The effects of transport infrastructure on housing supply: the role of land-use regulation*

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May 31, 2024

Abstract

We study the impact of new transportation infrastructure on housing supply using historical and micro data from Santiago and exploiting instrumental variables. We find that subway and highway expansions increase residential floor space substantially, but when we account for land-use regulation, we see two contrasting dynamics in the city. In the wealthiest quintile, the effect is negligible for more than 95% of the blocks due to their initial stringent regulation. However, in blocks in the first four quintiles of wealth, the impact on housing supply is substantial and homogeneous concerning the initial regulation. We provide evidence that the transport infrastructure triggers regulation to become more permissive everywhere but in the wealthiest neighborhoods. We quantify how land-use regulation limits housing supply, thus restraining welfare gains from transport infrastructure improvements.

1 Introduction

Increasing housing supply and the need for affordable housing has become a critical policy challenge in most large cities worldwide. Major urban centers have experienced an unprecedented housing affordability crisis, substantially burdening urban households. Many individuals face high rents or mortgage payments that consume a significant portion of their income. In the USA, the proportion of cost-burdened renters has doubled from 24% in the 1960s to 48% in 2016, and the median home value has risen by 112%, surpassing the 50% increase in median owner income (Favilukis et al., 2022).[1] Hsieh and Moretti (2019) argue that the scarcity of affordable housing options has underutilized the USA's most productive cities, emphasizing the

*The authors gratefully acknowledge helpful comments by Guillermo Alves, Fernando Ferreira, Felipe González, Jeanne Lafortune, Esteban Puentes, Fernanda Rojas-Ampuero, Pablo Valenzuela and participants of the 2020 Virtual Meeting of the Urban Economics Association, 2021 ITEA conference, 2021 LAUrban online seminar, and the 1st Annual LAUrban Meeting. We also thank Alan Thomas and Rodrigo Contreras from SECTRA. The authors gratefully acknowledge financial support from Chile's Agencia Nacional de Investigacion y Desarrollo (ANID) FONDECYT grant 1231755 to KA, ANID FONDECYT grant 1200801 to HS, ANID/FONDAP 1522A0002 to KA and HS, ANID PIA/PUENTE AFB220003 to HS, and ANID Millennium Nucleus on Intergenerational Mobility: From Modelling to Policy (MOVI) [NCS2021072] to KA.
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[1]Airgood-Obrycki et al. (2021) estimate that the number of renter households in the US who do not have enough income to afford a comfortable standard of living after paying rent and utilities each month is around 60 percent of working-age renter households (19.2 million).

criticality of addressing this issue. The COVID-19 pandemic further exacerbated the urgency of the affordability crisis.

The situation is equally concerning elsewhere. In the developing world, one-third of urban households experience overcrowding or reside in inadequate housing conditions, lacking access to basic amenities such as water, sanitation, and durable construction materials. This information, reported by the United Nations (2016), highlights the significant housing challenges urban populations face in developing countries. Inadequate housing conditions affect individuals' quality of life and well-being, hinder socioeconomic development, and perpetuate inequality. The issues are also pressing in upper-middle-income countries such as Chile. Alves (2021), using data from Brazil, shows that the equilibrium interaction between substantial household mobility and low housing supply elasticities explains how unbalanced urban economic growth leads to slum growth. Addressing the housing needs of urban families is crucial for improving living standards, reducing poverty, and fostering equitable urban growth.

This paper studies how the construction of transport infrastructure increases housing supply and the role of urban land-use regulation in shaping this impact. Specifically, we investigate the effect of increased accessibility on a city's residential floor space and how this response varies within the city and with different zoning and land-use regulations. The floor space supply response within a city is crucial for understanding urban policies and investment impacts. For example, it is central to assessing place-based policies and evaluating the causes of the differences in growth between household income and housing prices that have led to affordability issues.

We use detailed floor space and regulation data on over 11,000 blocks and exploit variation created by a substantial investment in urban transport infrastructure in Santiago, Chile. The subway network grew by 36 percent, and over 200 km of urban highways were built (see Figure 1) between 2001 and 2010, our study period. We deal with the potentially endogenous location of the infrastructure by exploiting instrumental variables based on historical data on floorspace, planned urban highways, and planned subway lines.

To guide our empirical analysis, we sketch a spatial equilibrium model based on recent work on quantitative urban models that delivers a log-linear relationship between a measure of access to employment and residential floor space. This measure captures general equilibrium effects, and, therefore, by estimating the elasticity of housing supply to this measure of accessibility, we overcome the concern of mixing general equilibrium effects. We also overcome the difficulty of separating spillovers from other location-specific time-varying factors typical of studies of distance-based treatments.

Our study provides three main results regarding the impact of the transportation infrastructure. First, we find that a ten percent increase in CMA induces an eight percent increase in the residential floor space. This result reveals the strong relevance of highways and subway lines in increasing the housing supply through market mechanisms. Second, the effect is not strongly heterogeneous concerning distance to the CBD and initial floor space density. Third, we also find that an increase in CMA has a more minor and not statistically significant effect on the residential floor space in blocks whose residents belong to the wealthiest income quintiles. These results contrast the substantial within-city heterogeneity of housing supply elasticities found by Baum-Snow and Han (2023) for the USA.

As for the role of land-use regulation, our main contribution is to quantify its relevance in determining how the equilibrium outcomes' response varies within the city and across socioeconomic groups. In blocks whose residents belong to the first four socioeconomic quintiles, the market access elasticity of housing is homogeneous across all levels of baseline regulation and moderately larger than the average effect. While this may seem counterintuitive, we provide evidence that the baseline regulation was initially permissive and becomes even more permissive in places where the increased accessibility is higher to accommodate the response to the demand shock caused by the infrastructure.

We also find that the urban dynamics differ in blocks with wealthier residents (in the wealthiest quintile of the sample). The elasticity is much smaller and not statistically different from zero for 96% of the blocks. We further show that the baseline regulation is initially restrictive in these blocks and, importantly, does not become less stringent with increased commuter market access. Hence, constricting regulation prevents residential floor space growth only in high-income residential areas, unlike in the rest of the city. The result is consistent with the home-voter theory of regulation (e.g., Fischel, 2005), but only at work for the wealthiest. It is also consistent with the fact that more stringent regulation correlates with the presence of homeowners associations in the USA (Clarke and Freedman, 2019), albeit through a different mechanism. The regulation was significantly softened in middle- and low-income areas to allow for development, which is consistent with the growth-machine hypothesis of regulation.

Our article provides general insights into the recent literature about housing supply. Murphy (2018) estimates a dynamic model of housing supply and shows that pro-cyclical costs incentivize some landowners to build before price peaks and that owners actively "time" the market, which reduces the elasticity of supply. Henderson et al. (2020) develop a dynamic model of housing supply differentiating the formal and informal technology. Saiz (2010) and Baum-Snow and Han (2023) study the floor space price elasticity using US data; Saiz (2010) focuses on differences between cities, while Baum-Snow and Han (2023), like us, concentrate on within-city differences. Our results are consistent with Baum-Snow and Han's (2023) findings, who find a substantial variation of floor space elasticities within the cities. However, they find that floor space supply responses increase with distance to the CBD, heterogeneity that does not hold in our study. We claim that the previous departure from the literature regarding heterogeneity relative to distance from the CBD is because Santiago's central area was relatively underdeveloped in the 2000s. This highlights the value of providing evidence from developing and middle-income country contexts.

Our findings reveal that considering the effect's heterogeneity may be crucial and differ significantly across countries. Recent research on quantitative models that focus on the effect of transport infrastructure on outcomes within cities typically assumes a constant price elasticity of floor space (see, e.g., Tsivanidis, 2023; Zárate, 2022; Heblich et al., 2020). Our work is more closely related to Tsivanidis (2023) and Severen (2021), who study the effect of the Bus Rapid Transit (BRT) system TransMilenio in Bogotá and Los Angeles Metro Rail, respectively, using data at the census tract level. Tsivanidis (2023) shows that commuter market access significantly affects real estate prices, employment, worker spatial reallocation, and welfare, but not housing supply.[2] Severen (2021) estimates the effects of the Los Angeles Metro Rail on similar urban outcomes, finding that the housing supply was inelastic.

Our paper also contributes to the literature on the spatial distribution of economic activity. While Baum-Snow (2007), Garcia-López et al. (2015), Baum-Snow et al. (2017), Gonzalez-Navarro and Turner (2018), and Baum-Snow (2020) study the decentralization of population in cities due to transport infrastructure changes, they do so by using two aggregate zones for metropolitan areas, namely the city center, and suburbs. We study the effect of transport infrastructure on economic activity using microdata at the block level.

Finally, we also contribute to the literature that studies or documents the impacts of regulation. Recent contributions include Turner et al. (2014), Gyourko and Molloy (2015), Severen and Plantinga (2018), Clarke and Freedman (2019), Gyourko et al. (2021), and Buitrago-Mora and Garcia-López (2023). We complement the literature by providing evidence from Latin America and studying its impact on shaping the equilibrium response to changes in transportation costs within a city.

2 Background and Data

We study the effect of a substantial investment in transport infrastructure in the Greater Santiago Area (henceforth, Santiago) between 2001 and 2010. During this decade, Chile's per capita GDP increased almost twofold from 9,937 USD to 18,129 USD (OECD, 2017), transitioning from a middle-income country to a high-income country (World Bank, 2019).

Santiago accounts for over 40 percent of the country's population and GDP (Banco Central, 2023). It has an extension of approximately 838 km^2 (INE, 2018), slightly larger than New York City, and in the studied period (2001 to 2010), experienced a population increase of 17.4 percent, from 6,061,185 to 7,112,808 inhabitants (INE, 2017). Inequality has been an issue in the country and Santiago for decades. Chile's Gini coefficient in 2000 was 0.55, and Santiago's Gini coefficient has been relatively similar in the last two decades (Asahi, 2015). In 2009, Chile was among the 12 percent most unequal countries according to the Gini coefficient (Asahi, 2015).

2.1 Transport infrastructure and commuting

2.1.1 Subway stations

Santiago's subway system was inaugurated in 1975, and by 2001, the subway network comprised three subway lines with 54 stations and 40 km of tracks. By then, the system encompassed a central line connecting the east and the west and two lines connecting the center with the southern part of the city (see Figure 1's Panel 1a). By 2010, the government had inaugurated over 53 km of additional subway rails, an increase of 36 percent in the network, making up 94 km and 101 stations. Two new lines, lines 4 and 4A, connected the southeastern part of the

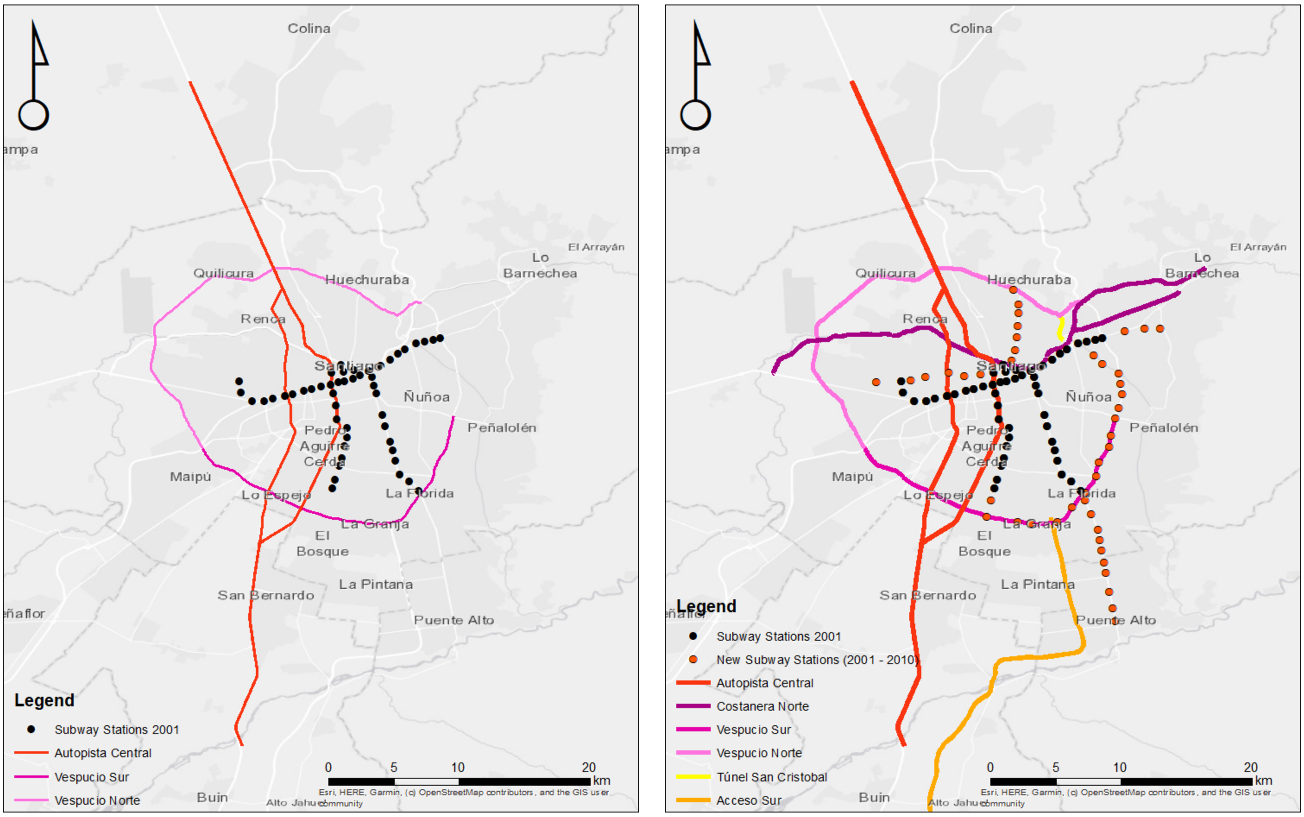
[2] There is also substantial evidence that property prices increase in the vicinity of new highways (Levkovich et al., 2016; Theisen and Emblem, 2020) and subways (Gibbons and Machin, 2005; Ahlfeldt, 2013; Bowes and Ihlanfeldt, 2001).

city (see Figure 1b). Also, 20 stations were added to existing lines, most expanding the network to the city's north.

As Figure 1 reveals, all parts of the city experienced an increase in proximity to the subway network, where the average distance to a station decreased from 6.3 to 4.3 km. The metro system recorded over two million daily trips, almost doubling 2001's usage (Metro de Santiago, 2010).

Figure 1: The evolution of Santiago's transport infrastructure (2001 - 2010).

(a) Transport Infrastructure in 2001 **(b)** Transport Infrastructure in 2010



Notes: Figure 1a shows Santiago's subway and urban highway networks in 2001, and Figure 1b shows the subway and urban highway networks in 2010.
Source: Own elaboration. The maps use georeferenced information on subways and urban highways from Pontificia Universidad Católica de Chile's "Observatorio de Ciudades UC" and the Chilean 2017 pre-census street shapefile.

2.1.2 Urban highways

Santiago substantially invested in urban highways during the 2000s. Between 2000 and 2006, the Chilean government planned the construction of 207 km of urban highways in six different projects valued at 1,582 million USD. One of the objectives of this massive intervention was to reduce the infrastructure deficit in the city (Gutiérrez and Fuentes, 2014). The highway network uses a free-flow tolling system (Gobierno de Chile, 2003), with an average toll of 0.32 USD/km.

