.102***	0.115***	0.105***	0.091***
	(0.022)	(0.027)	(0.027)	(0.026)
Post 2010 x 6-7 km from highway x Inside Vespucio	0.071***	0.075**	0.062*	0.062**
	(0.026)	(0.032)	(0.033)	(0.031)
Post 2010 x 7-8 km from highway x Inside Vespucio	0.085***	0.089**	0.109**	0.079*
	(0.031)	(0.045)	(0.048)	(0.044)
Post 2010 x 8-9 km from highway x Inside Vespucio	0.051*	0.068*	0.061	0.053
	(0.028)	(0.040)	(0.040)	(0.039)
Post 2010 x 9-10 km from highway x Inside Vespucio	0.057*	0.072*	0.024	0.049
	(0.031)	(0.037)	(0.036)	(0.037)
Covariates	No	Level	Log	Log and proportions
N of observations	175,300	127,360	111,272	127,360

Notes: Columns 1-4 provide the ATT for *manzanas* located proximate to *Acceso Sur* highway after its opening (on 2010), according to equation (7). Ten treatment categories are considered based on distance to the highway, at 1 km intervals until the 10th km. Control *manzanas* are those located further away than 10 km. "Inside Vespucio" refers to *manzanas* located inside Vespucio's ring road. *Manzana* and year fixed effects are included in all specifications. Unit of observation is manzana-year. Pre-treatment years include 2007, 2008, 2009 and 2010, while post-treatment years cover from 2011 to 2018. Clustered standard errors in parenthesis (clustering at the *manzana* level).* p<0.10, ** p<0.05, *** p<0.01.

Table 11: Dif-in-Dif with Heterogeneous Treatment Effects: *Manzanas* with Motorization Rate Above the 75 percentile

	(1)	(2)	(3)	(4)
Post 2010 x 0-1 km	-0.186***	-0.107***	-0.128***	-0.094**
	(0.040)	(0.041)	(0.043)	(0.040)
Post 2010 x 1-2 km	-0.197***	-0.144***	-0.198***	-0.139***
	(0.038)	(0.040)	(0.040)	(0.039)
Post 2010 x 2-3 km	-0.149***	-0.130***	-0.192***	-0.136***
	(0.029)	(0.031)	(0.031)	(0.031)
Post 2010 x 3-4 km	-0.093***	-0.061**	-0.102***	-0.056**
	(0.025)	(0.027)	(0.027)	(0.026)
Post 2010 x 4-5 km	-0.109***	-0.076***	-0.101***	-0.066***
	(0.020)	(0.021)	(0.021)	(0.021)
Post 2010 x 5-6 km	-0.108***	-0.091***	-0.114***	-0.080***
	(0.018)	(0.019)	(0.018)	(0.018)
Post 2010 x 6-7 km	-0.114***	-0.122***	-0.135***	-0.115***
	(0.024)	(0.025)	(0.025)	(0.025)
Post 2010 x 7-8 km	-0.124**	-0.088	-0.115*	-0.086
	(0.063)	(0.061)	(0.061)	(0.061)
Post 2010 x 8-9 km	-0.005	-0.023	-0.014	-0.013
	(0.030)	(0.030)	(0.030)	(0.030)
Post 2010 x 9-10 km	-0.046***	-0.078***	-0.064***	-0.067***
	(0.017)	(0.018)	(0.018)	(0.018)
Post 2010 x 0-1 km x High motorization	0.073*	0.008	0.036	0.002
	(0.043)	(0.042)	(0.045)	(0.043)
Post 2010 x 1-2 km x High motorization	0.142***	0.086**	0.129***	0.082**
	(0.041)	(0.041)	(0.043)	(0.041)
Post 2010 x 2-3 km x High motorization	0.120***	0.078**	0.114***	0.080**
	(0.034)	(0.034)	(0.035)	(0.034)
Post 2010 x 3-4 km x High motorization	0.052*	-0.003	0.010	-0.006
	(0.028)	(0.028)	(0.029)	(0.029)
Post 2010 x 4-5 km x High motorization	0.080***	0.031	0.035	0.024
	(0.024)	(0.024)	(0.025)	(0.024)
Post 2010 x 5-6 km x High motorization	0.058**	0.034	0.042*	0.025
	(0.024)	(0.024)	(0.024)	(0.024)
Post 2010 x 6-7 km x High motorization	0.120***	0.121***	0.117***	0.118***
	(0.031)	(0.031)	(0.032)	(0.031)
Post 2010 x 7-8 km x High motorization	0.115*	0.083	0.098	0.086
	(0.065)	(0.064)	(0.064)	(0.064)
Post 2010 x 8-9 km x High motorization	0.008	0.005	-0.016	0.001
	(0.037)	(0.037)	(0.037)	(0.037)
Post 2010 x 9-10 km x High motorization	0.106***	0.093***	0.097***	0.091***
	(0.025)	(0.025)	(0.025)	(0.025)
Covariates	No	Level	Log	Log and proportions
N of observations	127,458	127,458	111,398	127,458

Notes: Columns 1-4 provide the ATT for *manzanas* located proximate to *Acceso Sur* highway after its opening (on 2010), according to equation (7). Ten treatment categories are considered based on distance to the highway, at 1 km intervals until the 10th km. Control *manzanas* are those located further away than 10 km. "High motorization" refers to *manzanas* were the percentage of households owning a motorized vehicle is higher than the sample's 75th percentile (which is 0.775). *Manzana* and year fixed effects are included in all specifications. Unit of observation is manzana-year. Pre-treatment years include 2007, 2008, 2009 and 2010, while post-treatment years cover from 2011 to 2018. Clustered standard errors in parenthesis (clustering at the *manzana* level).* $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table 12: Dif-in-Dif with Heterogeneous Treatment Effects: *Manzanas* with average socioeconomic condition above the 75^{th} percentile

	(1)	(2)	(3)	(4)
Post 2010 x 0-1 km	-0.225	-0.109	-0.369***	-0.096
	(0.173)	(0.183)	(0.115)	(0.184)
Post 2010 x 1-2 km	-0.204***	-0.144***	-0.192***	-0.142***
	(0.042)	(0.044)	(0.043)	(0.043)
Post 2010 x 2-3 km	-0.121***	-0.094**	-0.153***	-0.105***
	(0.037)	(0.039)	(0.039)	(0.039)
Post 2010 x 3-4 km	-0.106***	-0.071**	-0.114***	-0.072**
	(0.029)	(0.031)	(0.030)	(0.030)
Post 2010 x 4-5 km	-0.119***	-0.087***	-0.114***	-0.081***
	(0.020)	(0.021)	(0.020)	(0.020)
Post 2010 x 5-6 km	-0.133***	-0.105***	-0.127***	-0.098***
	(0.018)	(0.019)	(0.018)	(0.019)
Post 2010 x 6-7 km	-0.132***	-0.133***	-0.142***	-0.129***
	(0.023)	(0.023)	(0.023)	(0.023)
Post 2010 x 7-8 km	-0.145***	-0.120**	-0.144***	-0.119**
	(0.049)	(0.048)	(0.049)	(0.048)
Post 2010 x 8-9 km	-0.010	-0.018	-0.010	-0.007
	(0.023)	(0.023)	(0.023)	(0.023)
Post 2010 x 9-10 km	-0.052***	-0.056***	-0.048***	-0.046***
	(0.013)	(0.013)	(0.013)	(0.013)
Post 2010 x 0-1 km x High CSE	0.133	0.021	0.288**	0.013
	(0.174)	(0.184)	(0.116)	(0.185)
Post 2010 x 1-2 km x High CSE	0.165***	0.092**	0.132***	0.090**
	(0.045)	(0.045)	(0.045)	(0.045)
Post 2010 x 2-3 km x High CSE	0.102**	0.042	0.081*	0.047
	(0.041)	(0.041)	(0.042)	(0.041)
Post 2010 x 3-4 km x High CSE	0.087***	0.019	0.042	0.020
	(0.032)	(0.033)	(0.033)	(0.033)
Post 2010 x 4-5 km x High CSE	0.108***	0.053**	0.065***	0.048**
	(0.024)	(0.024)	(0.025)	(0.024)
Post 2010 x 5-6 km x High CSE	0.106***	0.060**	0.071***	0.055**
	(0.024)	(0.024)	(0.025)	(0.024)
Post 2010 x 6-7 km x High CSE	0.156***	0.139***	0.132***	0.137***
	(0.030)	(0.030)	(0.031)	(0.030)
Post 2010 x 7-8 km x High CSE	0.155***	0.121**	0.135**	0.124**
	(0.053)	(0.052)	(0.053)	(0.052)
Post 2010 x 8-9 km x High CSE	0.017	-0.001	-0.021	-0.008
	(0.033)	(0.033)	(0.033)	(0.033)
Post 2010 x 9-10 km x High CSE	0.116***	0.079***	0.092***	0.076***
	(0.027)	(0.027)	(0.027)	(0.027)
Covariates	No	Level	Log	Log and proportions
N of observations	127,458	127,458	111,368	127,458