Figure 1 shows a map of Santiago's urban highways. The Autopista Central highway is the urban segment of the country's main intercity highway (Ruta 5) and has an (urban) extension of 61 km. The Costanera Norte connects east to west and is located in the city's northern area, with an extension of 42 km. The Américo Vespucio ring road, formed by Vespucio Sur (24 km) and Vespucio Norte (29 km), adds up to 53 km of highways.[3] The Acceso Sur highway connects the Vespucio Sur ring road with Ruta 5 in the south. Finally, the Túnel San Cristóbal connects Vespucio Norte with Costanera Norte in the western part of the central city.

2.2 Urban regulation in Chile

The urban land-use planning process in Chile involves several agents and policies. We provide a concise overview of the process. The Ministry of Housing and Urbanism is responsible for formulating regional and inter-municipal plans. Yet, the local land-use plans and detailed neighborhood-level plans are developed by municipalities.[4] These plans typically involve maximum FAR and height and land use allowed, among others, and are usually enforced. Indeed, according to OECD (2017), referring to the neighborhood-level regulation plans, "Where they exist, they form statutory land-use plans and tend to be strictly enforced."

The process and the regulation itself are substantially different than in the US. The main actors in the Chilean regulatory process that directly concern block-level regulation are the municipality mayor, the Municipal Council, and the urban planning advisor. In the USA, as Glaeser and Gyourko (2018) summarize, land-use regulation is under local control, and minimum-lot-size regulation is widely used and usually strict in the suburbs.

Another critical difference between the US and Chile is the effect of single-family zoning. In the US, this regulation that restricts developments to single-family units and effectively prevents tall buildings is prevalent in most metropolitan areas. For example, in many United States cities, 75% of land zoned for residential uses is zoned for single-family units (Badger and Bui, 2019). Moreover, "most single-family houses constructed in the United States in recent years are part of a common interest development (CID), governed by a homeowners association (HOA)" (Clarke and Freedman, 2019). Clarke and Freedman (2019) estimate a HOA premium in prices that is, on average, 4%. In Santiago, this type of regulation is rarely used, and it has been documented that it is not among the most relevant factors for floor space suppliers (Waintrub et al., 2016). Instead, the maximum FAR and height are usually the most pertinent factors.

2.3 Data

We obtained the floor space data from the Chilean Internal Revenue Service (Servicio de Impuestos Internos, SII). The SII categorizes the floor space into different land uses and disaggregates such information at the SII block level. We use the data for 2001 and 2010. The land uses include residential, commercial, educational, industrial, and services.[5] This study focuses on residential land use. Our sample is the blocks located in the urban area, within a 3km radius

[3] The ring road's missing segment is the Vespucio Oriente highway project, which is under construction as of 2022.

[4] This holds for municipalities with more than 50,000 inhabitants and if they employ an urban planner, which is the case for all the municipalities in the Greater Santiago Area.

[5] The land-use purposes are commerce, education, residential, industrial (industrial and mining activity), services (including public administration, offices, and health), a category named as not considered (that includes vacant land, agricultural land, forests, and everything not defined and without information), and others (including hotel, motel, sports and recreation, cult and others) (Suazo, 2017).

of a new subway station or an urban highway entry or exit. We explain the criteria to define the sample in more detail in Section 3.

Of the 45,041 blocks in Chile's Internal Revenue Service data, 34,151 SII blocks are three kilometers or closer to the post-expansion subway stations or urban highway entry or exit. Because of observations that are not physically feasible (such as floor space density of over 2,000), we winsorized 0.1 percent of the sample based on floor space and changes in floor space density values. This is 146 blocks, which is 0.32 percent of all blocks. Further descriptions of the winsorizing process and the outliers are in Appendix B1. As explained in Section 2.3.1, we have regulation data for 15,579 blocks; the final sample consists of 11,165 blocks.

We use Chile's 2002 population census (Instituto Nacional de Estadisticas, INE) to compute the socioeconomic covariates at the SII block level, such as socioeconomic decile, population, and the number of households. Lastly, we use GIS tools to calculate proximity covariates for each block's centroid, such as distance to subways, urban highways, and the CBD.

Table 1 summarizes descriptive statistics of the sample's blocks and baseline covariates. On average, blocks have a surface area of 10,280 square meters, 118 inhabitants (a density of 23,061 inhabitants per square kilometer), and 35 households. The sample's average residential floor space in 2001 was 3,316 m^2, which increased to 3,876 in 2010. The median block belongs to the 7th socioeconomic decile of the country, reflecting the fact that Santiago is relatively wealthy.[6] On average, the distance to the closest subway station decreased from 3 km in 2001 to 2 km in 2010. The average sample block is 7 km from the city's central business district and 1.3 km away from the closest urban highway in 2010.

Table 1: Descriptive statistics of the sample of blocks studied.

	Mean	SD	Min	Max
Socioeconomic decile	7	2	1	10
Population per block	118	99	2	1,726
Households per block	35	36	1	553
Block area (m^2)	10,095	31,672	64	1,259,430
Population density (population/km^2)	23,790	25,221	8	1,191,291
Block radius (m)	47	33	5	766
Residential floor space 2001 (m^2)	3,279	5,251	15	82,512
Residential floor space 2010 (m^2)	3,832	6,276	15	86,148
Min. distance to a subway station in 2010	1.98	1.41	0.04	8.57
Min. distance to a subway station in 2001	3.03	2.07	0.05	11.49
Min. distance to a new subway station in 2010	2.39	1.33	0.04	8.57
Min. distance to an urban highway	1.31	0.92	0.03	4.67
Min. distance to a main road in 2001	1.40	1.20	0.01	8.44
Min. distance to the CBD	7.00	3.06	0.13	18.90
Observations	11,165			

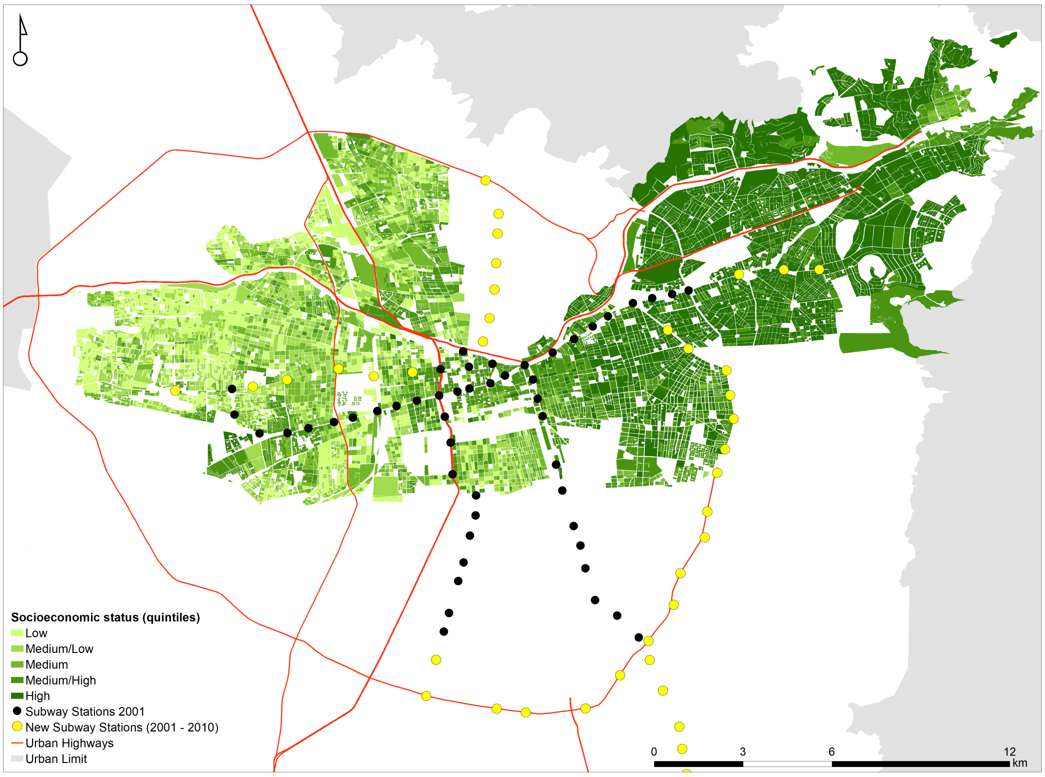
Notes: The table shows descriptive statistics of the sample of blocks located within the urban limit, within a 3km radius of a new subway station or an urban highway entry or exit. Variables studied are the socioeconomic level of the block, reporting the median socioeconomic decile. Also, the mean and standard deviation on the population, the number of households, surface area, density, radius of blocks, and the residential floor space in 2001 and 2010. The mean distances in kilometers to subway stations in 2010, 2001, and those inaugurated between 2001 and 2010, distance to the nearest urban highway, the nearest main road in 2001, and the central business district (CBD).
Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII) and data from the INE's 2001 population Census.

Figure 2 shows the spatial distribution of socioeconomic quintiles in the sample studied.

[6] The Chilean 2002 Census dataset reports a socioeconomic status index that takes discrete values from 1 to 10.

Darker colors represent blocks whose residents, on average, are in the highest socioeconomic quintile of the sample. There is a significant concentration of high-income families in the city's northeast. On the other hand, in the west, there are relatively more blocks from the lowest socioeconomic quintile than in the rest of the city.

Figure 2: Socioeconomic status in 2001 (quintiles).



Notes: The figure presents the distribution of the socioeconomic status of the sample expressed in quintiles. The sample studied is the blocks in the urban limit, within a 3km radius of a new subway station or an urban highway entry or exit. **Source:** Own elaboration using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII) and data from the INE's 2001 population Census.

Table 2 summarizes the initial floor-to-area ratio and the change in log floor space by socioeconomic quintiles between 2001 and 2010. The average floor space growth is 11 percent, with a standard deviation of 28 percent, a median of 5 percent, and a proportion of blocks without changes of 13 percent. These changes differ by socioeconomic quintile, where blocks in the lowest and highest socioeconomic quintiles experience changes above the average. Table 2 also shows that the sample's average initial floor space density is 0.43, increasing with the block's wealth. The difference in the changes in floor space by socioeconomic quintiles may be due to low initial density levels in these blocks.

To provide intuition on how the changes in floor space are related to the proximity to the new urban transport infrastructure (subway stations and urban highways), Figure 3a presents the spatial distribution of the variation in log floor space between 2001 and 2010 for residential land-use. It shows an increase in floor space near subway stations and urban highways. There are increases in floor space in the city's periphery, close to the new urban highways, which could represent an incipient suburbanization tendency, as found in Baum-Snow (2007) and

Table 2: Change in log floor space by socioeconomic status (2001 - 2010).

	Mean	SD	Median	Proportion of zeroes	Baseline residential floor space density
Total	11%	28%	5%	13%	0.46
Lowest quintile	14%	29%	9%	13%	0.28
Medium/Low quintile	11%	23%	6%	12%	0.35
Medium quintile	9%	22%	4%	16%	0.43
Medium/High quintile	10%	34%	2%	18%	0.68
Highest quintile	12%	31%	4%	9%	0.57%
Observations	11,165				

Notes: The table shows summary statistics of the change in the log floor space from 2001 to 2010 and the floor-to-area ratio in 2001, by socioeconomic status (quintiles), for the sample studied, which are blocks located in the urban limit, within a 3km radius of a new subway station or an urban highway entry or exit.
Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII) and data from the INE's 2001 population Census.

Baum-Snow et al. (2017). Because a relevant proportion of the correlation between an increase in floor space and the new urban transport infrastructure is in the city's wealthy northeast, we explore a similar visual correlation controlling for baseline characteristics.

Figure 3b shows the changes in floor space after controlling for baseline residents' income, distance to transport infrastructure (main roads and subway stations in 2001), population, location in the city (quintiles of distance to the CBD and dummies of the part of the city in which the block is located), and log accessibility in 2000. The pattern is similar to Panel 3a with a slight decoloration in the periphery, suggesting that the city's growth patterns were not explained by income, population, distance to the new urban transport infrastructure, location in the city, or previous accessibility.

2.3.1 Regulation data

The dataset used to characterize the urban regulation consists of approximately 201,400 lots in fourteen municipalities of Santiago, which we mapped to around 15,000 blocks. We built this dataset from inputs from TocToc, a real estate company that processed available public information, and from documents provided by the municipalities as raw data (decrees, municipal ordinances, and communal regulatory plans).

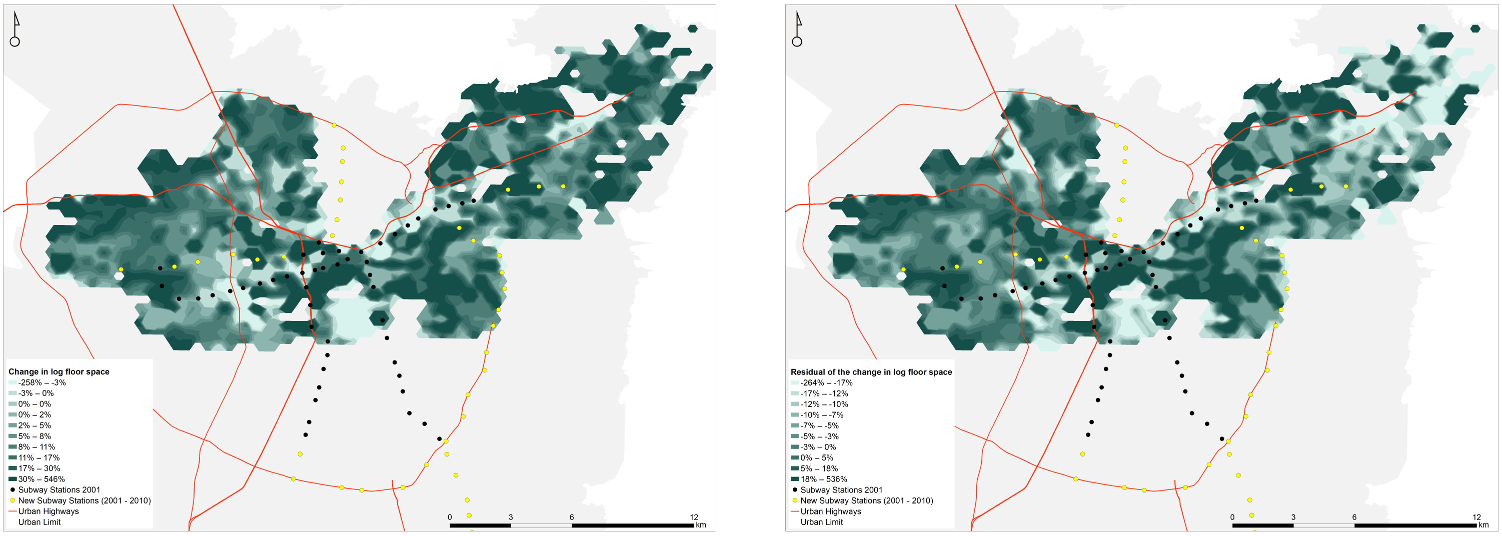
This unique dataset describes maximum height, floor-to-area ratio, building coverage ratio, population density, and allowed land use for 2001 and 2010. As the information is at the level of the lot, we compute the weighted average of the lots' indicators for each block using each plot's surface as weights. Additionally, we compute the difference between the maximum and the actual floor area ratio, i.e., the additional floor space that can be built. We denote this measure as a block's real estate potential (REP). Finally, we winsorized the lowest 1 percent of the sample with data on regulation based on the value of REP.[7]

Table 3 shows descriptive statistics of all three regulation variables in 2001 and 2010. The average REP decreased from 77% to 74% on average from 2001 to 2010. The mean FAR allowed by the regulation was 4.4 in 2001 and decreased slightly to 4.2 in 2010. Lastly, the

[7]These are 127 blocks with a REP lower than -250 percent for each year, meaning 250 percent built above the limit in the regulation. This scenario is technically possible as the norm is not retroactive, and regulation could have decreased over time in already developed blocks. Further descriptions of the winsorizing process and the outliers are in Appendix B1.