Notes: Columns 1-4 provide the ATT for *manzanas* located proximate to *Acceso Sur* highway after its opening (on 2010), according to equation (5). Ten treatment categories are considered based on distance to the highway, at 1 km intervals until the 10th km. Control *manzanas* are those located further away than 10 km. "High CSE" refers to *manzanas* were the average socioeconomic condition of the households that compose it -measured by CSE decils-, is higher than the sample's 75th percentile (8.95). *Manzana* and year fixed effects are included in all specifications. Unit of observation is manzana-year. Pre-treatment years include 2007, 2008, 2009 and 2010, while post-treatment years cover from 2011 to 2018. Clustered standard errors in parenthesis (clustering at the *manzana* level).* p<0.10, ** p<0.05, *** p<0.01.

Table 13: Dif-in-Dif with Heterogeneous Treatment Effects: *Manzanas* Located Further than the Median from the CBD

	CBD: Tobalaba		CBD: Baquedano	
	(1)	(2)	(3)	(4)
Post 2010 x 0-1 km	-0.134	-0.072	-0.156	-0.097
	(0.161)	(0.161)	(0.134)	(0.135)
Post 2010 x 1-2 km	-0.092**	-0.030	-0.105**	-0.019
	(0.040)	(0.044)	(0.047)	(0.047)
Post 2010 x 2-3 km	-0.113***	-0.061*	-0.113***	-0.061*
	(0.028)	(0.036)	(0.027)	(0.034)
Post 2010 x 3-4 km	-0.096***	-0.082***	-0.090***	-0.081***
	(0.021)	(0.026)	(0.022)	(0.026)
Post 2010 x 4-5 km	-0.074***	-0.062***	-0.077***	-0.052**
	(0.017)	(0.019)	(0.018)	(0.021)
Post 2010 x 5-6 km	-0.071***	-0.041**	-0.076***	-0.047**
	(0.016)	(0.019)	(0.018)	(0.020)
Post 2010 x 6-7 km	-0.070***	-0.051***	-0.051***	-0.037**
	(0.016)	(0.018)	(0.016)	(0.018)
Post 2010 x 7-8 km	-0.074***	-0.021	-0.070***	-0.023
	(0.016)	(0.021)	(0.017)	(0.020)
Post 2010 x 8-9 km	-0.021	-0.016	-0.020	-0.017
	(0.015)	(0.019)	(0.015)	(0.019)
Post 2010 x 9-10 km	-0.005	-0.013	0.002	-0.016
	(0.013)	(0.015)	(0.013)	(0.015)
Post 2010 x 0-1 km x Far from CBD	0.073	0.011	0.085	0.061
	(0.162)	(0.161)	(0.135)	(0.135)
Post 2010 x 1-2 km x Far from CBD	0.054	-0.001	0.058	0.017
	(0.042)	(0.047)	(0.048)	(0.049)
Post 2010 x 2-3 km x Far from CBD	0.123***	0.032	0.114***	0.070*
	(0.032)	(0.041)	(0.031)	(0.039)
Post 2010 x 3-4 km x Far from CBD	0.101***	0.067**	0.085***	0.099***
	(0.025)	(0.030)	(0.025)	(0.030)
Post 2010 x 4-5 km x Far from CBD	0.068***	0.053**	0.067***	0.063**
	(0.020)	(0.024)	(0.021)	(0.025)
Post 2010 x 5-6 km x Far from CBD	0.043**	-0.016	0.048**	0.017
	(0.020)	(0.025)	(0.021)	(0.025)
Post 2010 x 6-7 km x Far from CBD	0.095***	0.083**	0.046*	0.051
	(0.027)	(0.035)	(0.027)	(0.035)
Post 2010 x 7-8 km x Far from CBD	0.085**	0.035	0.075**	0.048
	(0.033)	(0.043)	(0.033)	(0.049)
Post 2010 x 8-9 km x Far from CBD	-0.012	-0.040	-0.003	-0.049
	(0.031)	(0.058)	(0.032)	(0.060)
Post 2010 x 9-10 km x Far from CBD	0.050	0.003	-0.018	-0.057
	(0.046)	(0.051)	(0.035)	(0.052)
Covariates	No	Yes	No	Yes
N of observations	175,474	127,458	175,474	127,458

Notes: This table provides the ATT for *manzanas* located proximate to *Acceso Sur* highway after its opening (on 2010), according to equation (5). Ten treatment categories are considered based on distance to the highway, at 1 km intervals until the 10th km. Control *manzanas* are those located farther away than 10 km. "Far from CBD" refers to *manzanas* whose centroids are located at a distance greater than the median from Santiago's CBD. Columns 1-2 use Tobalaba subway station as CBD, while columns 3-4 use Baquedano subway station (the median distance is 12.76 km and 10.80 km respectively). Covariates included in columns 2 and 4 are in logs and proportions. *Manzana* and year fixed effects are included in all specifications. Unit of observation is manzana-year. Pre-treatment years include 2007, 2008, 2009 and 2010, while post-treatment years cover from 2011 to 2018. Clustered standard errors in parenthesis (clustering at the *manzana* level).* $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Table 14: Dif-in-Dif Treatment Effects for Distance to Highway and Distance to Highway's Entry Points

	(1)	(2)	(3)	(4)
Post 2010 x 0-1 km from highway	-0.276*	0.021	-0.096	-0.025
	(0.141)	(0.276)	(0.269)	(0.271)
Post 2010 x 1-2 km from highway	-0.230	0.053	-0.091	0.002
	(0.141)	(0.275)	(0.269)	(0.270)
Post 2010 x 2-3 km from highway	-0.186	0.048	-0.097	-0.011
	(0.140)	(0.273)	(0.267)	(0.269)
Post 2010 x 3-4 km from highway	-0.130	0.087	-0.050	0.038
	(0.136)	(0.271)	(0.265)	(0.266)
Post 2010 x 4-5 km from highway	-0.079	0.085	-0.048	0.037
	(0.134)	(0.268)	(0.262)	(0.264)
Post 2010 x 5-6 km from highway	-0.023	0.037	-0.084	-0.006
	(0.134)	(0.266)	(0.260)	(0.262)
Post 2010 x 6-7 km from highway	0.054	0.070	-0.038	0.040
	(0.135)	(0.264)	(0.259)	(0.261)
Post 2010 x 7-8 km from highway	0.038	0.063	-0.041	0.040
	(0.135)	(0.262)	(0.257)	(0.259)
Post 2010 x 8-9 km from highway	0.104	0.079	0.011	0.067
	(0.139)	(0.261)	(0.256)	(0.259)
Post 2010 x 9-10 km from highway	0.173	0.121	0.084	0.122
	(0.139)	(0.249)	(0.243)	(0.246)
Post 2010 x 0-1 km from entry	0.172	-0.121	-0.008	-0.067
	(0.142)	(0.275)	(0.270)	(0.271)
Post 2010 x 1-2 km from entry	0.127	-0.127	0.005	-0.074
	(0.141)	(0.274)	(0.269)	(0.270)
Post 2010 x 2-3 km from entry	0.132	-0.111	-0.002	-0.055
	(0.140)	(0.273)	(0.267)	(0.269)
Post 2010 x 3-4 km from entry	0.079	-0.155	-0.053	-0.102
	(0.136)	(0.270)	(0.264)	(0.266)
Post 2010 x 4-5 km from entry	0.036	-0.144	-0.034	-0.089
	(0.134)	(0.267)	(0.262)	(0.264)
Post 2010 x 5-6 km from entry	-0.039	-0.107	-0.002	-0.056
	(0.135)	(0.266)	(0.260)	(0.262)
Post 2010 x 6-7 km from entry	-0.087	-0.106	-0.018	-0.069
	(0.135)	(0.264)	(0.259)	(0.261)
Post 2010 x 7-8 km from entry	-0.072	-0.075	0.017	-0.047
	(0.135)	(0.262)	(0.257)	(0.259)
Post 2010 x 8-9 km from entry	-0.104	-0.098	-0.037	-0.079
	(0.139)	(0.261)	(0.256)	(0.259)
Post 2010 x 9-10 km from entry	-0.140	-0.134	-0.082	-0.126
	(0.139)	(0.250)	(0.243)	(0.247)
Covariates	No	Level	Log	Log and proportions
N of observations	175,474	127,458	111,368	127,458

Notes: Columns 1-4 provide the ATT for *manzanas* located proximate to *Acceso Sur* highway and their entry points after its opening (on 2010), according to equation (6). Ten treatment categories are considered based on distance to the highway, at 1 km intervals until the 10th km. Other ten treatment categories are defined using distance to the entry points, also for every 1 km. Each treatment category is interacted with the "Post 2012" variable separately. Control *manzanas* are those located further away than 10 km. *Manzana* and year fixed effects are included in all specifications. Unit of observation is manzana-year. Pre-treatment years include 2007, 2008, 2009 and 2010, while post-treatment years cover from 2011 to 2018. Clustered standard errors in parenthesis (clustering at the *manzana* level).* p<0.10, ** p<0.05, *** p<0.01.

Table 15: Dif-in-Dif Treatment Effects for Distance to Highway and Distance to Underground Section of the Highway

	(1)	(2)	(3)	(4)
Post 2010 x 0-1 km from highway	-0.189***	-0.019	-0.020	-0.012
	(0.027)	(0.068)	(0.081)	(0.065)
Post 2010 x 1-2 km from highway	-0.160***	0.021	-0.003	0.023
	(0.028)	(0.069)	(0.081)	(0.066)
Post 2010 x 2-3 km from highway	-0.139***	0.009	-0.026	-0.003
	(0.029)	(0.069)	(0.081)	(0.066)
Post 2010 x 3-4 km from highway	-0.105***	0.063	0.028	0.056
	(0.026)	(0.067)	(0.080)	(0.064)
Post 2010 x 4-5 km from highway	-0.114***	0.077	0.036	0.062
	(0.023)	(0.066)	(0.081)	(0.064)
Post 2010 x 5-6 km from highway	-0.099***	0.075	0.020	0.046
	(0.022)	(0.064)	(0.080)	(0.063)
Post 2010 x 6-7 km from highway	-0.003	0.156**	0.097	0.131**
	(0.028)	(0.064)	(0.079)	(0.063)
Post 2010 x 7-8 km from highway	-0.011	0.139**	0.065	0.113*
	(0.030)	(0.065)	(0.082)	(0.065)
Post 2010 x 8-9 km from highway	0.036	0.141*	0.113	0.127*
	(0.034)	(0.073)	(0.088)	(0.073)
Post 2010 x 9-10 km from highway	0.109***	0.160**	0.178**	0.159**
	(0.035)	(0.068)	(0.086)	(0.068)
Post 2010 x 0-1 km from underground section	0.101***	-0.056	-0.052	-0.046
	(0.033)	(0.070)	(0.084)	(0.068)
Post 2010 x 1-2 km from underground section	0.075**	-0.081	-0.062	-0.073
	(0.030)	(0.068)	(0.082)	(0.066)
Post 2010 x 2-3 km from underground section	0.094***	-0.069	-0.060	-0.051
	(0.030)	(0.066)	(0.081)	(0.065)
Post 2010 x 3-4 km from underground section	0.052**	-0.144**	-0.138*	-0.124*
	(0.026)	(0.065)	(0.080)	(0.064)
Post 2010 x 4-5 km from underground section	0.077***	-0.142**	-0.117	-0.112*
	(0.024)	(0.065)	(0.081)	(0.064)
Post 2010 x 5-6 km from underground section	0.046**	-0.150**	-0.106	-0.108*
	(0.023)	(0.064)	(0.080)	(0.063)
Post 2010 x 6-7 km from underground section	-0.030	-0.201***	-0.158**	-0.166***
	(0.026)	(0.064)	(0.079)	(0.063)
Post 2010 x 7-8 km from underground section	-0.024	-0.155**	-0.088	-0.121*
	(0.027)	(0.064)	(0.081)	(0.064)
Post 2010 x 8-9 km from underground section	-0.036	-0.162**	-0.139	-0.140*
	(0.032)	(0.072)	(0.087)	(0.072)
Post 2010 x 9-10 km from underground section	-0.076**	-0.174***	-0.177**	-0.164**
	(0.033)	(0.067)	(0.085)	(0.067)
Covariates	No	Level	Log	Log and proportions
N of observations	175,474	127,458	111,368	127,458

Notes: Columns 1-4 provide the ATT for *manzanas* located proximate to *Acceso Sur* highway and their entry points after its opening (on 2010), according to equation (6). Ten treatment categories are considered based on distance to the highway, at 1 km intervals until the 10th km. Other ten treatment categories are defined using distance to the highway's underground section, also for distance intervals of 1 km and until the 10th km. Each treatment category is interacted with the "Post 2012" variable separately. Control *manzanas* are those located further away than 10 km. *Manzana* and year fixed effects are included in all specifications. Unit of observation is manzana-year. Pre-treatment years include 2007, 2008, 2009 and 2010, while post-treatment years cover from 2011 to 2018. Clustered standard errors in parenthesis (clustering at the *manzana* level).* p<0.10, ** p<0.05, *** p<0.01.

Table 16: Linear Combinations of Treatment Effects and Different Heterogeneities

	Inside Vespucio		High Motorization		Far from CBD		High CSE	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post 2010 x 0-1 km from highway	-0.072	-0.089	-0.114***	-0.092***	-0.071***	-0.036**	-0.092***	-0.084***
	(0.078)	(0.080)	(0.016)	(0.017)	(0.013)	(0.016)	(0.015)	(0.017)
Post 2010 x 1-2 km from highway	-0.057	-0.022	-0.055***	-0.056***	-0.047***	-0.002	-0.039***	-0.052***
	(0.041)	(0.041)	(0.015)	(0.017)	(0.012)	(0.017)	(0.015)	(0.017)
Post 2010 x 2-3 km from highway	-0.065**	-0.061*	-0.030	-0.057***	0.001	0.010	-0.018	-0.058***
	(0.028)	(0.035)	(0.018)	(0.020)	(0.015)	(0.021)	(0.021)	(0.020)
Post 2010 x 3-4 km from highway	-0.043*	-0.085***	-0.041***	-0.062***	-0.005	0.018	0.018	-0.052***
	(0.026)	(0.030)	(0.014)	(0.016)	(0.012)	(0.017)	(0.014)	(0.016)
Post 2010 x 4-5 km from highway	-0.005	-0.034	-0.029**	-0.042***	-0.010	0.011	-0.012	-0.033**
	(0.019)	(0.022)	(0.013)	(0.015)	(0.010)	(0.015)	(0.013)	(0.015)
Post 2010 x 5-6 km from highway	-0.002	-0.007	-0.050***	-0.055***	-0.028**	-0.029*	-0.027*	-0.043***
	(0.019)	(0.022)	(0.016)	(0.016)	(0.011)	(0.015)	(0.016)	(0.016)
Post 2010 x 6-7 km from highway	0.003	-0.000	0.005	0.003	-0.004	0.014	0.024	0.008
	(0.018)	(0.020)	(0.019)	(0.019)	(0.021)	(0.030)	(0.019)	(0.019)
Post 2010 x 7-8 km from highway	-0.003	0.013	-0.009	-0.000	0.004	0.025	0.010	0.005
	(0.017)	(0.020)	(0.019)	(0.019)	(0.028)	(0.045)	(0.019)	(0.020)
Post 2010 x 8-9 km from highway	0.023	0.004	0.003	-0.012	-0.023	-0.63	0.008	-0.014
	(0.016)	(0.021)	(0.022)	(0.022)	(0.029)	(0.057)	(0.024)	(0.023)
Post 2010 x 9-10 km from highway	0.057***	0.012	0.060***	0.023	-0.016	-0.073	0.064***	0.030
	(0.013)	(0.015)	(0.018)	(0.019)	(0.033)	(0.050)	(0.024)	(0.024)
Covariates	No	Yes	No	Yes	No	Yes	No	Yes
N of observations	175,474	127,458	175,474	127,458	175,474	127,458	175,474	127,458