Figure 3: Smoothed difference in log floor space (2001 - 2010).

(a) No controls. **(b)** Controlling for baseline characteristics.



Notes: Figure 3a presents the distribution of the change in log floor space for residential land use between 2001 and 2010. Figure 3b displays the distribution of the change in log floor space for residential land use between 2001 and 2010, controlling for baseline covariates (the residual of the regression of change in log floor space on baseline covariates, which are log accessibility 2000, log distance to main roads (Alameda, Ruta 5, and Vespucio), log distance to the nearest subway station in 2001, dummies of the part of the city in which the block is located (North, West, East, or Center part of the city), quintiles to the central business district, log population, log surface area, and the baseline socioeconomic quintile of the block).
Source: Own elaboration using ArcGIS's Kernel Interpolation with Barriers, using the Epanechnikov kernel function and quintiles as the data classification method. The land-use information for 2001 and 2010 comes from the Chilean Internal Revenue Service (SII).

mean maximum height for residential land use was 43 meters, roughly equivalent to thirteen floors, and was reduced to 41 meters in 2010. These statistics show that the regulation became slightly more stringent.

Table 3: Descriptive statistics of regulation for residential land-use

	2001		2010		Change	
	Mean	SD	Mean	SD	Mean	SD
REP	76.71	32.72	74.13	34.54	-2.58	14.02
FAR	4.42	3.87	4.15	3.70	-0.27	1.35
Height	43.33	35.55	40.88	34.67	-2.45	13.18
Observations	11,165		11,165		11,165	

Notes: The table shows descriptive statistics of the real estate potential for residential land-use (REP), floor-to-area ratio (FAR) regulation, and height regulation for blocks located in the urban limit within a 3km radius of a new subway station or an urban highway entry or exit.
Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII) and the dataset on regulation described in Section 2.3.1.

3 Framework and empirical strategy

Recent literature has advanced the understanding of the internal city structure by developing quantitative spatial models of cities. These models have generalized the relationship between the density of economic activity and access to transportation infrastructure (see, e.g., Ahlfeldt et al., 2015). Accounting for agglomeration, residential externalities, amenities, and production, this class of urban models has shown that a single measure of accessibility summarizes the effect of a city's entire transit network on any location (Tsivanidis, 2023). The measure, usually referred to as commuter market access (CMA) or residential market access (RMA), reflects the access to jobs and considers the commuting times from a location to all others weighted by some measure of employment.

This strand of literature provides the theoretical foundation for our reduced-form estimation of the impact of increased CMA on residential floor space. A higher CMA increases the willingness to pay for floor space—a demand-side effect—which induces the developers' response that, in equilibrium, may be reflected in increased floor space – a supply-side impact. By looking at the effect of market access on the residential floor space, we study the changes in equilibrium floor space supply—whether supply- or demand-driven.

We sketch an urban spatial model that captures individual labor and housing decisions to conceptualize the relationship between transportation investments and housing demand. We then complement the model with a simple housing supply model, which allows for solving the equilibrium and provides theoretical support for our reduced-form strategy.[8]

3.1 The model

The model draws elements from Ahlfeldt et al. (2015), Tsivanidis (2023) and Baum-Snow and Han (2023), but abstracts from modeling worker heterogeneity, externalities, and nested choices to focus on the central intuition. Moreover, we focus on the workers' side of the model to derive the structural relationship between residential floor space and commuter market access.

3.1.1 Workers

A continuum of individuals with unit mass choose where to live and work and have Cobb-Douglas preferences over a numeraire good and housing. This implies that individuals spend a constant share of their income on each good (β for the numeraire and $1-\beta$ for housing). An individual living in i and working in j earns a salary of w_j and has a disutility from commuting d_{ij}, which is a function of the travel time t_{ij}. Letting amenities, A_i, and commuting affect utility multiplicatively, and p_i be the price per unit of residential floor space, the indirect utility that individual ω receives from a pair of residential and work locations (i, j) is:

$$v_{ij} = \frac{A_i w_j p_i^{\beta-1}}{d_{ij}} z_{ij} \tag{1}$$

where z_{ij} is an idiosyncratic shock and varies with the individual's blocks of residence and employment.

The elements from the model that depend on the commuting pair i, j (the commuting disutility and the shock) can be interpreted in two ways. One interpretation is that traveling reduces the effective labor supply at the workplace, so the income perceived is w_j/d_{ij}, and z_{ij}

[8]For details about the urban models that deliver the relationship between outcomes and CMA, see Redding and Rossi-Hansberg (2017) for a review of the topic, and Ahlfeldt et al. (2015), Tsivanidis (2023), and Heblich et al. (2020) for recent studies.

is a productivity shock. The second interpretation is that d_{ij} directly affects the utility and is unrelated to productivity or wages, and z_{ij} is a utility shock.[9]

The shock captures that individuals can have idiosyncratic reasons for living and working in different areas. As it is common in the literature, we assume that the shock z_{ij} is drawn from a Frechet distribution with shape parameter θ and scale parameter $s = 1$:[10]

$$F_z(z_{ij}) = e^{-z_{ij}^{-\theta}}, \ \theta > 1 \tag{2}$$

This is the simplest way to model the heterogeneity in the utility derived by choosing the commute pair (i, j). Using the properties of the Frechet distribution, the probability that a worker chooses to live in i and work in j is:[11]

$$\pi_{ij} = \frac{(A_i w_j p_i^{\beta-1}/d_{ij})^\theta}{\sum_r \sum_s (A_r w_s p_r^{\beta-1}/d_{rs})^\theta} \tag{3}$$

Intuitively, places with higher amenities and lower prices are more attractive, and higher wages and low commuting costs attract workers.

Summing over all destinations j, we can write the resident supply to block i as:

$$\pi_i = \lambda_P \left(A_i p_i^{\beta-1}\right)^\theta \text{CMA}_i \tag{4}$$

$$\text{with } \ \text{CMA}_i \equiv \sum_j (w_j/d_{ij})^\theta \tag{5}$$

where λ_P is constant across locations, and CMA_i is block's i Commuter Market Access.

Equation (4) shows that in equilibrium, the population of block i is increasing in the CMA, conditional on prices, as it has better access to employment. Before the shock is revealed, the expected income of living in i, $\bar{y_i}$ is:

$$\bar{y_i} = \mathbb{E}\left[\max_j w_j z_{ij\omega}/d_{ij}\right] = \lambda_R \text{CMA}_i^{1/\theta} \tag{6}$$

where $\lambda_R = \Gamma(1 - \frac{1}{\theta})$ is a constant.

Using that individuals spend a share of $1 - \beta$ of the income on housing and Eq. (6), the aggregate housing demand in block i follows:

$$H_i = \lambda_R \frac{\pi_i (1-\beta)}{p_i} \text{CMA}_i^{1/\theta} \tag{7}$$

Equation (7) predicts that the housing demand increases in the commuter market access and

[9] Thisse et al. (2021) provide an interpretation where a continuum of types of individuals is represented with preferences over all origin-destination pairs.

[10] Ahlfeldt et al. (2015) assumes that the shape parameter depends on origin- and destination-specific values. Tsivanidis (2023) and Baum-Snow and Han (2023) introduce nested preference shocks over residential locations that allow for modeling an additional margin of substitution in demand for residential locations.

[11] The key to derive the result is that the distribution of the indirect utility follows a Frechet distribution with the same shape parameter θ and a scale parameter of $(A_i w_j p_i^{\beta-1}/d_{ij})$. Moreover, the maximum also follows a Frechet distribution with shape parameter θ and a scale parameter of $\sum_{i,j}(A_i w_j p_i^{\beta-1}/d_{ij})$. The full derivations are in the Appendix of Ahlfeldt et al. (2015).

amenities and decreases in the price. Importantly, it provides the intuition for the direct effect of an investment in infrastructure. Impacting commuter market access, conditional on prices and population, induces a housing demand shock. However, as shown below, the indirect effect through equilibrium changes is relevant and can also be expressed as a function of CMA.

3.1.2 Housing supply

We close the housing market by modeling the supply of residential floor space. We follow Brueckner et al. (1987) and Brueckner et al. (2017) and consider a perfectly competitive market where firms use the fixed amount of available land per block $\bar{L}_i$ and capital K to produce housing, according to the concave constant returns function $H_i(K, L)$. These firms rent land and capital at prices r and ι, respectively. Let S be the capital-land ratio and $H(S, 1) \equiv h(S)$, giving floor space per land unit. The profit per unit of land of a developer in block i is then:

$$p_i \cdot h_i(S) - \iota \cdot S - r_i \tag{8}$$

As customary in the literature, we assume that the production function has the following Cobb-Douglas form $H_i(K, L) = B_i L_i^{1-\alpha} K_i^{\alpha}$. This implies that $h_i(S) = B_i S^{\alpha}$ and, using profit maximization, the supply of floor space per unit of land in block i is given by:

$$h_i = \left(\frac{\iota}{\alpha}\right)^{\frac{\alpha}{\alpha-1}} \cdot p_i^{\frac{\alpha}{1-\alpha}} \tag{9}$$

which can be transformed into aggregate supply per block by multiplying it by $\bar{L}_i$.

As for the regulation, we follow Brueckner et al. (2017) and model a FAR limit as a maximum value of $h_i(S)$, which, in turn, implies a maximum value of the capital to land ratio. If the unrestricted supply is beyond this limit, then the supply becomes inelastic and equal to the limit $\bar{h}_i$. In summary, the aggregate housing supply in block i is:

$$H_i^S = \begin{cases} \bar{L}_i \cdot \bar{\alpha} \cdot p_i^{\frac{\alpha}{1-\alpha}} \text{ if } & \bar{\alpha} \cdot p_i^{\frac{\alpha}{1-\alpha}} \leq \bar{h}_i \\ \bar{L}_i \cdot \bar{h}_i, & \text{otherwise} \end{cases} \tag{10}$$

where $\bar{\alpha} \equiv (\iota/\alpha)^{(\alpha/(\alpha-1))}$.

3.1.3 Housing market equilibrium

Combining the population supply equation in (4) with the market clearing condition for housing, we can solve for the residential floor space as a function of CMA. In particular, by equating demand in (7) and supply in (10), we can relate the price per unit of floor space at block i with population supply π_i and CMA_i. Then, we obtain the structural relation between prices and commuter market access by plugging in the expression for π_i from (4). Substituting this into the housing supply function, we obtain our main equation:

$$\ln H_i = \ln a_i + \frac{(1 + \frac{1}{\theta})\alpha}{1 + \theta(1-\beta)(1-\alpha)} \ln \text{CMA}_i \tag{11}$$

Where $\ln a_i$ is the log of the product between equilibrium constants, block i's area $\bar{L}_i$, and its amenities A_i.

Equation (11) provides a relationship between the housing supply and the commuter market access in block i. Moreover, it offers theoretical support for our empirical approach in that changes in CMA capture the full effect of the transport network. The housing supply elasticity depends on the individuals' preferences through β, the housing supply technology via α, and the dispersion parameter of the Frechet distribution. Intuitively, the market access elasticity of residential floor space is larger if the housing supply is more elastic to capital (larger α), if there is more dispersion in idiosyncratic preferences over residence and workplace pairs (smaller θ), and when housing is less important in the utility (larger β).

3.2 Empirical strategy

We estimate the first difference version of Eq. (11):

$$\Delta \ln H_i = \delta \cdot \Delta \ln \text{CMA}_i + \phi \cdot X_{i0} + \epsilon_i \tag{12}$$

By estimating the time-differenced equation, we control for time-invariant unobserved characteristics of blocks. We also control for pre-treatment (before the transport infrastructure expansion) baseline variables (X_{i0}), such as block surface and socioeconomic variables.

Our main identification concern is that infrastructure is not located randomly. If changes in the transport infrastructure (hence, in commuter market access) are correlated with changes in the time-varying unobservables, our estimates would be biased. This would happen if, for example, planners located the new subway lines based on expected structural density trends to enhance the city's growing areas or assist declining municipalities. We deal with the potentially endogenous location of the infrastructure using planned and historical routes as instrumental variables for the new infrastructure.

A second threat to identification, as described in Redding and Turner (2015), is that separating spillovers from other location time-varying factors requires additional assumptions in the presence of general equilibrium effects of transport infrastructure. We argue that this is less of a concern for two reasons. First, the treatment is continuous; thus, the identification is not based on differences between pure treated and control groups. Second, as our model shows, our measure is based on quantitative spatial models of the city and captures the full effect of the improvements in outcomes, considering all mechanisms (including general equilibrium effects).

Lastly, the changes in CMA rely on using endogenous outcomes, such as post-treatment employment. To deal with this, we instrument for the difference in market access by keeping labor outcomes and modal shares fixed at previous levels (more details below). In this way, we isolate the effect of travel time changes induced by the new infrastructure.

3.3 Planned route instrumental variable

To address the potentially endogenous placement of the subways and urban highways, we follow the tradition in the urban economics literature of using planned routes as instruments (see, e.g., Baum-Snow, 2007; Duranton and Turner, 2012; Redding and Turner, 2015; Brinkman and Lin, 2022).

In the 1950s, Santiago comprised 17 municipalities and began to experience the typical problems of a fast-developing big city. In response, the government implemented the first metropolitan regulation in 1960. The so-called *Plan Regulador Intercomunal de Santiago* put the municipalities under a common rule, defined the urban limit, and set the land use zoning for the entire city. A second effort to deal with urban growth was made in 1966 when the Chilean government called for the realization of a study of the transport system for Santiago. The study, awarded to a consortium of French companies and a Chilean consultant office, was delivered to the Chilean authorities at the end of 1967.

Based on the study described above, in 1968, the Chilean government published a transportation investment and regulatory plan. This is the primary source for our planned route instrument. The study includes analyses, projections, and general transportation schemes for the envisioned future of Santiago's Metropolitan Region. Our instrumental variable is based on the general outline and maps of a proposed solution based on public transportation and investments in the road network. The public transport solution was based on a metro network, with three urban and two suburban lines, fed by a dense network of bus lines. We only use this proposed metro network to instrument the subway lines. The 1968 study also proposed a new road infrastructure scheme for the following years, which we use as the instrument for the highways. Figure 4 shows the planned public transportation and road infrastructure network, where Panels (a) and (b) show the original maps and Panels (c) and (d) the digitalized version. We instrument the changes in accessibility from 2001 to 2010 with changes in accessibility between our baseline year (2001) and a situation where the planned network was built. Furthermore, we used the commercial floorspace in 1990 as weights for the destinations in our accessibility measure.

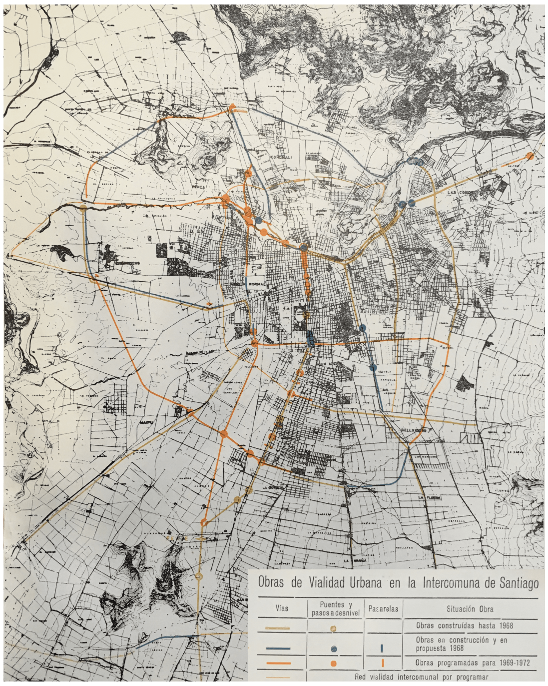
A primary concern with our instrument is that the planned location of the metro stations and the high-speed roads can directly impact the housing supply. This could happen if the urban planning process followed the 1968 study and implemented housing policies in the places planned to be connected. The concern may also arise if the 1968 transportation infrastructure plan anticipates housing growth. To tackle this concern, we control for the proximity to the CBD and to the transport infrastructure. However, there are other reasons why the planned routes will likely have little direct effect on outcomes. In 1973, Augusto Pinochet led a coup d'état against Salvador Allende's government that gave place to a dictatorship led by himself that lasted until 1990. The dictatorship's economic policy motto was liberalization, and urban planning was no exception. The dictatorship designed a new urban development policy that radically modified the guidelines developed in the 1960s. The implemented procedure established that urban land was not scarce and defined a flexible planning system that freed investors from restrictions such as the urban limit or the suburban protection strips (Biblioteca Nacional de Chile, 2023).

Furthermore, as documented by Rojas Ampuero (2022), besides a strong military response to any opposition, forced slum clearance was implemented between 1979 and 1985. This led to a massive reallocation of the population within the city, primarily to poorly connected municipalities in the periphery of the Metropolitan Region, with undeveloped housing markets due to their remoteness and lack of essential services. An illustrative example is the case of Puente

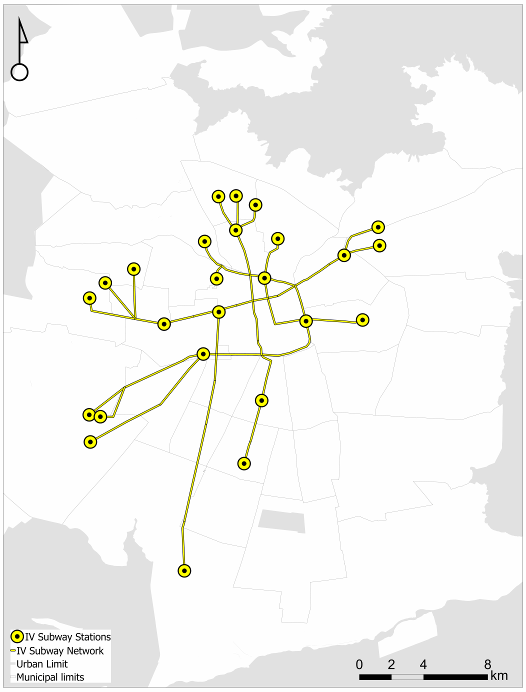
Figure 4: 1968 Planned infrastructure, Ministry of Public Infrastructure and Transport

(a) Raw Subway Map 1968

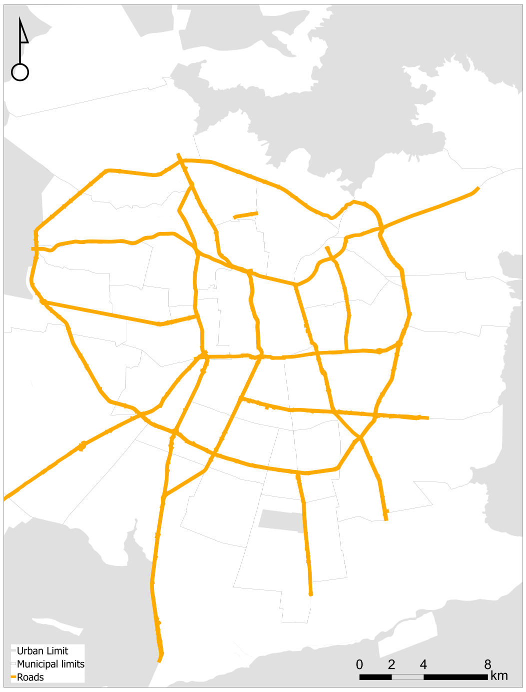
(b) Raw Road Map 1968



(c) IV Subway map



(d) IV Urban Highways map



Notes: Figures 4a and 4b present the 1968 plans of the Ministry of Public Infrastructure and Transport for subway and roads in Santiago. Figures 4c and 4d present the digitalized 1968 plans and the 2001 and 2010 transport networks for subway and urban highways.
Source: Centre of documents of the Housing Ministry of Chile.

Alto, a municipality outside the Santiago province, which became one of the most populated municipalities in the region. In 2005, with this new density distribution, the planned line 4, intended to connect the center to the municipality of San Bernardo (in the south of the city), was built to connect Puente Alto instead, which is in the south but approximately 10km to the east. This case and the deviation from the plan provide evidence of the exclusion restriction of our instrument.

3.4 Commuter market access

As equation (5) shows, the commuter market access of a block i is given by $\sum_j (w_j/d_{ij})^\theta$, which reflects that nearby well-paid jobs are preferred. Usually, the CMA is computed by solving a system of equilibrium equations that relies on the employment at each location instead of requiring georeferenced wage data. In summary, it calculates the market access for each location consistent with the following observed data to be the model's equilibrium: workplace and residential employment per block, floor space prices, and commuting costs. To our knowledge, georeferenced disaggregated employment data is not available for Santiago. Consequently, we use the commercial floor space as a proxy for employment, which implies that the proxy for CMA assumes that attractive jobs are located in zones with more commercial floor space.

As for the proximity, which is a decreasing function of commuting times, T_{it}, we follow Ahlfeldt et al. (2015) and use the following function:

$$d_{ij} = \exp(\kappa \cdot T_{ij}) \tag{13}$$

where κ is a parameter set to 0.01 based on Ahlfeldt et al. (2015) and Tsivanidis (2023).

As discussed above, the weights in the post-treatment year are mechanically endogenous. We instrument the change in market access $ln\text{CMA}_{i\,2010} - ln\text{CMA}_{i\,2001}$ for the change in market access when the weights are fixed at a predetermined level. To provide an additional source of exogeneity to the accessibility measure, we construct the weights using data from 1990. However, because we only have aggregated data for 1990, we use Chile's Estraus zones as the spatial unit of destination. The Ministry of Planning constructed these zones to analyze transport systems in the country's main cities. For the Santiago Metropolitan area, there are 618 Estraus zones (see Niehaus et al., 2016, for details); consequently, for each of the approximately 11,000 blocks, we calculate the market access considering 618 destinations weighted by their commercial floor space.

We must compute the travel time between origin-destination pairs for each available mode: car, buses, and subway. We calculate the minimum travel times for each block i to the 618 Estraus zones using ArcGIS's Network Analysis Tools and speeds reported in SECTRA (2001) and SECTRA (2012). We also consider that in 2007, a fare integration for buses and the subway was implemented, changing the decision-making process of individuals traveling on public transportation. Due to this change, in 2010, public transport users could use buses and the subway for different trip stages, paying only the subway fare. Therefore, in the post-treatment year 2010, we allow combining both modes. Details of the calculation of travel times are in Appendix A2.

We must also consider that modes are used with different intensities in different city areas. For example, a highway in areas where the predominant mode is public transport should have a less significant impact than a subway line. We must also estimate a mode choice model to aggregate over modes to account for this. We follow Ahlfeldt et al. (2015) and measure overall travel times by weighting each mode's minimum travel time using the share of trips undertaken by each available mode. We estimate a Logit mode choice model for each year using Santiago's 2001 and 2012 Mobility Survey. We then predict shares for each mode and each origin-destination pair to use as weights. Because the post-treatment weights are mechanically endogenous, as mentioned in Section 3.4, the weights for our instrumental variable are also fixed at a predetermined level, using the information only from 2001.

3.5 Predicted commuter market access

Table A1 summarizes our sample's changes in log CMA from 2001 to 2010. Market access improved by 13% on average, with a standard deviation of 8%, a median of 11%, and a 90th percentile of 22%. Changes are similar amongst socioeconomic quintiles, with the first four quintiles experiencing an increase in market access between 11% and 13%. The difference in the wealthiest quintile was, on average, 17%.

Figure 5 shows the change in market access. In the Appendix, we detail the changes induced by the instrumental variable (Figure **??**), and Figure A2 presents a close-up of the west part of the subway network. Darker colors stand for more significant changes in accessibility, varying within the treated area. The scattering observed in these figures is expected for these types of indexes (Gibbons and Machin, 2005), and it provides a visual representation of the variation in the space.

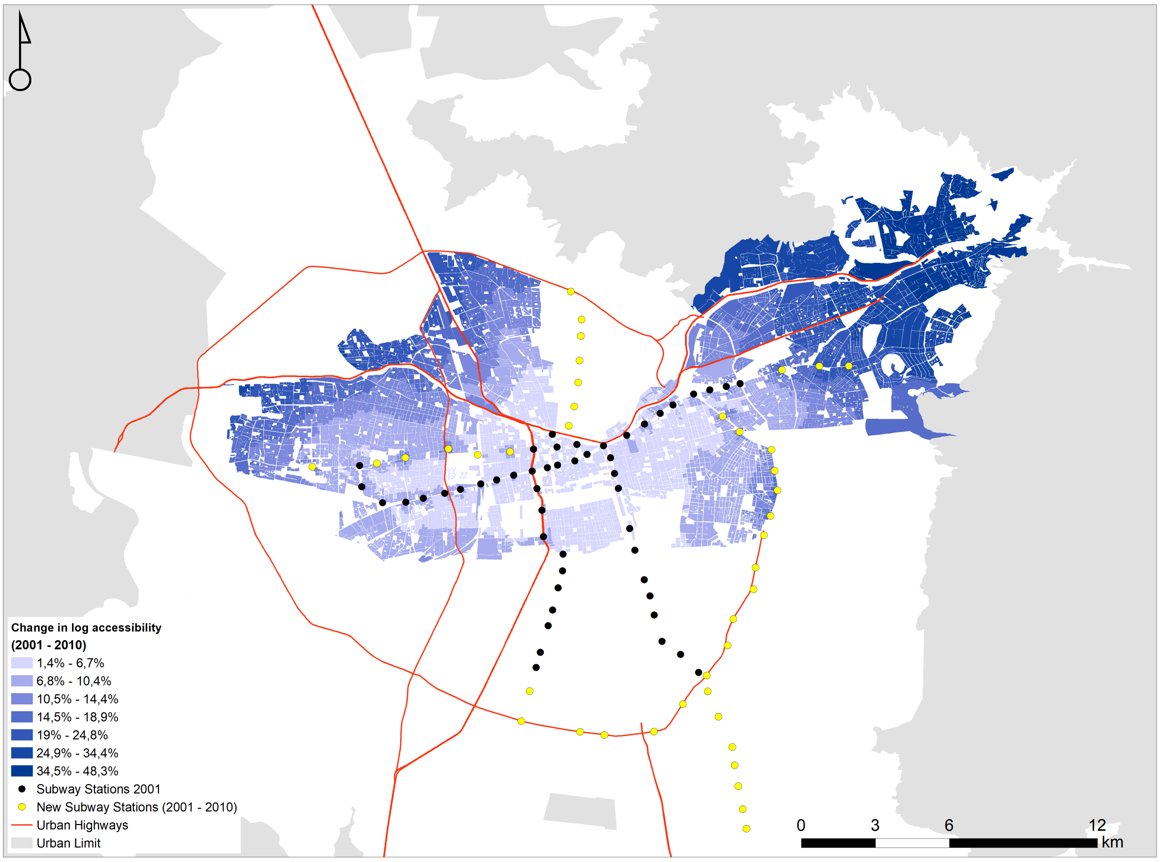
4 Results

4.1 Main Results

Table 4 shows the estimation of the market access elasticity of residential floor space from our first-difference model in equation (12). The main result with an OLS estimation is that a one-percent increase in our measure of market access increases the residential floor space by 0.77. Table 5 shows the results when we instrument the change in log accessibility from 2001 to 2010. As explained above, our instrumental variable uses data from 1990 to compute the employment destination weights and from 2002 to obtain the mode-specific travel time weights (preferences over modes). With this, we avoid having an endogenous measure of how attractive workplaces are. Importantly, the effect of the infrastructure is instrumented using the changes in travel times that the planned route would have brought. For ease of exposition, we denote the full instrument as $\Delta \ln(Acc._{IV})$.

Panel A of Table 5 shows the IV results: the elasticity of floor space to market access is 0.85 with the instrument. The estimate is slightly larger than the OLS coefficient in Table 4. Panel B shows the first-stage results. The instrument is strong, as the Kleibergen-Paap rk Wald F statistic is 2,021, which is well above the Stock and Yogo (2005) critical value for one endogenous regressor (assuming i.i.d. errors) and a 10% maximal bias of the IV estimator relative to OLS at the 5% level of 16.38.

Figure 5: Change in log accessibility (2001 - 2010).



Notes: The figure presents the change in log accessibility index from 2001 to 2010 using 2010 and 2001 accessibility weights. The sample studied are blocks located in the urban limit, within a 3km radius of a new subway station or an urban highway entry or exit.
Source: Own elaboration using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII), georeferenced information on subways and urban highways from the Observatory of Cities of the Pontificia Universidad Católica de Chile (Observatorio de Ciudades UC), and the INE's 2017 pre-census street shapefile.

Table 4: OLS Results: Effects of endogenous accessibility on floor space (2001-2010).

	(1)
$\Delta \ln(Acc._{2010-2001})$	0.77^{***}
	(0.21)
Observations	11,165
R^2	0.03

Standard errors in parentheses are clustered at the census-tract level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Notes: The table reports the OLS estimate of the elasticity of residential floor space to accessibility. The regression controls for log accessibility 2000, log distance to main roads (Alameda, Ruta 5, and Vespucio), log distance to the nearest subway station in 2001, dummies of the part of the city in which the block is located (North, West, East, or Center part of the city), quintiles to the central business district, log population, log surface area, and the baseline socioeconomic quintile of the block.
Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII) and data from the INE's 2001 population Census.

While increased prices due to improved accessibility have been extensively documented, its impact on floor space is far less studied. To the best of our knowledge, we can use no direct evidence of this elasticity to compare with our findings. However, our resulting elasticity can be

Table 5: IV Results: Effects of accessibility on floor space (2001-2010).

Panel A: Two-Stage Least Squares	
$\Delta \ln(Acc._{2010-2001})$	0.85***
	(0.22)
Observations	11,165
R^2	0.03
Wu-Hausman F(1, 11,144)	1.36 (p = 0.24)
Panel B: First Stage (dependent variable: $\Delta \ln(Acc._{2010-2001})$)	
$\Delta \ln(Acc._{IV})$	0.99***
	(0.02)
Observations	11,165
R^2	0.98
Kleibergen-Paap rk Wald F statistic	2,021.7
Stock-Yogo weak ID test CV (10%)	16.38

Standard errors in parentheses are clustered at the census-tract level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: Panel A of the table reports the 2SLS estimate of the elasticity of residential floor space to accessibility. Panel B reports the first stage regression of the endogenous measure of accessibility, $\Delta \ln(Acc._{2010-2001})$, on the instrument, $\Delta \ln(Acc._{IV})$. The regression controls for log Accessibility 2000, log distance to main roads (Alameda, Ruta 5, and Vespucio), log distance to the nearest subway station in 2001, dummies of the part of the city in which the block is located (North, West, East, or Center part of the city), quintiles to the central business district, log population, log surface area, and the baseline socioeconomic quintile of the block.

Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII) and data from the INE's 2001 population Census.

interpreted further by noting that it can be written as the product of the price elasticity of floor space and the elasticity of prices to market access changes.[12] Using the average elasticity of residential prices with respect to market access of 0.4 obtained by Tsivanidis (2023), our results imply a price elasticity of floor space of 2.13, which is in the range of previous estimations by Saiz (2010) and Baum-Snow and Han (2023).

4.2 Robustness

We perform a series of robustness checks that we summarize in this Section. In a nutshell, we test the robustness of our results by considering different sub-samples, using alternative measures of accessibility, and including additional and alternative covariates. We also use HAC standard errors to allow for spatial correlation of errors across blocks within 500m of each other. Some results are presented below, while the rest are in the Appendix A1.

We first present the results when no controls are included and add covariates one by one to reach our preferred specification in column 7. Table 6 summarizes the results. In all cases, we obtain a positive and statistically significant effect. Second, Table A2 shows the results when we exclude from the analysis the blocks within 100, 250, and 500 meters from the new infrastructure in columns 2, 3, and 4, respectively. As a reference, column 1 shows the main results with the whole sample, just as in Table 5. The point estimates are very similar across samples, and the differences between the elasticities are not statistically different from zero. Therefore, our results are not driven by changes in areas surrounding the new subway stations or highway entries and exits.

Third, we use different market access measures using different assumptions regarding the

[12]This is, $\epsilon^{\text{floorspace}}_{\text{market access}} = \epsilon^{\text{floorspace}}_{\text{price}} \cdot \epsilon^{\text{price}}_{\text{market access}}$

Table 6: Effects of accessibility on floor space (2001-2010).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\Delta \ln(Acc._{2010-2001})$	0.40***	0.41***	0.39***	0.70***	0.92***	0.86***	0.85***
	(0.08)	(0.08)	(0.14)	(0.21)	(0.22)	(0.22)	(0.22)
Log Surface	No	Yes	Yes	Yes	Yes	Yes	Yes
CBD	No	No	Yes	Yes	Yes	Yes	Yes
City dummies	No	No	Yes	Yes	Yes	Yes	Yes
Log Acc. in 2000	No	No	No	Yes	Yes	Yes	Yes
Log Distance to SW 2001	No	No	No	No	Yes	Yes	Yes
Log Distance to Main Road	No	No	No	No	Yes	Yes	Yes
SES	No	No	No	No	No	Yes	Yes
Log Population in 2000	No	No	No	No	No	No	Yes
Observations	11,165	11,165	11,165	11,165	11,165	11,165	11,165
R^2	0.01	0.02	0.02	0.02	0.03	0.03	0.03

Standard errors in parentheses are clustered at the census-tract level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Notes: The table reports 2SLS estimates of the elasticity of residential floor space to accessibility. Each column is from a different regression; covariates are added progressively in each specification. Column 1 does not have any covariates. Column 2 controls for log surface area of the block. Column 3 controls for spatial controls such as dummies of the part of the city in which the block is located (North, West, East, or Center part of the city), and quintiles to the central business district. Column 4 controls for log Accessibility in 2000. Column 5 controls for distance to transport infrastructure such as log distance to main roads (Alameda, Ruta 5, and Vespucio), and nearest subway station in 2001. Column 6 controls for the baseline socioeconomic quintile of the block. Column 7 has the same specification as Table 5, also controlling for log population, as well as the baseline socioeconomic quintile of the block and spatial controls used in the previous columns.
Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII) and data from the INE's 2001 population Census.

destination weights and the commuter elasticity parameter. Table A3 displays the results. Column 1 reproduces the main result in Table 5. Column 2 reports the results using industrial and commercial floor space to compute the destination weights. Column 3 estimates a model that does not use destination weights at all, and Column 4 uses $\theta = 1$ instead of $\theta = 3$ as the shape parameter of the Frechet distribution (see equation (5)).

We also explore the robustness of including other socioeconomic covariates and the baseline residential floor space density. Table A4 summarizes the results. Column 1 shows our preferred specification. In column 2, we control for the number of households per block instead of controlling for the population. Column 3 includes municipality fixed effects; in Column 4, we control for the baseline floor area ratio. The elasticity is large and statistically significant in all cases, with a minor size variation across specifications. In summary, adding covariates or using alternative density measures does not affect our result. Finally, we compute HAC standard errors to allow for spatial correlation of errors across blocks within 500m of each other. The elasticity estimate is still significant at the 1% level (see Table A5).

5 Heterogeneity

Having estimated the average elasticity, we move to take advantage of the micro-scale of our data to study three important sources of heterogeneity: baseline residential floor space density (henceforth initial density), socioeconomic status, and distance to CBD. For the initial density and socioeconomic status, we interact our key variable $\Delta ln(acc)$ with an indicator for five equally sized groups (quintiles) based on the baseline (pre-determined) value of the variable. For the distance to the CBD, we follow Baum-Snow and Han (2023) and interact the change in market access with the distance and the distance squared.

5.1 Distance to the CBD

Table 7 summarizes the results of interacting the change in market access with the distance to the CBD (column 1) and the distance squared (column 2). We also include the baseline floor space density as a control in columns 3 and 4 to check whether the result is affected by a correlation between the CBD distance and a lower fraction of developed blocks, as it is in Baum-Snow and Han (2023).

Table 7: Heterogeneity in the results - Distance to CBD (km).

	(1)	(2)	(3)	(4)
$\Delta \ln(Acc._{2010-2001})$	0.76***	1.67*	0.52*	1.34
	(0.29)	(0.92)	(0.29)	(0.91)
$\Delta \ln(Acc._{2010-2001}) \times CBD$	0.00	-0.13	0.01	-0.10
	(0.02)	(0.14)	(0.02)	(0.14)
$\Delta \ln(Acc._{2010-2001}) \times CBD^2$		0.00		0.00
		(0.00)		(0.00)
Initial density	No	No	Yes	Yes
Observations	11,165	11,165	11,165	11,165
R^2	0.03	0.03	0.04	0.04

Standard errors in parentheses are clustered at the census-tract level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table reports 2SLS estimates of the elasticity of residential floor space to accessibility. All regressions control for log Accessibility 2000, log distance to main roads (Alameda, Ruta 5, and Vespucio), log distance to the nearest subway station in 2001, dummies of the part of the city in which the block is located (North, West, East, or Center part of the city), log population, log surface area, and the baseline socioeconomic quintile of the block. All regressions control for log accessibility 2000, log distance to main roads (Alameda, Ruta 5, and Vespucio), log distance to the nearest subway station in 2001, dummies of the part of the city in which the block is located (North, West, East, or Center part of the city), log population, log surface area, and the baseline socioeconomic quintile of the block. Column 1 shows results for the interaction of $\Delta \ln(Acc._{2010-2001})$ with the distance to the CBD, and column 2 shows results for the interaction of $\Delta \ln(Acc._{2010-2001})$ with the distance to the CBD (adding the linear and quadratic terms of such distance). Columns 3 and 4 recreate columns 1 and 2, and also controls for the initial density of the block.

Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII), the dataset on regulation described in Section 2.3.1, and data from the INE's 2001 population Census.

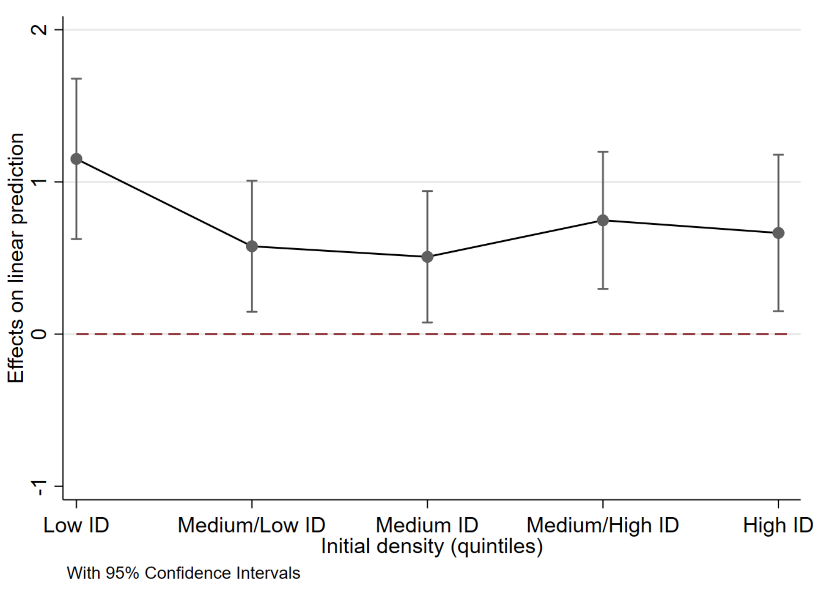
The coefficient on the interaction between the market access change and CBD distance squared is almost zero in both specifications. On the other hand, in the linear specification, the slope is slightly larger than zero and not significant at conventional levels. Therefore, we find that the effect of increased market access on residential floor space is reasonably homogeneous concerning the distance to the CBD.

This contrasts with the usual result of the literature of a growing-with-distance (from the CBD) elasticity (e.g. Baum-Snow and Han, 2023). We argue that the central areas of Santiago were not highly developed and thus had room for increased floor space. Even though there is a difference in vacant land between the central and suburban areas, the difference is significantly less when considering the possibility of redevelopment. Below, we explore the heterogeneity concerning baseline development, confirming this intuition.

5.2 Initial density

Figure 6 and Table A6 summarize the results of the heterogeneity of the effect of changes in market access by initial floor space density, i.e., the initial floor area ratio. They show that the impact of increased market access is not heterogeneous to the initial density. The homogeneity is present because most blocks are not highly developed in the baseline year. For example, ninety percent of the sample has a constructed floor-area ratio lower than 0.63. Therefore, there is room for a supply response to the increased market access almost everywhere.

Figure 6: Heterogeneity in the results - Initial density (ID).



Notes: The figure reports 2SLS estimates of the elasticity of residential floor space to accessibility interacted with the initial density of the block (expressed in quintiles) to study heterogeneous effects. The regression controls for log Accessibility 2000, log distance to main roads (Alameda, Ruta 5, and Vespucio), log distance to the nearest subway station in 2001, dummies of the part of the city in which the block is located (North, West, East, or Center part of the city), quintiles to the central business district, log population, log surface area, and the baseline socioeconomic quintile of the block. These coefficients are plotted from the results in Table A6.
Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII) and data from the INE's 2001 population Census.

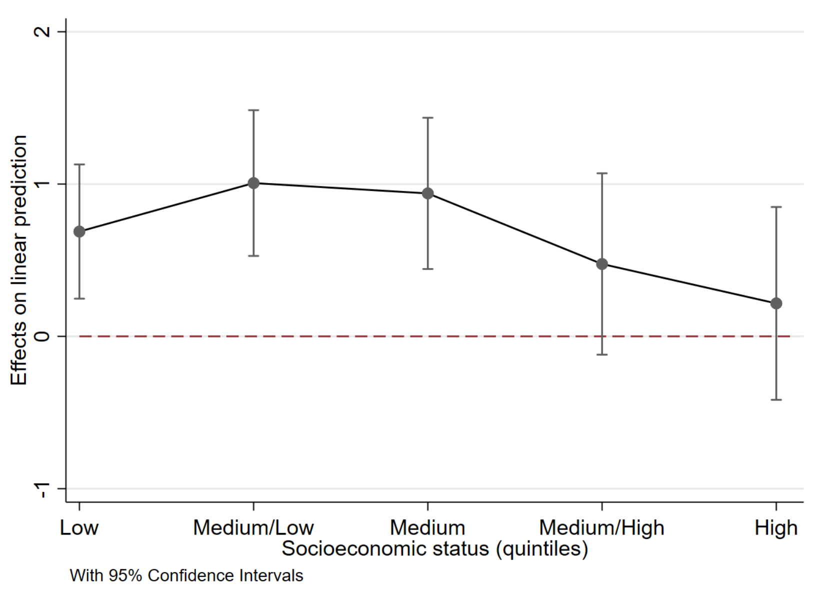
5.3 Income

Figure 7 and Table A7 summarize the analysis and reveal no significant heterogeneity concerning income except for the wealthiest quintiles, where the elasticity becomes not statistically significant. The result is surprising as there is evidence in Latin American countries that the effects of increased market access are heterogeneous concerning income (see, e.g., Tsivanidis, 2023), and differences are expected to be larger for a highly unequal place like Santiago.

The lack of socioeconomic heterogeneity may be due to several reasons. The heterogeneity concerning CBD distance and initial floor space is negligible, so a correlation between high-income and development patterns cannot explain the result. A similarity in preferences between income groups could also explain the result, but preferences in Santiago have substantial heterogeneity regarding commuting (Tirachini et al., 2017).

In the following Section, we explore the hypothesis that differences in regulation and its dynamics can explain the lack of heterogeneity found in this Section.

Figure 7: Heterogeneity in the results - Socioeconomic status.



Notes: The figure reports 2SLS estimates of the elasticity of residential floor space to accessibility interacted with the baseline socioeconomic quintile of the block to study heterogeneous effects. The regression controls for log accessibility 2000, log distance to main roads (Alameda, Ruta 5, and Vespucio), log distance to the nearest subway station in 2001, dummies of the part of the city in which the block is located (North, West, East, or Center part of the city), quintiles to the central business district, log population, and log surface area of the block. These coefficients are plotted from the results in Table A7's column 1.
Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII), the dataset on regulation described in Section 2.3.1, and data from the INE's 2001 population Census.

6 The role of regulation

To understand the regulation's role in shaping the economic activity distribution, we use a unique dataset that details every block's maximum FAR and height in our sample of 14 municipalities.[13] We also compute the difference between the maximum residential floor space allowed by the regulation and the actual floor space built in 2001, an index that we call real estate potential (REP). With this exercise, we can control for the presence of regulation and study its role in the heterogeneity of the effects of market access on residential floor space.

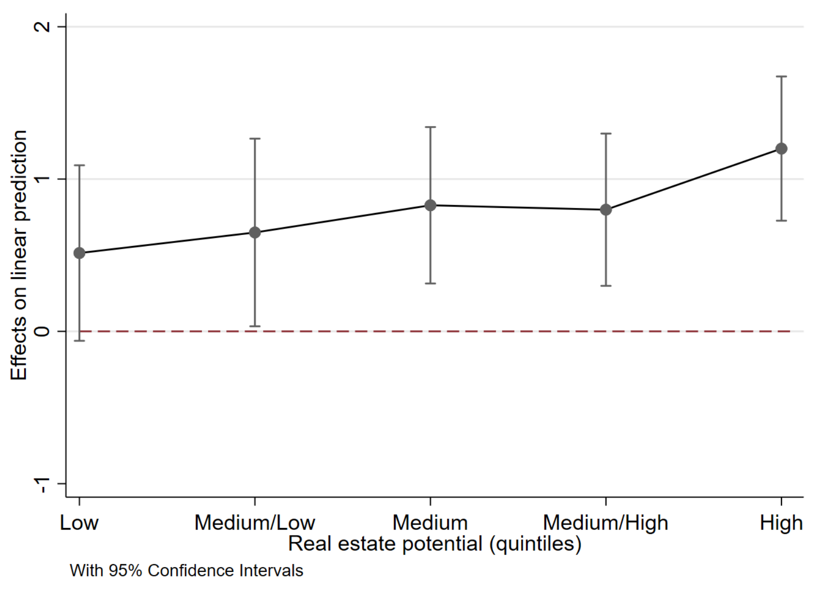
We begin by studying the heterogeneity of the market access impact with respect to the real estate potential. Table A8 shows the results when interacting our key variable with an indicator of REP quintiles, and Figure 8 summarizes the results.