Notes: This table provides the linear combination between the coefficient accompanying the interaction term $Post_t\text{x}Near_i$ and the one accompanying $Post_t\text{x}Near_i\text{x}Z_i$, for each of the ten $Near_i$ categories, were Z_i represents an indicator variable that takes the value of one for five deferment covariates levels. First, in columns 1-2, Z_i activates for *manzanas* located inside of Vespucio's ring road. Then for columns 3-4 it takes the value of one in *manzanas* that have a household motorization rate higher than the 75^th percentile of the sample, this is 0.775 of households own a private motorized vehicle. In columns 5-6 the dummy activates for *manzanas* located farther away from the CBD than the median of the sample. Baquedano Subway station is considered the CBD, and the median distance to it is of 10.80 km. Estimates are using Tobalaba as CBD are remarkably similiar, while no significant heterogeneous effects where found for when using La Moneda as CBD. Finally, in columns 7-8, $Z_i = 1$ in *manzanas* with an average household socioeconomic index (CSE) higher than the 75^th percentile (which is 8.95 for CSE in decils). In the equations used to estimate the coefficients, ten treatment categories are considered based on distance to the highway, at 1 km intervals until the 10th km. Control *manzanas* are those located further away than 10 km. *Manzana* and year fixed effects were included in all specifications. Unit of observation is manzana-year. Covariates included in even numbered columns are in log and proportions form. Pre-treatment years include 2007, 2008, 2009 and 2010, while post-treatment years cover from 2011 to 2018. Clustered standard errors in parenthesis (clustering at the *manzana* level).* p<0.10, ** p<0.05, *** p<0.01.

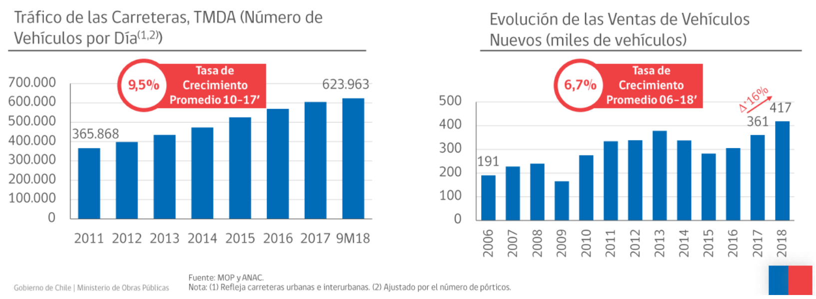
Table 17: Linear Combinations of Treatment Effects and Distance to Highway's Entry Point and Underground Section Effects

	Entry Point		Underground Section	
	(1)	(2)	(3)	(4)
Post 2010 x 0-1 km from highway	-0.104***	-0.091***	-0.088***	-0.059**
	(0.017)	(0.022)	(0.018)	(0.024)
Post 2010 x 1-2 km from highway	-0.103***	-0.072***	-0.086***	-0.050**
	(0.013)	(0.018)	(0.014)	(0.020)
Post 2010 x 2-3 km from highway	-0.054***	-0.066***	-0.045***	-0.054***
	(0.014)	(0.019)	(0.015)	(0.020)
Post 2010 x 3-4 km from highway	-0.051***	-0.064***	-0.053***	-0.069***
	(0.011)	(0.015)	(0.012)	(0.016)
Post 2010 x 4-5 km from highway	-0.043***	-0.052***	-0.037***	-0.051***
	(0.009)	(0.013)	(0.010)	(0.013)
Post 2010 x 5-6 km from highway	-0.061***	-0.062***	-0.053***	-0.062***
	(0.010)	(0.013)	(0.010)	(0.013)
Post 2010 x 6-7 km from highway	-0.033**	-0.030*	-0.032**	-0.035**
	(0.013)	(0.016)	(0.013)	(0.016)
Post 2010 x 7-8 km from highway	-0.034**	-0.007	-0.035**	-0.008
	(0.015)	(0.019)	(0.014)	(0.019)
Post 2010 x 8-9 km from highway	0.001	-0.012	0.001	-0.013
	(0.013)	(0.018)	(0.013)	(0.018)
Post 2010 x 9-10 km from highway	0.033***	-0.004	0.033***	-0.005
	(0.012)	(0.014)	(0.012)	(0.014)
Covariates	No	Yes	No	Yes
N of observations	175,474	127,458	175,474	127,458

Notes: This table provides the linear combination between the coefficient accompanying the interaction term $Post_t$ x $Near_{r,i}$, and the one accompanying $Post_t$ x $Near2_{r,i}$, for each of the ten $Near_{r,i}$ and $Near2_{r,i}$ categories. In the equations used to estimate the coefficients, ten treatment categories are considered based on distance to the highway, at 1 km intervals until the 10th km. This is, $Near_{r,i} = 1$ if the *manzana* i is located at a distance of $r - 1 < distance < r$, with $r = \{1, 2, 3, ..., 10\}$. Likewise, $Near2_{r,i}$ represents an additional treatment, also divided in ten treatment categories, that are defined using the minimum distance to the highway's entry points in columns 1-2, and distance to the highway's underground section in columns 3-4. Control *manzanas* are those located further away than 10 km. *Manzana* and year fixed effects were included in all specifications. Unit of observation is manzana-year. Covariates included in even numbered columns are in log and proportions form. Pre-treatment years include 2007, 2008, 2009 and 2010, while post-treatment years cover from 2011 to 2018. Clustered standard errors in parenthesis (clustering at the *manzana* level).* p<0.10, ** p<0.05, *** p<0.01.

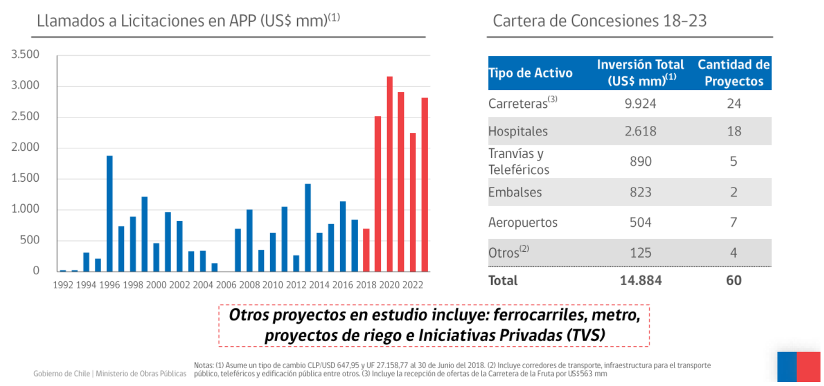
D Chile's Highway Demand, Future Investments, and Vehicle Fleet

Figure 15: Demand for highways and vehicle purchase evolution for Chile



Source: MOP (2019)

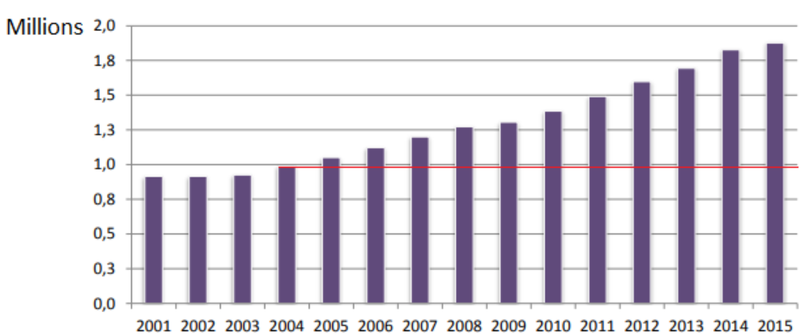
Figure 16: Projected highway investments in Chile, 2018-2023



Tipo de Activo	Inversión Total (US$ mm)(1)	Cantidad de Proyectos
Carreteras(3)	9.924	24
Hospitales	2.618	18
Tranvías y Teleféricos	890	5
Embalses	823	2
Aeropuertos	504	7
Otros(2)	125	4
Total	**14.884**	**60**

Source: MOP (2019)

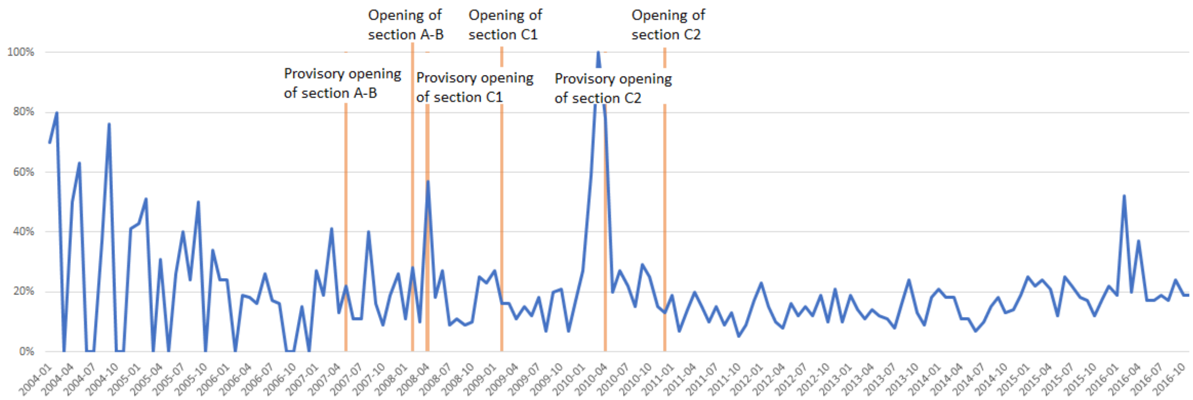
Figure 17: Number of motorized vehicles in the Metropolitan Region, 2001-2015



Source: Coordinación de Concesiones de Obras Públicas (2017) with data from INE

E Timeline of Events Related to *Acceso Sur*'s Opening and Google Searches Trends

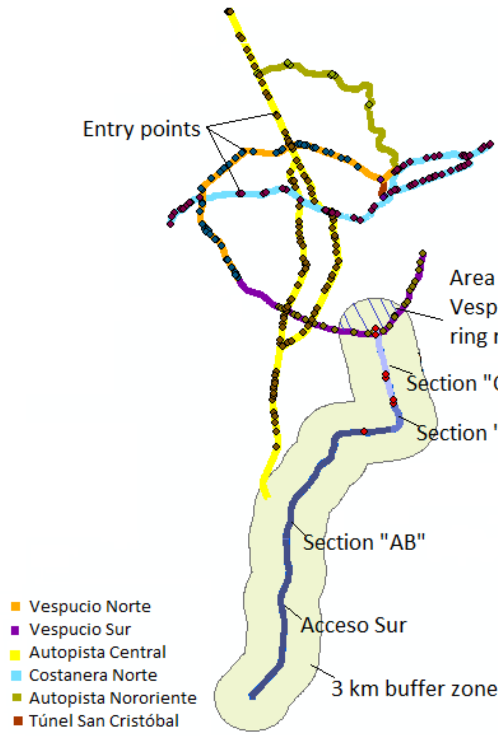
Figure 18: Google searches under the term "acceso sur" in Chile



Source: Own elaboration based on Google Trends data

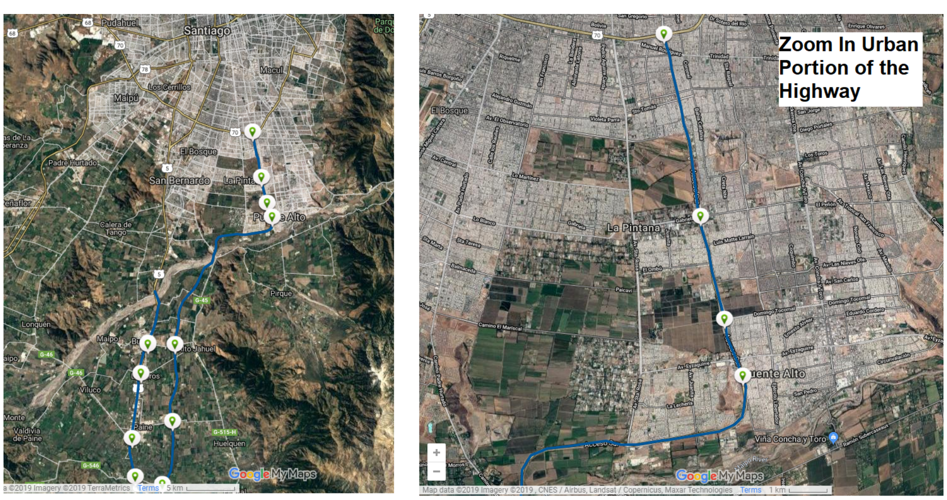
F Santiago's Highways and *Acceso Sur* Sections

Figure 19: Santiago's highways and *Acceso Sur* sections



Source: Own elaboration

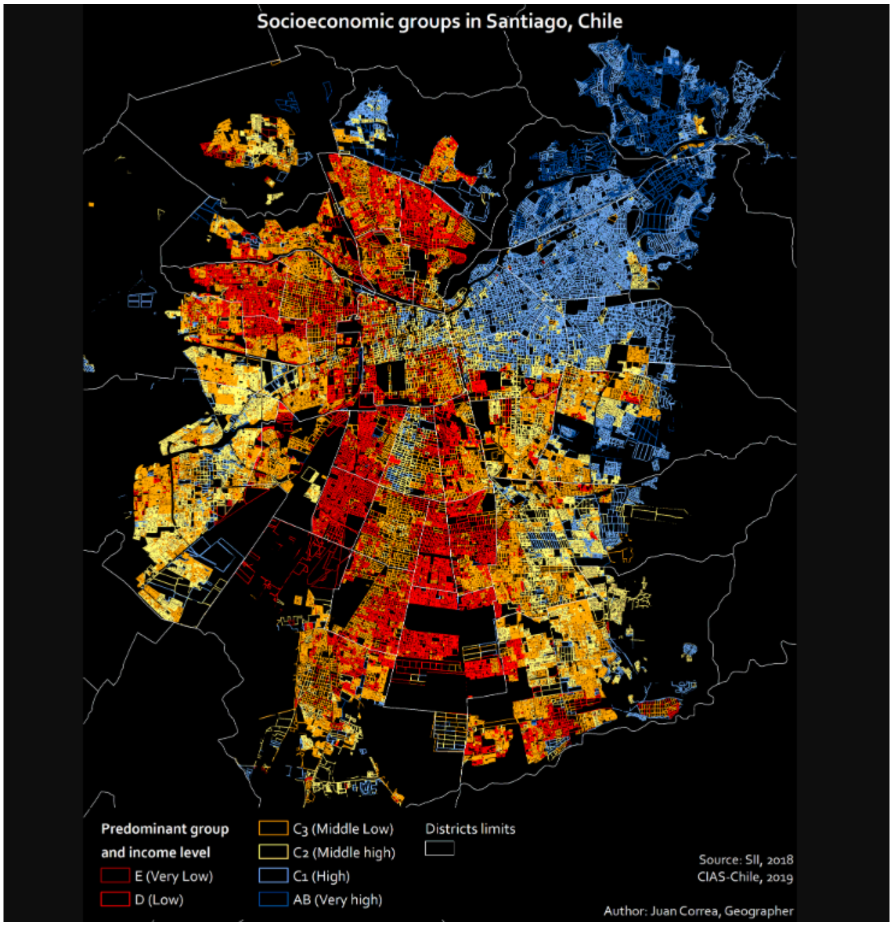
Figure 20: *Acceso Sur* highway crossing points



Source: Terrametrics (2019)