Figure 8 reveals that there is not a remarkable heterogeneity. The elasticity of floor space to market access is approximately the same in blocks from the first three quintiles of lowest real estate potential, even though the mean REP increases fivefold in that range. Figure 8 also shows that the elasticity is moderately larger in the blocks with more room to accommodate floor space.

We believe that the two central hypotheses that aim to explain the processes affecting land-use regulations are at play behind these results. First is the "growth machine" hypothesis, which states that the real estate industry is the most powerful agent behind the decisions taken

[13]The dataset is described in Section 2.3.1.

Figure 8: Heterogeneity in the results - Real estate potential (REP).



Notes: The figure reports 2SLS estimates of the elasticity of residential floor space to accessibility interacted with the real estate potential of the block (expressed in quintiles) to study heterogeneous effects. The regression controls for log accessibility 2000, log distance to main roads (Alameda, Ruta 5, and Vespucio), log distance to the nearest subway station in 2001, dummies of the part of the city in which the block is located (North, West, East, or Center part of the city), quintiles to the central business district, log population, log surface area, and the baseline socioeconomic quintile of the block. These coefficients are plotted from the results in Table A8.
Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII), the dataset on regulation described in Section 2.3.1, and data from the INE's 2001 population Census.

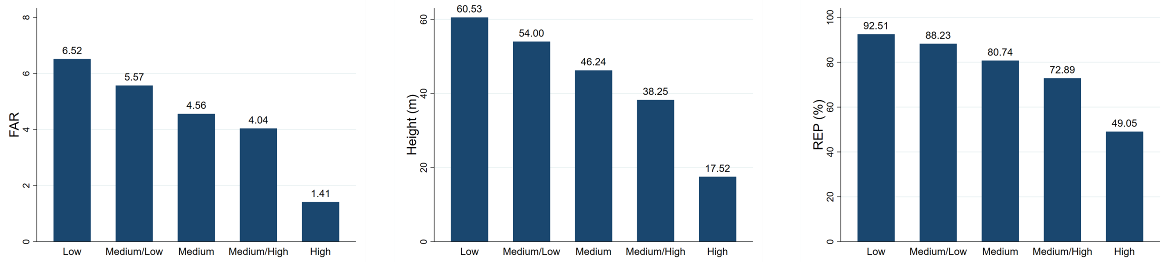
by city officials on the uses of urban land. On the other hand, the "home voter" theory claims that property owners are today the most influential actors in how cities' land use is regulated (Fischel, 2005; Been et al., 2014; Gabbe, 2018). The real estate industry, thus, would push for relaxing the regulation in places with increased market access to take advantage of the housing demand shock. This pressure aligns with a municipality that maximizes revenue from property taxes. On the contrary, the homeowners would seek to maintain the status quo and prevent densification.

To shed light on the issue, we begin by studying whether there are differences between income groups in the floor space elasticity and its heterogeneity concerning regulation. Figure 9 illustrates the baseline distribution of the real estate potential and the maximum FAR and height allowed in the blocks belonging to different socioeconomic quintiles. The facts that stand out are that in the baseline (the year 2001), the regulation was significantly more stringent in the wealthiest quintile's blocks and that it is, on average, permissive and homogeneous in the rest of the blocks.

To examine if this difference in initial regulation between income groups drives the results, we estimate the same model of REP heterogeneity as above (Figure 8) but separately for the subsample of the wealthiest quintile's blocks and the rest. Figure 10 and Table A9 present the results. Note that the quintiles of REP are defined using the full sample; therefore, they do not represent quintiles within socioeconomic groups. For example, blocks in the wealthiest quintile

Figure 9: Average regulation indicators at baseline by socioeconomic status.

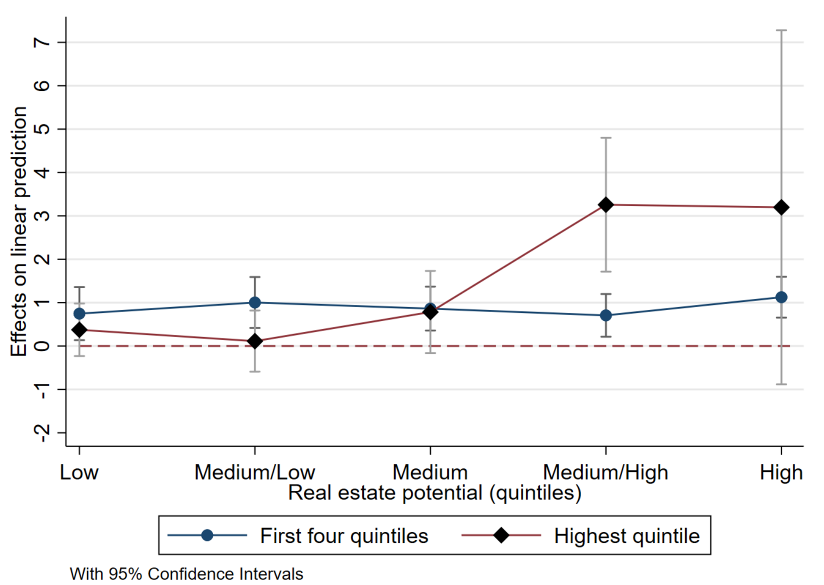
(a) Maximum FAR **(b)** Maximum Height **(c)** Real estate potential



Notes: Figures report the mean and standard deviation of the real estate potential (REP), floor-to-area ratio, and height detailed in the regulation of the block at baseline. The sample studied are blocks located in the urban limit, within a 3km radius of a new subway station or an urban highway entry or exit. These statistics are also displayed in Table B5.
Source: Own calculations using the data from the Chilean Internal Revenue Service (SII) on land-use for 2001 and 2010 and georeferenced blocks, the dataset on regulation described in Section 2.3.1, and also data from INE's 2001 population Census.

are much likelier to have a low real estate potential than those in the other four quintiles. Indeed, 62% of the wealthiest blocks are in the lowest REP category (low), while the share is 9% in the other four socioeconomic groups.

Figure 10: Heterogeneity in the results - Real estate potential (REP) and socioeconomic status.



Notes: The figure reports 2SLS estimates of the elasticity of residential floor space to accessibility interacted with the real estate potential of the block (expressed in quintiles) and a dummy for the socioeconomic status (0 if the block is in the first four quintiles and 1 if the block is in the fifth quintile) to study heterogeneous effects. The regression controls for log accessibility 2000, log distance to main roads (Alameda, Ruta 5, and Vespucio), log distance to the nearest subway station in 2001, dummies of the part of the city in which the block is located (North, West, East, or Center part of the city), quintiles to the central business district, log population, log surface area of the block. Regression in column 1 shows results for the first four socioeconomic quintiles, and column 2 shows results for the highest socioeconomic quintile. These coefficients are plotted from the results in Table A9.
Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII), the dataset on regulation described in Section 2.3.1, and data from the INE's 2001 population Census.

The results show an underlying difference between income groups in how the market access elasticity of floor space varies with regulation. In the richest quintile, the estimated elasticity is not statistically different from zero for the three lower categories of real estate potential, which represent 96% of the blocks. On the other hand, it is substantially more prominent in the remaining 4% of blocks (the two highest categories of REP). The findings starkly contrast with those obtained in the rest of the sample. The elasticity in the other four socioeconomic group's blocks is stable across all levels of initial regulation and statistically significant in all cases. In other words, our results reveal that in most blocks, the initial level of regulation does not restrict development. However, the story differs for high-income blocks, where the law seems to work as expected.

These results suggest that the home voters' ability to impede residential development when the market access improves due to transportation infrastructure development works only for high-income groups. They also indicate that in the other blocks, the growth machine can influence regulators to make the regulation less stringent, or it was sufficiently lax initially and not changed. To determine which one of the two possible hypotheses holds, we examine the relationship between the regulatory changes and the transport infrastructure.

As a final exercise, we estimate our main specification but use the log change in the maximum floor-to-area ratio allowed in the block as the dependent variable. We also study the heterogeneity of this impact with respect to the socioeconomic level (wealthiest versus other quintiles). Table 8 displays the results and reveals a strong effect of increased market access on the permitted maximum floor-to-area ratio, except for the wealthiest quintile. In other words, the regulation becomes more permissive due to increased accessibility everywhere in the city but for the most affluent.

Table 8: Effects of accessibility on regulation: maximum FAR allowed (2001-2010).

	(1)	(2)
$\Delta \ln(Acc._{2010-2001})$	1.34***	
	(0.42)	
$\Delta \ln(Acc._{2010-2001}) \times$ First four quintiles		1.42***
		(0.50)
$\Delta \ln(Acc._{2010-2001}) \times$ Highest quintile		0.34
		(0.52)
Observations	11,165	11,165
R^2	0.27	

Standard errors in parentheses are clustered at the census-tract level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Notes: The table reports 2SLS estimates of the elasticity of the maximum FAR allowed to accessibility. All regressions control for log Accessibility 2000, log distance to main roads (Alameda, Ruta 5, and Vespucio), log distance to the nearest subway station in 2001, dummies of the part of the city in which the block is located (North, West, East, or Center part of the city), quintiles to the central business district, log population, and log surface area of the block. Column 2 shows results for the interaction of $\Delta \ln(Acc._{2010-2001})$ with a dummy for the socioeconomic status (0 if the block is in the first four quintiles and 1 if the block is in the fifth quintile).
Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII), the dataset on regulation described in Section 2.3.1, and data from the INE's 2001 population Census.

In summary, the lack of effect of increased accessibility on residential floor space in high-income neighborhoods is due to the combination of stringent initial regulation and some characteristics of the wealthiest quintile that prevents a regulatory change. We believe this aligns with the so-called home-voter regulation theory (Fischel, 2004, 2010), where high-income residents successfully lobby against lenient regulation. The results are also consistent with the evidence correlating homeowners associations with stringent regulation and residents with higher income (Clarke and Freedman, 2019).

7 Conclusions

This paper uses Santiago as the case study to investigate the impact of transport infrastructure on the spatial allocation of economic activity and the role of urban land-use regulation in shaping this impact. The analysis takes advantage of our administrative data's micro-scale and detailed regulation data that we assembled for this project. Specifically, it studies the effects of increased accessibility on a city's residential floor space and how this response varies with income, distance to the CBD, floor space density, and zoning and land-use regulation.

We estimate an average elasticity that aligns with the literature but provides heterogeneous effects that contrast the previous evidence. Compared to Baum-Snow and Han (2023), the impact of increased accessibility is not strongly heterogeneous concerning CBD distance. We think that our findings relative to heterogeneity in the key elasticity along distance from the CBD differ from the previous literature because, in our case, the areas close to the CBD were relatively underdeveloped in our baseline period. This highlights the relevance of examining the previously mentioned heterogeneity in a developing context.

Also, we show that land-use and zoning regulation is crucial in determining how the equilibrium outcomes' response varies within the city and across socioeconomic groups. In blocks whose residents belong to the first four socioeconomic quintiles, the market access elasticity of floor space is homogeneous across all levels of baseline regulation and moderately larger than the average effect. We also find that the urban dynamics differ entirely in blocks with residents in the wealthiest quintile. The elasticity is small and not statistically different from zero for 96% percent of those blocks. On the other hand, for the rest of the blocks of most permissive regulation, the elasticity is more than three times the average elasticity obtained without accounting for heterogeneous effects. We provide evidence that baseline regulation is initially restrictive, but, importantly, we show that –unlike in the rest of the city– it does not become more permissive in places where the increased accessibility is more significant.

We believe that our contribution is essential for understanding urban policies and investment impacts as our results imply that the welfare effects of investments in urban infrastructure are limited by regulation in specific ways that seem different from previous (mainly from the US) literature. We believe that urban land-use regulation's affordability and welfare consequences, especially in developing countries, are a crucial avenue for future research. We also deem it important to study the regulation changes and the relevant mechanisms behind them to inform urban planning.

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Appendix

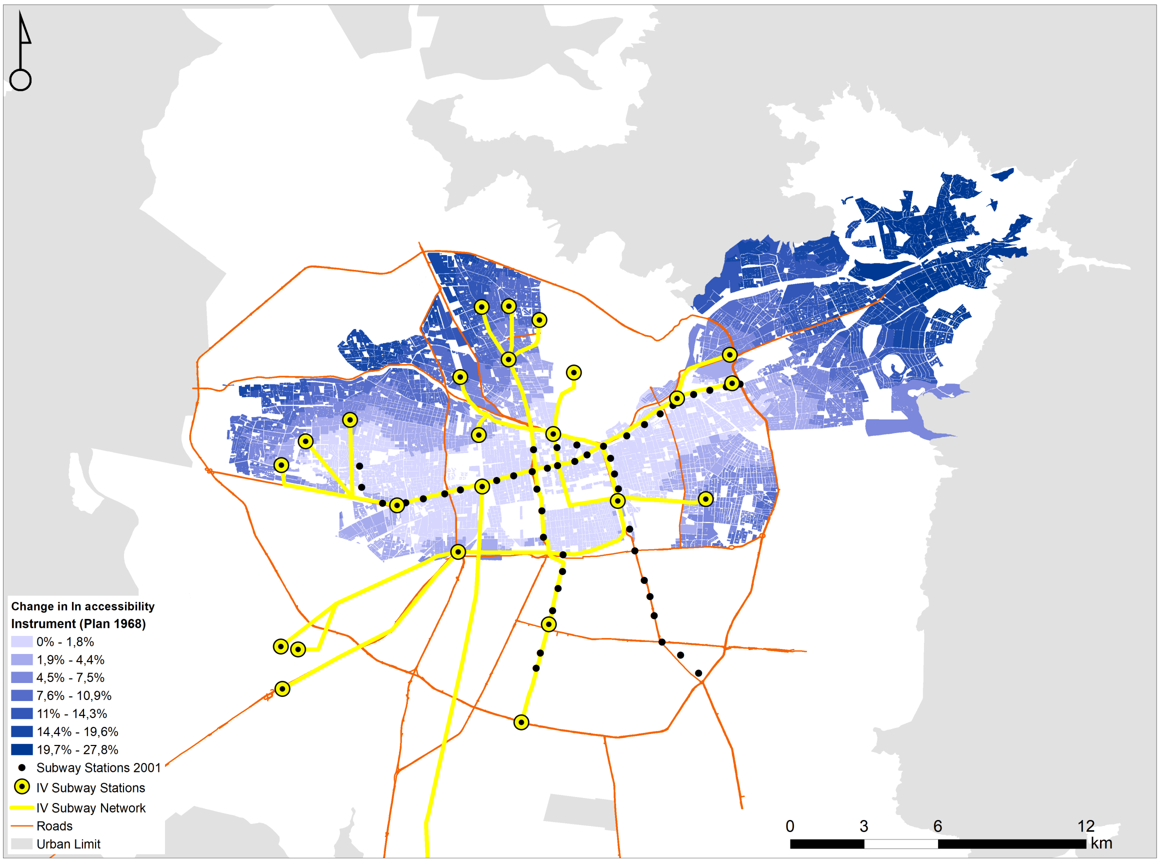
A1 Additional results and descriptive statistics

Table A1: Change in log accessibility by socioeconomic status (2001 - 2010).