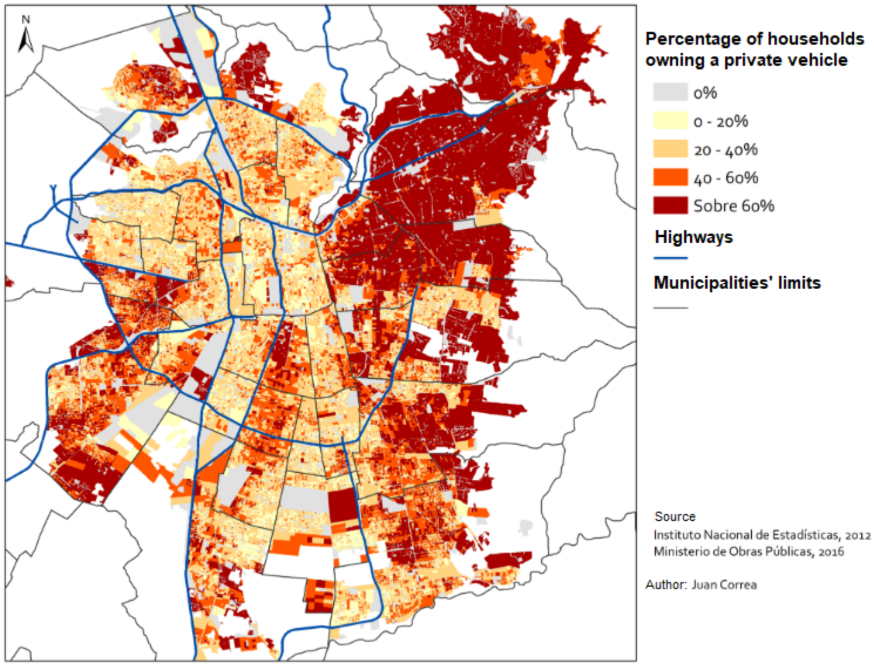
G Characterization of Santiago

Figure 21: Socioeconomic groups in Santiago



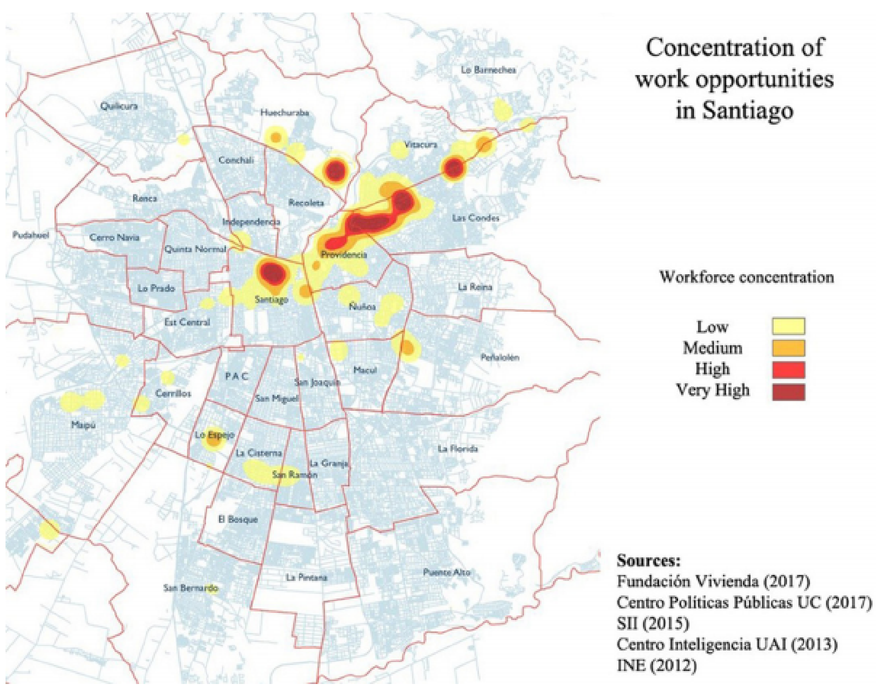
Source: Correa (2019)

Figure 22: Highways and tenancy of cars in Santiago



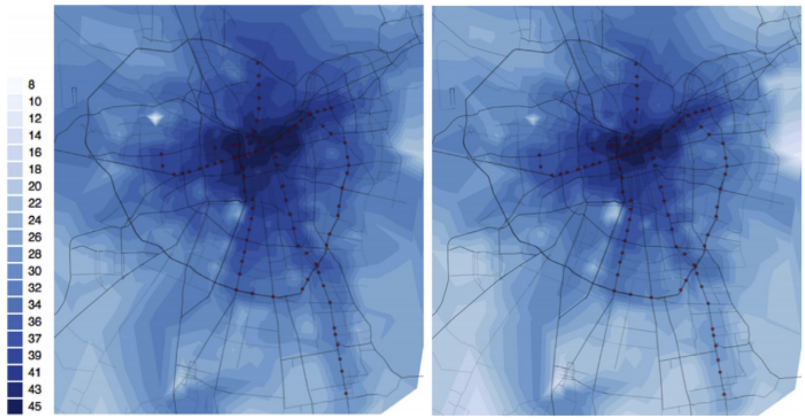
Source: Correa (2019)

Figure 23: Concentration of work opportunities in Santiago



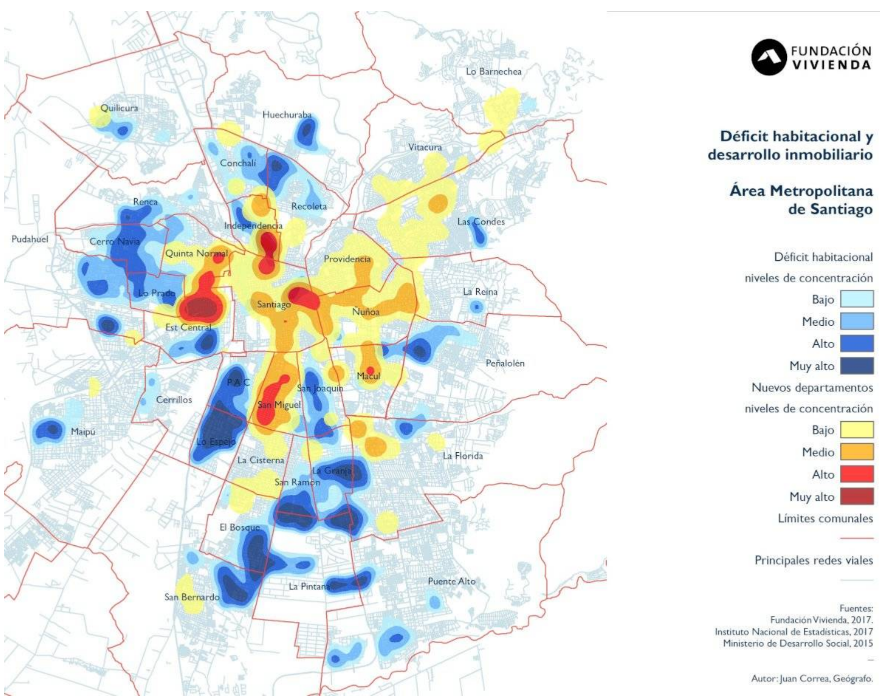
Source: Correa (2017), translated in Iglesias et al. (2019)

Figure 24: Employment accessibility by public transport in 2005 (left) and 2010 (right)



Source: Niehaus et al. (2016)

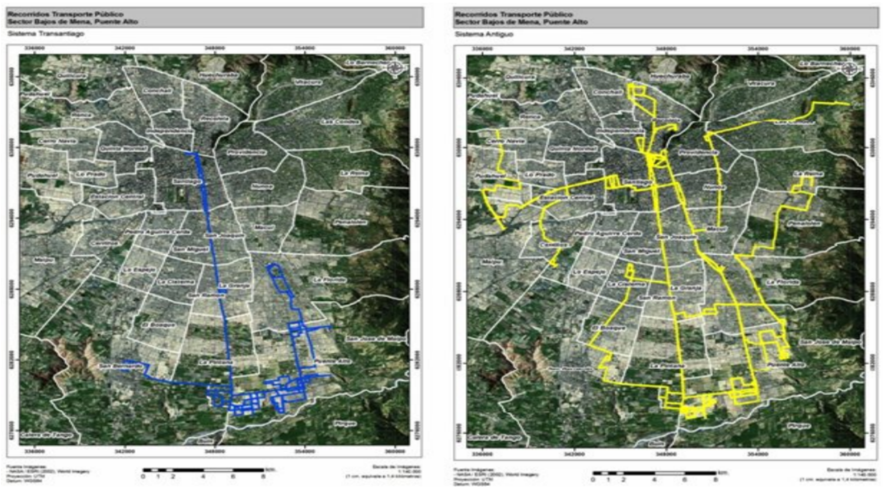
Figure 25: Housing deficit and real estate development