	Mean	SD	P50	P90	Max	Proportion of zeroes
Total	13%	8%	12%	24%	48%	0%
Lowest quintile	14%	6%	14%	23%	44%	0%
Medium/Low quintile	13%	6%	12%	21%	27%	0%
Medium quintile	13%	7%	11%	22%	45%	0%
Medium/High quintile	11%	8%	8%	21%	47%	0%
Highest quintile	17%	10%	15%	30%	48%	0%
Observations	11,165					

Notes: The table shows summary statistics of changes in the log accessibility index from 2001 to 2010 using 2001 and 2010 accessibility weights, by socioeconomic status (quintiles), for the sample studied are areas located in the urban limit, within a 3km radius of a new subway station or an urban highway entry or exit.
Source: Own elaboration using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII), georeferenced information on subways and urban highway from the Observatory of cities of the Pontificia Universidad Católica de Chile (Observatorio de Ciudades UC), the INE's 2017 pre-census street shapefile, and data from the INE's 2001 population Census.

Figure A1: Change in log accessibility (2001 - 2010) using 1990 destination weights and planned routes traveling times (instrumental variable).



Notes: The figure presents the change in the log accessibility index from 2001 to 2010, using travel times from the planned routes and 1990 accessibility weights. The sample studied are blocks located in the urban limit, within a 3km radius of a new subway station or an urban highway entry or exit.
Source: Own elaboration using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII), georeferenced information on subways and urban highways from the Observatory of cities of the Pontificia Universidad Católica de Chile (Observatorio de Ciudades UC), and the INE's 2017 pre-census street shapefile.

Table A2: Robustness of effects of accessibility on floor space to different subsamples (2001-2010).

	(1)	(2)	(3)	(4)
$\Delta \ln(Acc._{2010-2001})$	0.85***	0.88***	0.92***	0.97***
	(0.22)	(0.22)	(0.23)	(0.27)
Observations	11,165	11,063	10,480	8,624
R^2	0.03	0.03	0.03	0.03

Standard errors in parentheses are clustered at the census-tract level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$
Notes: The table reports 2SLS estimates of the elasticity of residential floor space to accessibility. All regressions control for log Accessibility 2000, log distance to main roads (Alameda, Ruta 5, and Vespucio), log distance to the nearest subway station in 2001, dummies of the part of the city in which the block is located (North, West, East, or Center part of the city), quintiles of distance to the central business district, log population, log surface area, and the baseline socioeconomic quintile of the block. Column 1 shows the result in Table 5, which is the sample within a 3km radius of a new subway station or an urban highway entry or exit, while columns 2 to 4 drop blocks from the first 100, 250, and 500 meters from a new subway station or an urban highway entry or exit.
Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII) and data from the INE's 2001 population Census.

Figure A2: Change in log accessibility (2001 - 2010) - Close-up of the west of Santiago's subway network.

Notes: The figure presents the change in log accessibility index from 2001 to 2010 using 2010 and 2001 accessibility weights, zoomed in to the west of the subway network. The sample studied are blocks located in the urban limit, within a 3km radius of a new subway station or an urban highway entry or exit.
Source: Own elaboration using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII), georeferenced information on subways and urban highways from the Observatory of Cities of the Pontificia Universidad Católica de Chile (Observatorio de Ciudades UC), and the INE's 2017 pre-census street shapefile.

Table A3: Robustness of effects of accessibility on floor space to alternative accessibility measures (2001-2010).

	(1)	(2)	(3)	(4)
$\Delta \ln(Acc._{2010-2001})$	0.85***	0.88***	0.50*	2.61***
	(0.22)	(0.21)	(0.29)	(0.82)
Observations	11,165	11,165	11,165	11,165
R^2	0.03	0.03	0.03	0.03

Standard errors in parentheses are clustered at the census-tract level. $^{*}\ p < 0.1$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$
Notes: The table reports 2SLS estimates of the elasticity of residential floor space to accessibility. Regressions in each column control for log accessibility 2000, log distance to main roads (Alameda, Ruta 5, and Vespucio), log distance to the nearest subway station in 2001, dummies of the part of the city in which the block is located (North, West, East, or Center part of the city), quintiles to the central business district, log population, log surface area, and the baseline socioeconomic quintile of the block. Column 1 shows the same result as Table 5, which uses built-up surface for commercial land use in 2009 and 2000 as destination weight for each period. Column 2 uses a different destination weight for the endogenous variable and the instrument, using commercial and industrial land use instead of only commercial use. Column 3 uses equal destination weight, which gives the same value to all w_j in equation (5). Column 4 uses a different shape parameter of the Frechet distribution, with $\theta = 1$ in equation (5) instead of $\theta = 3$, which makes individuals more inelastic to changes in traveling costs.
Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII) and data from the INE's 2001 population Census.

Table A4: Robustness of effects of accessibility on floor space to adding additional controls (2001-2010)

	(1)	(2)	(3)	(4)	(5)
$\Delta \ln(Acc._{2010-2001})$	0.85***	0.86***	0.77***	0.69***	0.91***
	(0.22)	(0.22)	(0.29)	(0.22)	(0.22)
Log Surface	Yes	Yes	Yes	Yes	Yes
CBD	Yes	Yes	Yes	Yes	Yes
City dummies	Yes	Yes	No	Yes	Yes
Log Acc. in 2000	Yes	Yes	Yes	Yes	Yes
Log Distance to SW 2001	Yes	Yes	Yes	Yes	Yes
Log Distance to Main Road	Yes	Yes	Yes	Yes	Yes
SES	Yes	Yes	Yes	Yes	Yes
Log Population in 2000	Yes	No	Yes	Yes	Yes
Log Households in 2001	No	Yes	No	No	No
Municipality Dummies	No	No	Yes	No	No
Initial density	No	No	No	Yes	No
REP	No	No	No	No	Yes
Observations	11,165	11,165	11,165	11,165	11,165
R^2	0.03	0.03	0.05	0.04	0.05

Standard errors in parentheses are clustered at the census-tract level. $^{*}\ p < 0.1$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$
Notes: The table reports 2SLS estimates of the elasticity of residential floor space to accessibility. Regressions show results for residential land use. Each column is from a different regression; covariates are modified in each specification. Column 1 has the same specification as Table 5, controlling for log accessibility 2000, log distance to main roads (Alameda, Ruta 5, and Vespucio), log distance to the nearest subway station in 2001, dummies of the part of the city in which the block is located (North, West, East, or Center part of the city), quintiles to the central business district, city sector dummies, log population, log surface area, and the baseline socioeconomic quintile of the block. Column 2 changes log population for log housing. Column 3 changes dummies of the part of the city in which the block is located for municipality dummies. Column 4 has the same covariates as column 1 and controls for the initial density of the block. Column 5 has the same covariates as column 1 and controls for the real estate potential in 2001 of the block.
Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII), the dataset on regulation described in Section 2.3.1, and data from the INE's 2001 population Census.

Table A5: Robustness of accessibility effects on floor space to different correction of standard errors (2001-2010).

	(1)	(2)
$\Delta \ln(Acc._{2010-2001})$	0.85***	0.85***
	(0.22)	(0.25)
Observations	11,165	11,165
R^2	0.03	0.03

Standard errors in parentheses. $^{*}\ p < 0.1$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$
Notes: The table reports 2SLS estimates of the elasticity of residential floor space to accessibility. Regressions in each column control for log accessibility 2000, log distance to main roads (Alameda, Ruta 5, and Vespucio), log distance to the nearest subway station in 2001, dummies of the part of the city in which the block is located (North, West, East, or Center part of the city), quintiles to the central business district, log population, log surface area, and the baseline socioeconomic quintile of the block. Column 1 shows the same result as Table 5, which shows standard errors clustered on the census tract. Column 2 shows HAC standard errors (heteroskedastic and autocorrelation consistent), accounting for a spatial correlation within a radius of 0.5 km from the centroid of the block.
Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII) and data from the INE's 2001 population Census.

Table A6: Heterogeneity in the results - Initial density (ID).

	(1)
$\Delta \ln(Acc._{2010-2001})$	1.15***
	(0.27)
First quintile ID (lowest) $\times \Delta \ln(Acc._{2010-2001})$	0.00
	(.)
Second quintile ID $\times \Delta \ln(Acc._{2010-2001})$	-0.57***
	(0.18)
Third quintile ID $\times \Delta \ln(Acc._{2010-2001})$	-0.64***
	(0.18)
Fourth quintile ID $\times \Delta \ln(Acc._{2010-2001})$	-0.40**
	(0.19)
Fifth quintile ID (highest) $\times \Delta \ln(Acc._{2010-2001})$	-0.49**
	(0.19)
First quintile ID (lowest)	0.00
	(.)
Second quintile ID	0.04
	(0.03)
Third quintile ID	0.01
	(0.03)
Fourth quintile ID	-0.04
	(0.03)
Fifth quintile ID (highest)	-0.04
	(0.03)
Observations	11,165
R^2	0.05

Standard errors in parentheses are clustered at the census-tract level

Notes: The table reports 2SLS estimates of the elasticity of residential floor space to accessibility interacted with the initial density of the block (expressed in quintiles) to study heterogeneous effects. The regression controls for log accessibility 2000, log distance to main roads (Alameda, Ruta 5, and Vespucio), log distance to the nearest subway station in 2001, dummies of the part of the city in which the block is located (North, West, East, or Center part of the city), quintiles to the central business district, log population, log surface area, and the baseline socioeconomic quintile of the block. These coefficients are plotted in Figure 6.
Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII) and data from the INE's 2001 population Census.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A7: Heterogeneity in the results - Socioeconomic status.

	(1)	(2)
$\Delta\ln(Acc._{2010-2001})$	0.69***	0.68***
	(0.22)	(0.22)
Low × $\Delta\ln(Acc._{2010-2001})$	0.00	0.00
	(.)	(.)
Medium/Low × $\Delta\ln(Acc._{2010-2001})$	0.32**	0.41**
	(0.16)	(0.16)
Medium × $\Delta\ln(Acc._{2010-2001})$	0.25	0.44**
	(0.20)	(0.20)
Medium/High × $\Delta\ln(Acc._{2010-2001})$	-0.21	-0.01
	(0.23)	(0.23)
High × $\Delta\ln(Acc._{2010-2001})$	-0.47*	-0.28
	(0.24)	(0.24)
Low	0.00	0.00
	(.)	(.)
Medium/Low	-0.06**	-0.05**
	(0.03)	(0.03)
Medium	-0.07**	-0.07**
	(0.03)	(0.03)
Medium/High	-0.02	-0.01
	(0.03)	(0.03)
High	-0.01	0.02
	(0.04)	(0.04)
REP	No	Yes
Observations	11,165	11,165
R^2	0.04	0.06

Standard errors in parentheses are clustered at the census-tract level

Notes: The table reports 2SLS estimates of the elasticity of residential floor space to accessibility interacted with the baseline socioeconomic quintile of the block to study heterogeneous effects. The regression controls for log accessibility 2000, log distance to main roads (Alameda, Ruta 5, and Vespucio), log distance to the nearest subway station in 2001, dummies of the part of the city in which the block is located (North, West, East, or Center part of the city), quintiles to the central business district, log population, and log surface area of the block. Column 2 also controls for the initial real estate potential of the block. The coefficients from column 1 are plotted in Figure 7.
Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII), the dataset on regulation described in Section 2.3.1, and data from the INE's 2001 population Census.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A8: Heterogeneity in the results - Real estate potential (REP).

	(1)
$\Delta \ln(Acc._{2010-2001})$	0.51*
	(0.29)
First quintile REP (lowest) $\times$ $\Delta \ln(Acc._{2010-2001})$	0.00
	(.)
Second quintile REP $\times$ $\Delta \ln(Acc._{2010-2001})$	0.14
	(0.12)
Third quintile REP $\times$ $\Delta \ln(Acc._{2010-2001})$	0.31**
	(0.14)
Fourth quintile REP $\times$ $\Delta \ln(Acc._{2010-2001})$	0.28
	(0.28)
Fifth quintile REP (highest) $\times$ $\Delta \ln(Acc._{2010-2001})$	0.69***
	(0.26)
First quintile REP (lowest)	0.00
	(.)
Second quintile REP	0.05**
	(0.02)
Third quintile REP	0.08***
	(0.03)
Fourth quintile REP	0.12***
	(0.04)
Fifth quintile REP (highest)	0.10***
	(0.04)
Observations	11,165
R^2	0.06

Standard errors in parentheses are clustered at the census-tract level

Notes: The table reports 2SLS estimates of the elasticity of residential floor space to accessibility interacted with the real estate potential of the block (expressed in quintiles) to study heterogeneous effects. The regression controls for log accessibility 2000, log distance to main roads (Alameda, Ruta 5, and Vespucio), log distance to the nearest subway station in 2001, dummies of the part of the city in which the block is located (North, West, East, or Center part of the city), quintiles to the central business district, log population, log surface area, and the baseline socioeconomic quintile of the block. These coefficients are plotted in Figure 8.
Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII), the dataset on regulation described in Section 2.3.1, and data from the INE's 2001 population Census.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A9: Heterogeneity in the results - Real estate potential (REP) and socioeconomic status.

	(1)
$\Delta \ln(Acc._{2010-2001})$	
First quintile REP (lowest) x First four quintiles	0.75**
	(0.31)
First quintile REP (lowest) x Highest quintile	0.37
	(0.31)
Second quintile REP x First four quintiles	1.00***
	(0.30)
Second quintile REP x Highest quintile	0.11
	(0.36)
Third quintile REP x First four quintiles	0.86***
	(0.26)
Third quintile REP x Highest quintile	0.78
	(0.48)
Fourth quintile REP x First four quintiles	0.71***
	(0.25)
Fourth quintile REP x Highest quintile	3.26***
	(0.79)
Fifth quintile REP (highest) x First four quintiles	1.13***
	(0.24)
Fifth quintile REP (highest) x Highest quintile	3.20
	(2.08)
Observations	11,165
R^2	0.07

Standard errors in parentheses are clustered at the census-tract level

Notes: The table reports 2SLS estimates of the elasticity of residential floor space to accessibility interacted with the real estate potential of the block (expressed in quintiles) and a dummy for the socioeconomic status (0 if the block is in the first four quintiles and 1 if the block is in the fifth quintile) to study heterogeneous effects. The regression controls for log accessibility 2000, log distance to main roads (Alameda, Ruta 5, and Vespucio), log distance to the nearest subway station in 2001, dummies of the part of the city in which the block is located (North, West, East, or Center part of the city), quintiles to the central business district, log population, log surface area of the block. These coefficients are plotted in Figure 10.
Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII), the dataset on regulation described in Section 2.3.1, and data from the INE's 2001 population Census.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

A2 Construction of travel times and modal shares

We provide additional technical descriptions of the calculation of the traveled times. As the base for all our traveling times (for all modes), we use the Chilean 2017 pre-census street shapefile. We take the following considerations to recreate as closely as possible the scenario of each year.

To account for the extension of the road network, we study blocks inside the urban limit. The urban limit has been relatively unchanged over time. There are two types of urban highways, which are treated differently. First, new urban highways, such as Costaner Norte and Tunel San Cristóbal. These highways pass through non-road spaces, such as under the river Mapocho, through a hill or vacant land. For these urban highways, we construct barriers to use in the network to recreate the scenario of 2001. These barriers are carefully built to delete these roads from the map while, at the same time, not breaking the flow of the network. Second, some subways are upgrades from the previous important roads, such as the Autopista Central and parts of the Americo Vespucio ring road. For these urban highways, we consider a change in speed, as described below.

To construct the minimum travel times for each block i to the 618 Estraus zones, we compute the origin-destination cost matrix using ArcGIS's Network Analysis Tools. We adapt the 2017 pre-census street network and the subway network from the Observatory of Cities of the Pontificia Universidad Católica de Chile (Observatorio de Ciudades UC), considering alterations to the urban highway network and subway network to replicate their versions in 2010 and 2001.[14] The speed parameters are documented in official reports of average travel speed for every transportation mode (SECTRA, 2001, 2012). For our baseline scenario, the average speed is 34 km/h for car trips, 23 km/h for public transportation (buses), 35km/h for subway, and 4km/h for walking. These speeds also apply to our 2010 network, except for the urban highways, which have an average traveling speed of 60km/h. This information comes from Santiago's 2001 Mobility Survey (in Spanish, *Encuesta de Movilidad*) for the morning rush hour. To account for bus access and waiting times, we add four minutes to each bus trip, as the bus network is highly dense and buses stopped almost at every corner in 2001. For subway trips, the walking time is given by the network analysis tool. This network does not consider one-way streets or forbidden turns. This methodology does not consider the role of congestion in the minimum traveling time options.

Finally, in 2007, Santiago's public transport system was renewed, which included a fare integration for buses and the subway, changing the decision-making process of individuals traveling on public transportation. Due to this change, public transport users in 2010 could use buses and the subway for different stages of a trip, paying only the subway fare. Therefore, in the post-treatment year 2010, we allow for the combination of both modes; we consider the same 4 minutes of waiting at the bus stop (Díaz et al., 2004), and an additional 4.9 minutes of transfer between modes (Guo and Wilson, 2011).

To better understand the accessibility measure, we provide an example. For the trip from block 1415602151 to Estraus zone 2, traveling times by car, bus, and subway in 2001 were

[14] As we study blocks within the urban limit, all modifications of peripheral roads are not a problem for our network.

approximately 20, 34, and 114 minutes. For 2010, these times are 18, 33, and 48. The weight for 2001 and 2010 of Estraus zone 2 is 0.04 and 0.05 of floor space to the surface of Santiago. In this example, the log accessibility measure passes from -10.36 to -9.73. Thus, accessibility grows 62.5 percent.

A2.1 Aggregation by mode

To aggregate by mode, we follow Ahlfeldt et al. (2015) and measure overall travel times by weighting each mode's minimum travel time using data on the share of trips undertaken by each available mode. Thus

$$T_{ijt} = \sum_{r \in \{\text{car,bus,subway}\}} \Omega_{ijt}^{r} \cdot t_{ijt}^{r} \tag{14}$$

As we have modal share data representative at the municipality level rather than at the block level, we cannot directly use observed shares as weights. Instead, we estimate a modal choice model and predict mode shares of commuting trips by the block of origin to use as weights in Eq. (14).

Following Ahlfeldt et al. (2015), we estimate a mode choice model for each year using Santiago's 2001 and 2012 Mobility Survey. We observe the modal share of commuting trips for each municipality, so we need to construct a travel time by mode representative of the municipality for each period. To do this, we use the travel times by mode using the GIS Software. For each block in a municipality m, we average travel times over all destinations and then average over blocks in that municipality. This provides a single travel time for each mode in each municipality for each period.

We then estimate the logit model in equations (15)-(17) that explain the mode share of journeys in each municipality as a function of the average difference in driving times.

$$ln(\frac{car_m}{bus_m}) = \beta_1 + \beta_2 \Delta_m^{cb} + \epsilon_m \tag{15}$$

$$ln(\frac{car_m}{subway_m}) = \beta_3 + \beta_4 \Delta_m^{cs} + \epsilon_m \tag{16}$$

$$ln(\frac{subway_m}{bus_m}) = \beta_5 + \beta_6 \Delta_m^{sb} + \epsilon_m \tag{17}$$

$$subway_m + bus_m + car_m = 1 \tag{18}$$

Δ_m^{kl} is the average difference in travel time between modes k and l: car and bus in equation (15), car and subway in equation (16), and subway and bus in equation (17).

The weights used for each mode and each origin-destination pair, Ω_{ijt}^{r} in equation (14), are the predicted modal shares of trips from the origin (block) to the destination (Estraus zone). Our estimated model delivers these modal shares by evaluating the travel times by modes. Because the post-treatment weights are mechanically endogenous, as mentioned in Section 3.4, the weights for our instrument are also fixed at a predetermined level, using the information from 2001.

Online Appendix

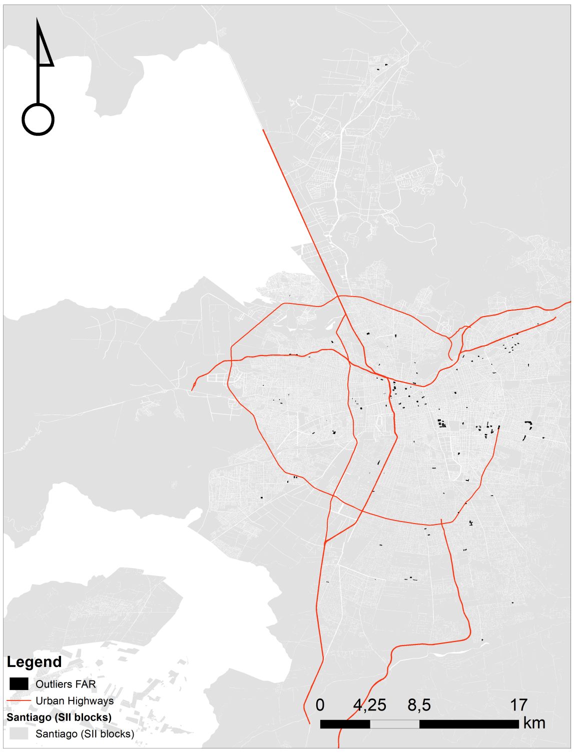
B1 Outliers

B1.1 Outliers: floor-to-area ratio

From the sample of blocks of the Chilean National Taxing System, we remove those blocks that had extreme FAR values and extreme changes in FAR from 2001 to 2010. Using the trimming option of the Winsor command in Stata, we first removed the 0.1% highest values of the FAR variable for each year. Then we remove the 0.1% highest and lowest value of the change in the FAR variable (the dependent variable of our regression). We prioritized removing as little as possible. There are 146 blocks considered outliers from a total of 45,041, which is 0.32% of the sample (292 out of 90,082 of the whole panel).

As shown in Figure B3, these blocks are scattered over the city, reducing our concern of biases produced by the exclusion of these observations. Table B1 summarizes descriptive statistics of FAR for the outlier sample, which illustrates the extreme values these variables take.

Figure B1: Identification of outliers based on FAR



Notes: The figure presents the location of all outliers from the sample of blocks from the Chilean National Taxing System dataset.

Source: Own elaboration using information from the Chilean Internal Revenue Service (SII) for 2001 and 2010.

B1.2 Outliers: Real estate potential

For the subsample with information on regulation, we also use the trimming option of the Winsor command in Stata, removing the lowest 1% of REP values for 2001 and 2010. These are 127 from the sample of 15,579 blocks with information on regulation and non-zero values on

Table B1: Descriptive statistics of floor-to-area ratio of outliers.

	Mean	SD	Min	Max
2001	87.35	284.50	0.00	2599.00
2010	62.09	223.93	0.00	2599.00
Δ	-18.89	174.60	-2073.62	160.92
Observations	146			

Notes: The table provides descriptive statistics of floor-to-area ratio (FAR) for outlier blocks.
Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII).

Table B2: Descriptive statistics of real estate potential of outliers.

	Mean	SD	Min	Max
2001	-58.63	356.37	-3782.07	0.70
2010	-266.28	1923.50	-20,743.25	1.00
Δ	-209.20	1886.09	-20,743.95	204.07
Observations	127			

Notes: The table provides summary statistics of real estate potential (REP) for outlier blocks.
Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII) and the dataset on regulation described in Section 2.3.1.

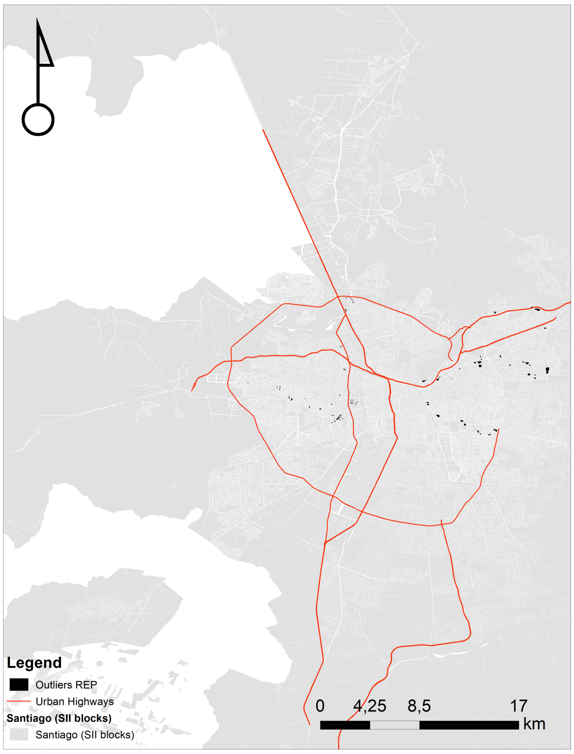
the norm of floor area ratio. These extreme values are due to significant differences in built-up surface compared to the regulation, which is possible due to the non-retroactive nature of the norm, or because the regulation is relatively small. This last case could happen where there are few small lots with residential land-use, where information on the regulation is calculated based on the lot's surface area. For some cases, the regulation of a particular lot is defined by a general norm that allows room for constructions under a 70-degree angle from official lines of the public space facing the property (Ministerio de Vivienda y Urbanismo, 2021). We provide an estimated value of the constructibility and height of a particular lot subject to this type of specifications based on the surface area of the lot and the tangent of a 70-degree angle.

As shown in Figure B2 these blocks are scattered over the city, reducing our concern of biases produced by the exclusion of these observations. Table B2 summarizes descriptive statistics of REP for the outlier sample, which illustrates the extreme values these variables take.

B2 Inauguration Dates

B3 Others

Figure B2: Identification of outliers based on REP



Notes: The figure presents the location of outliers based on the real estate potential (REP) criteria.

Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII) and the dataset on regulation described in Section 2.3.1.

Table B3: Inauguration dates of transport infrastructure.

Highway of Subway Line	Number of Stations	Type of Highway	Inaguration
Line 5	2		31/Mar/04
Line 2	2		08/Sep/04
Line 2	2		22/Dec/04
Line 2	2		25/Nov/05
Line 5	1		30/Nov/05
Line 4	9		30/Nov/05
Line 4	8		30/Nov/05
Autopista Vespucio Norte		Upgrade	04/Jan/06
Line 4	5		02/Mar/06
Vespucio Sur Express		Upgrade	27/Apr/06
Autopista Central		Upgrade	08/May/06
Line 4A	6		16/Aug/06
Line 2	3		21/Dec/06
Costanera Norte		New	04/Oct/07
Túnel San Cristóbal		New	03/Jul/08
Line 4	1		05/Nov/09
Line 1	3		07/Jan/10
Line 5	5		12/Jan/10
Autopista Acceso Sur		New	01/Apr/10

Notes: The table shows the opening dates of the transport infrastructure and their type.

Source: Information from Chile's Concessions and archives of the Metro of Santiago.

Table B4: Floor space by year and land-use.

Year	Total	Residential		Commercial		Industry		Others	
	$meters^2$	$meters^2$	%	$meters^2$	%	$meters^2$	%	$meters^2$	%
2001	147,188,504	95,780,986	65%	20,549,464	14%	10,499,375	7%	20,358,679	14%
2010	181,173,522	113,246,609	63%	24,627,789	14%	11,157,208	6%	32,141,916	18%

Notes: The table shows the floor space by land-use of the blocks located within the urban limit for 2001 and 2010.
Source: Own calculations using land-use information for 2001 and 2010 from the Chilean Internal Revenue Service (SII).

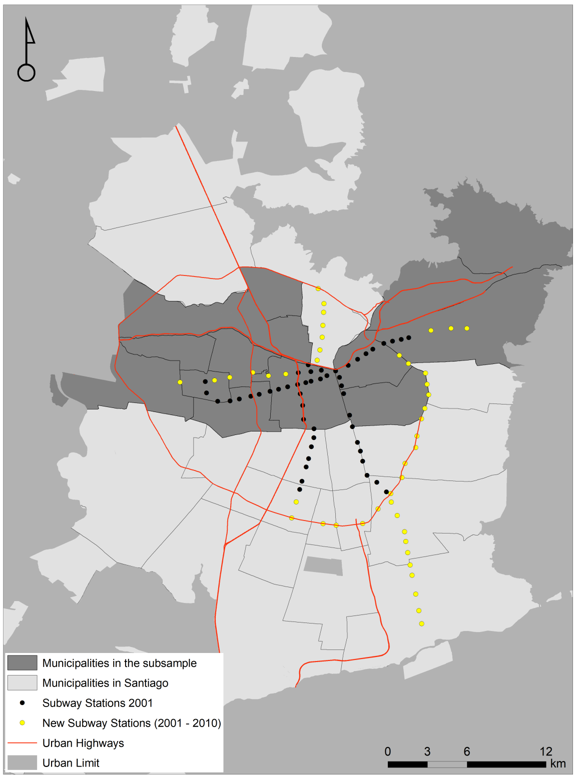
Table B5: Average regulation indicators at baseline by socioeconomic status.

	REP (%)		FAR		Height	
	Mean	SD	Mean	SD	Mean	SD
Low	92.51	12.07	6.52	3.58	60.53	32.11
Medium/Low	88.23	17.03	5.57	3.85	54.00	34.98
Medium	80.74	32.29	4.56	3.75	46.24	35.47
Medium/High	72.89	34.91	4.04	3.81	38.25	36.23
High	49.05	38.60	1.41	1.97	17.52	19.58
Total	76.71	32.72	4.42	3.87	43.33	35.55
Observations	11,1651		11,165		11,165	

Notes: The table reports mean and standard deviation of the real estate potential (REP), floor-to-area ratio, and height detailed in the regulation of the block at baseline. The sample studied are blocks located in the urban limit, within a 3km radius of a new subway station or an urban highway entry or exit. These statistics are also displayed in Figure 9.

Source: Own calculations using the data from the Chilean Internal Revenue Service (SII) on land-use for 2001 and 2010 and georeferenced blocks, the dataset on regulation described in Section 2.3.1, and also data from INE's 2001 population Census.

Figure B3: Municipalities in the subsample of the regulation dataset.



Notes: The Figure presents the 14 municipalities of the subsample, which has data on regulation (dark grey) compared to the rest of the city (light grey).

Source: Own elaboration using information from the Chilean Geospatial Data Infrastructure (IDE).