Source: Correa (2018)

H Public Transport Coverage in *Acceso Sur* Area

Figure 26: Comparison of pubic transport coverage of areas near *Acceso Sur*: “Yellow buses” versus Transantiago



New system: Transantiago

Old system: "Yellow buses"

Source: Landon (2013)

I Distribution of Services Around *Acceso Sur*

Figure 27: Distribution of SENAME juvenile justice programs and rights protection offices

Source: Own elaboration using 2015 data from SENAME. Map also available in: http://www.geoportal.cl/geoportal/sharedMap?id=1505fec65c295063185fc99c1898b0dd

Figure 28: Distribution of SENAME protection programs

Source: Source: Own elaboration using 2015 data from SENAME. Map also available in: http://www.geoportal.cl/geoportal/sharedMap?id=c9f829a980900d1378ae160cf8e86b01

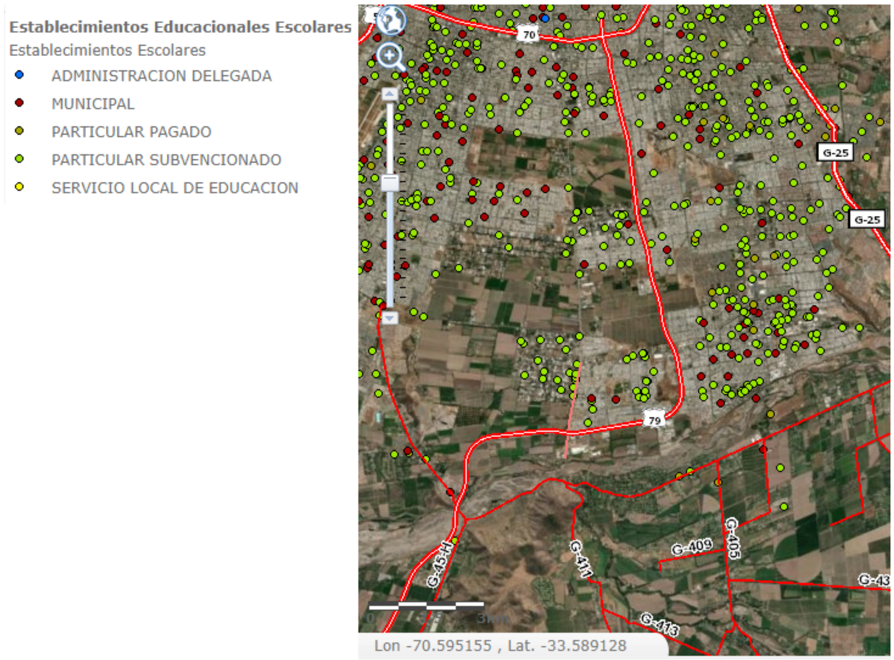
Figure 29: Distribution of dialisis centers

Source: Source: Own elaboration using 2019 data from MINSAL. Map also available in: http://www.geoportal.cl/geoportal/sharedMap?id=02fdbce605f0d5ebde13dcd6a0a8cced

Figure 30: Distribution of health centers and SNSS Hospitals

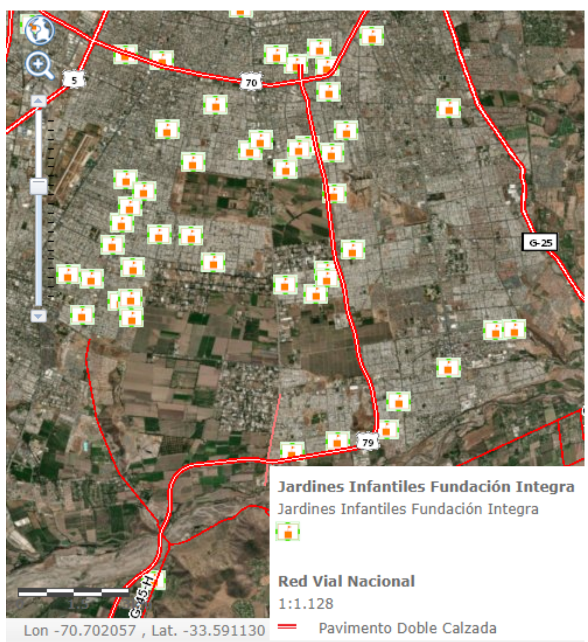
Source: Source: Own elaboration using 2019 data from MINSAL. Map also available in: http://www.geoportal.cl/geoportal/sharedMap?id=5e69aaaa2c2428720f1be94bbc74d934

Figure 31: Distribution of Educational Establishments



Source: Source: Own elaboration using 2019 data from Ministerio de Educación. Map also available in: http://www.geoportal.cl/geoportal/sharedMap?id=5e69aaaa2c2428720f1be94bbc74d934

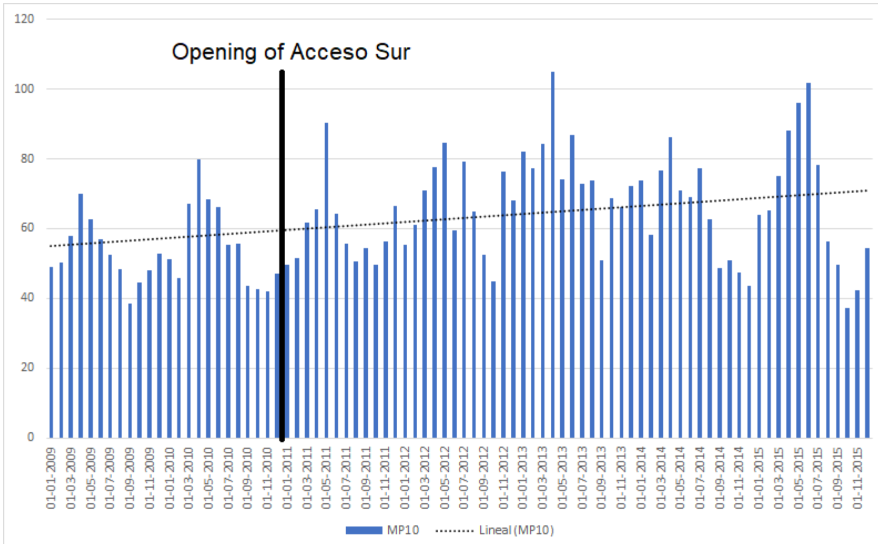
Figure 32: Distribution of Nurseries and Day Care Centres from Fundación Integra



Source: Source: Own elaboration using 2013 data from Fundación Integra. Map also available in: http://www.geoportal.cl/geoportal/sharedMap?id=5e69aaaa2c2428720f1be94bbc74d934

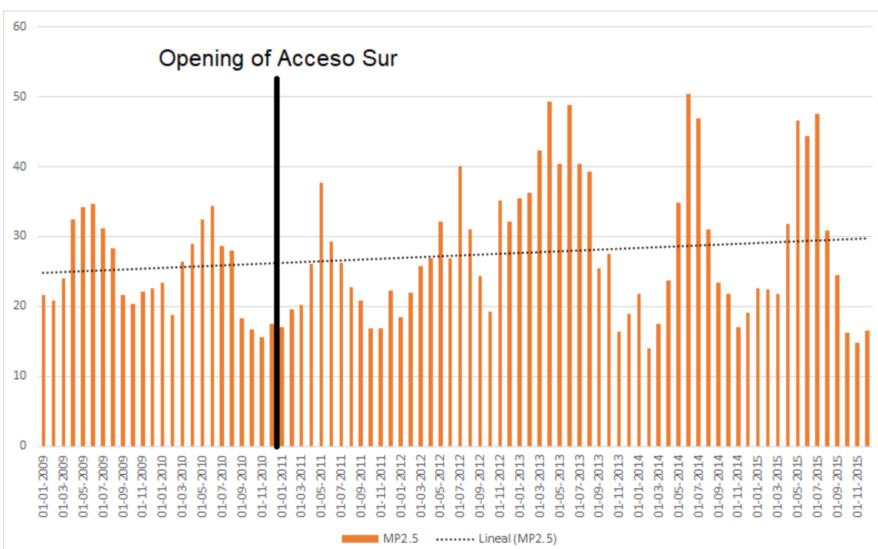
J Negative Environmental Externalities of *Acceso Sur*

Figure 33: Particulate Matter 10 as measured in Puente Alto environmental station



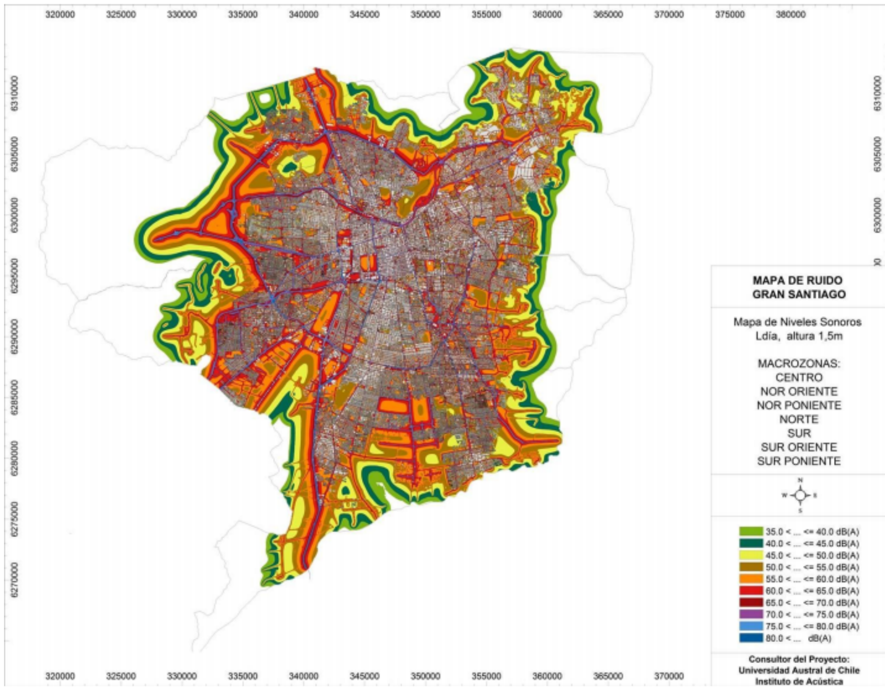
Notes: Only validated records, monthly average (g/m). Source: SINCA (2019). The primary norm of air quality for MP10 is 150 g/m3N as a 24 hours concentration, and 50 g/m3N as anual concentration. (DS N°59/1998 MINSEGPRES).

Figure 34: Particulate Matter 2.5 as measured in Puente Alto enviromental station



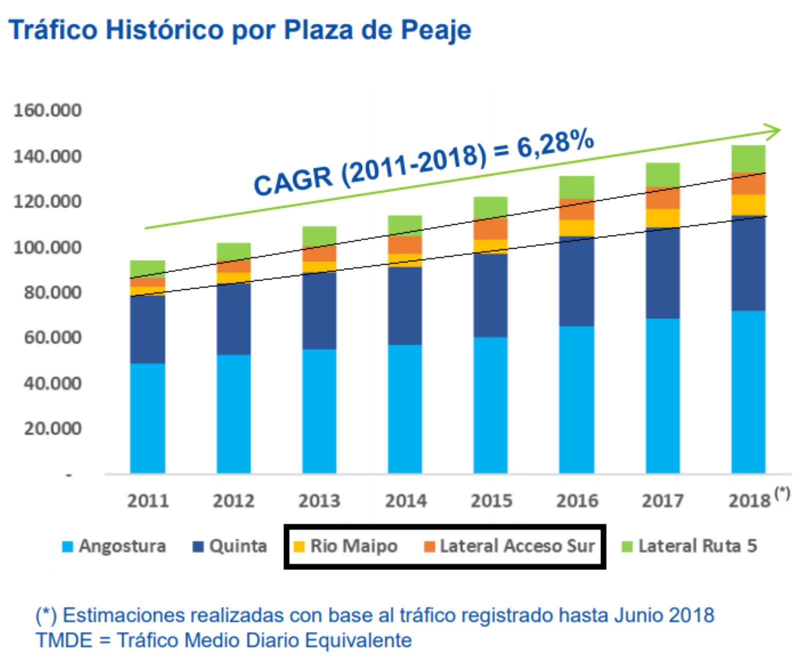
Notes: Only validated records, monthly average (g/m). Source: SINCA (2019). The primary norm of air quality for MP10 is 20 g/m3N as a 24 hours concentration, and 50 g/m3N as anual concentration. (DS N 12/2010 Ministerio del medio Ambiente).

Figure 35: Acoustic map of land transport during day hours for the Gran Santiago, 2016



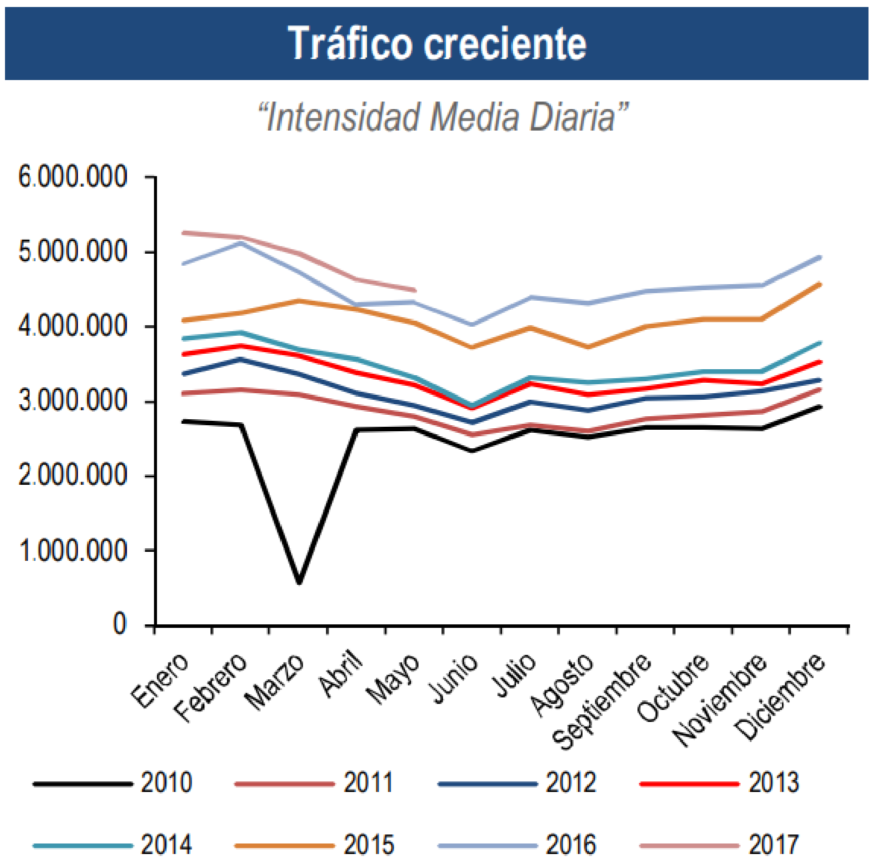
Source: de Acústica UACh (2016)

Figure 36: Vehicle Flow in *Acceso Sur* Highway as Measured by Payed-Tolls Registries



Source: Ruta del Maipo (2018b)

Figure 37: Vehicle Flow in Ruta Maipo Highway as Measured by Daily Medium Intensity



Source: Feller Rate (2017)

K Pictures of *Acceso Sur*

Figure 38: *Acceso Sur* pedestrian runway (near Rosa Ester street)

Source: Google Maps

Figure 39: *Acceso Sur* elevated crossing point (Av. Eyzaguirre)

Source: Google Maps

Figure 40: Streets running above *Acceso Sur* highway's underground section (Av. Cardenal Raúl Silva Henríquez with Pedro Lira street)

Source: Carrasco (2015)

Figure 41: Crossing point at the surface-level portion of *Acceso Sur* highway (at the intersection with Batallón Chacabuco street)

Source: Carrasco (2015)

Figure 42: Street graffiti asking for a traffic light ("*Would you give us 1 traffic light?*")

Source: Landon (2013)